ASSESSING THE POTENTIAL ROLE OF COLEOPTERA (INSECTA) AS BIOINDICATORS IN SIMBALBARA WILDLIFE SANCTUARY, HIMACHAL PRADESH

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BY

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Certificate

This is to certify that the thesis of **Mr. Vinay K. Bhargava** entitled **"Assessing the potential role of Coleoptera (Insecta) as bioindicators in Simbalbara Wildlife Sanctuary, Himachal Pradesh"** is an original piece of work submitted to the Saurashtra University, Rajkot (Gujarat), for the award of **Doctor of Philosophy in Wildlife Science**.

Mr. Bhargava has put in more than six terms of the research work embodied in this thesis under our guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institution.

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Summary

Introduction

Bioindicators are organisms used to characterise the health of the ecosystems. One of the key aims of research on bioindicators is to 'identify' species or other taxonomic units that would reliably indicate disturbances in the environment, and reflect the responses of other species or the overall biodiversity. However, there is no perfect bioindicator and selecting the most suitable one depends to a great extent on the goal of the survey. In this study the suitability of select beetle families as bioindicators to monitor human influence on forest ecosystems was undertaken. Beetles have been used in forest ecosystems where their species number and/or abundances change along a habitat disturbance gradient; a common trend being that large, poorly dispersing specialist species decrease with increased disturbance while small generalist species with good dispersal ability increase. Some species are not affected by moderate disturbance.

Recently, a lot of work has been done on many Coleopteran families like Carabidae, Cicindelidae, Staphylinidae, Scarabaeidae and Psephenidae to designate and use them as ecological indicators for many purposes apart from other orders of class Insecta like Ephemeroptera, Plecoptera and Trichoptera. There is a distinct advantage of using Coleoptera to other groups because they fit in, for more criteria for suitability to, as bioindicators. The idea is to study a representative sample of an ecosystem that can provide quick, yet reliable information. The presence and condition of beetles gives more accurate information about the health of the ecosystem because their behaviour is directly related to the anthropogenic-induced landscape modification in the form of agricultural fields, plantations, and urbanisation. This indicator measures for the habitat that is to be physically protected, where endangered species are known to occur, with good soil characteristics, coverage of invasive species within protected areas and protection of high priority habitats in future.

The purpose of this research work is to find out the status of beetles in a biogeographically significant area of Simbalbara Wildlife Sanctuary, Himachal Pradesh in Shivalik Himalaya in north western India; and to assess their potential role to assess the human influence on forest ecosystem on a more local scale. Further,

patterns of species biodiversity, taxonomy, and their suitability as bioindicator were explored using a set of standard methods and ecological indexes. The set of methods and indexes used in this work is similar in many ways to the measures used or proposed elsewhere; but the objective is to determine the suitability and application of bioindicators for monitoring and inventorying study at a local scale; and how well they can be applied to a larger scale.

Diversity Patterns of Beetles (Coleoptera) in Simbalbara Wildlife Sanctuary, Himachal Pradesh

The order of Coleoptera (Insecta) is by far the largest not only in phylum Arthropoda but also in the entire animal kingdom; and it includes more species known to science than any other order. The most authoritative calculations indicate that already now more than 350,000 species of beetles have been described in about 190 families across the world; in India, about 15,501 beetle species are found. Their sheer number and ecological status is manifested in numerous roles they play in the biosphere. Benefits from beetles are both economical and environmental; and besides dominating the food chains and food webs in biomass and species richness, nutrient recycling, plant propagation, maintenance of plant and animal community composition and structure, and food for insectivorous vertebrates; some beetles are the major pest of standing and stored forest produce, decomposers in nutrient cycle, pollinators, and biological control agents.

Present study deals with determining the beetle diversity and composition in various microhabitats in Simbalbara Wildlife Sanctuary, Himachal Pradesh characterised by Sal (*Shorea robusta*) dominated forest ecosystems. The study was carried out from September 2005 to August 2008 to obtain reliable data in different seasons across 13 microhabitats in and around the sanctuary. Sampling for beetles in each microhabitat was carried out following different methods to capture beetles from different forest strata. A total of 5,404 adult beetles were captured representing five families, 95 genera and 194 species. Using the abundance-based estimator, Chao1, the predicted richness for the total area sampled is 206.88± 2.66 (SD), species. This indicates that the inventory was almost complete at the regional scale (92%). The species richness was highest in mixed forest habitats compared to open forest habitats and plantations.

Comparison of different habitats revealed that species composition was much more similar in the vegetation type with similar dominant tree species than among different vegetation types with dissimilar tree species. Thus, the study revealed the relative importance of diverse microhabitat types on diversity and composition of beetle assemblages.

Bioindicator Families of Coleoptera and their Taxonomy

Sustainable forest management is a widely held international goal and monitoring indicators of sustainability has been proposed as a mechanism for assessing sustainability. The urgency with which meaningful, practical and immediate assessments of sustainability must be developed is highlighted by the fact that national and international sustainable forest management certification systems are expanding rapidly and influencing market demand. Monitoring a few indicator species is an intuitively appealing method of measuring the ecological sustainability of forest management because it is impossible to measure and monitor the effects of forest management on all species or environmental conditions of interest.

In the present study for determining the bioindicator families, the degree of habitat specificity for each species of a family was calculated and quantified using Bulla's diversity index (H') followed by indicator species analysis. All those families that showed the mean H' more than 11.00 and observed indicator value (IndVal) less than 10 were excluded from further analyses as they were considered inappropriate to meet the criterion of a bioindicator taxon. Thus, out of 66 families, five families of beetles viz. Carabidae (Ground beetles, 36 species), Cicindelidae (Tiger beetles, 25 species), Scarabaeidae (Dung beetles, 66 species), Staphylinidae (Rove beetles, 15 species) and Cerambycidae (Long-horned beetles, 52 species) were found to be the appropriate for the purpose of bioindicator taxon to 'monitor' habitat conditions; and each species were taxonomically identified subsequently.

Potential Use of Bioindicator Families as Indicator for Monitoring Human Influence on Forest Ecosystems

Anthropogenic-induced demographic changes have the best-documented effects on genetic diversity, reducing both species diversity and intraspecific diversity. Changing patterns of land use and the impact of socio-economic factors on forest management practices have brought about major changes in forest ecosystems. There is a need to study the influence of multiple use management on ecosystem stability and social structures, especially in regions where forest areas and human settlements are situated in proximity to one another. The present study analyses the effect of local habitat variables and environmental factors in control and experiment plots on regional beetles' species richness and diversity. The underlying objective was to find out the nature of assemblage patterns conferred by habitat variables and other environmental factors pertaining to monitor the human influence on forest ecosystems.

The habitat heterogeneity hypothesis states that the more complex the habitat, the higher the species diversity and structure; and it was inadvertently found true for the richness and diversity of the beetle species. Bioindicator beetle families were modeled using multiple regression and a set of independent variables extracted from canonical correspondence analysis ordination of vegetation, microclimate and disturbance variables. Habitat variables viz. average tree and shrub density, average girth at breast height and canopy cover, litter layer, pH, plant species richness were found to be important predictors for assemblages apart from few anthropogenic disturbance variables like fuelwood collection, fire, grazing and lopping. The effect of disturbance was significant between primary and logged forest; and it indicates that the logged forests can recovered rapidly in floristics in a time dependent manner.

Further from the management perspective maintaining the understorey vegetation or ground cover may be important for sustaining the diversity of beetles. Maintenance of such forests habitats can provide overwintering refuge sites for many predatory species. The results from this study indicate that the loss of species richness and abundance of beetles, and changes in beetle composition can occur in severely disturbed environment. Consequently, these results support the establishment or maintenance of mixed forest patches in such environments.

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INTRODUCTION

1.1 Dominance and Global Variation in Insect Diversity

Ten years ago there were approximately 750,000 named insect species (www.scientificamerican.com). Today, that number is over 1,000,000; and according to recent estimate by entomologists there are likely over eight million different species of insects on earth. When one compare that to 4,650 named and 4,809 estimated mammal species or the 72,000 named and 1,500,000 estimated fungi, it is easy to see that insects "out-populate" any other living taxonomic group on earth (www.scientificamerican.com). Insects can be found in every environment on our planet. While a select few insects, such as the Arctic wooly bear, are able to inhabit the harsh Arctic climate, the majority of insects are found in the warm and moist tropics. Insects have adapted to a broad range of habitats, successfully finding their own niche, because they will consume almost any substance that has nutritional value. Insects perform a vast number of important functions in our ecosystem (Wilson 1987, Wilson and Peters 1988). They aerate the soil, pollinate blossoms, and control insect and plant pests; they also decompose dead materials, thereby reintroducing nutrients into the soil. Burrowing bugs such as ants and beetles dig tunnels that provide channels for water, benefiting plants. Bees play a major role in pollinating fruit trees and flower blossoms. Gardeners love the big-eyed bug and praying mantis because they control the size of certain insect populations, such as aphids and caterpillars, which feed on new plant growth. Finally, all insects fertilize the soil with the nutrients from their droppings.

Many insects are herbivores, or plant-eaters, which makes them primary consumers. This abundance of primary consumers provides protein and energy for secondary consumers, known as carnivores. There are many secondary consumers, such as spiders, snakes, and toads that could not survive without feeding on insects. Tertiary consumers eat other carnivores;

for example, bears and chimpanzees eat insects as well as other animals. Insects are invertebrate animals of the class Insecta, the largest and (on land) most widely distributed taxon within the phylum Arthropoda. Insects are the most diverse group of organisms (Wheeler 1990); potentially they are highly indicative of environmental change through close adaptation to their environment; they represent the majority of links in the community food chain; and they are likely having the largest biomass of the terrestrial animals (Holden 1989, Stork and Gaston 1990).

Thus, knowledge about them is fundamental to studying the environment. Insects comprise the most diverse group of animals on the earth, with around 9, 25,000 species described - more than all other animal groups combined. Insects may be found in nearly all environments on the planet, although only a small number of species have adapted to life in the oceans where crustaceans tend to predominate.

Insects are very important component of biosphere, in short, they make ecosystems tick. Not only that, they are also numerous, fascinating, varied and economically important. They cannot be ignored (Samways 1994). The insect ecologies are incredibly variable and insects often dominate the food chains and food webs in biomass and species richness. Feeding specializations of different insect groups include: detrivory, saprophagy, xylophagy and fungivory, aquatic filter feeding and grazing, phytophagy, including sap feeding and carnivory (predation, parasitism, and parasitoids). Some insect groups show various combinations of these major feeding types. Insects may be aquatic or terrestrial throughout or during a part of their life cycle (Gullan and Cranston 1999).

It is interesting to note that the insects as a group amongst arthropods is the only one not found in the marine environment (except one bug *Halobates* sp., the marine sea skaters). Their lifestyles may be solitary, gregarious, sub-social or highly social. They may be conspicuous or concealed and active by day or night. Insect life cycles allow survival under a wide range of environmental conditions, including seasonal extremes of heat and cold, wet and dry, and unpredictable climates. Insects are essential in the following roles within the ecosystems (Gullan and Cranston 1999)

- Nutrient recycling, via leaf litter and wood degradation, dispersal of fungi, disposal of carrion and dung, and soil turnover;
- Plant propagation, including pollination and seed dispersal;
- Maintenance of plant community composition and structure, via phytophagy, including seed feeding;
- Food for insectivorous vertebrates, including many birds, mammals, reptiles and fish;
- Maintenance of animal community structure, through transmission of diseases of large animals, and predation and parasitism of smaller ones.

Each insect species is a part of a greater assemblage and, if lost, the complexities of and abundances of the other organisms are likely to be affected. Some insects are considered to be the ‘keystone species’ because the loss of their critical ecological functions is argued to cause the failure of the wider ecosystem. For example, the valuable role of the termites as converters of cellulose in tropical soils suggests that they form keystone group in soil structuring. In the aquatic ecosystems, the guild of larval insects that breaks down wood and leaves derived from the surrounding terrestrial environment, and releases their nutrients, performs a comparable service (Gullan and Cranston 1999). Insects are intimately associated with our survival, in that certain insects damage our health and that of our domestic animals and others adversely affect our agriculture and horticulture. Some insects greatly benefit human society, either by providing us with food directly or by contributing to materials that we use or food that we eat.

Furthermore, the services of the predatory beetles and the bugs or parasitic wasps that control pests often go unrecognized, especially by the city dwellers. Insects also contain a wide array of chemical compounds, some of which can be collected, extracted or synthesized and used by us (Gullan and

Cranston 1999). For example, chitin, a component of the insect cuticle, can act as a haemostatic agent for tissue repair in humans, enhance wound or burn healing, reduce serum cholesterol, serve as non-allergic drug carrier, provide a strong biodegradable plastic, and enhance the removal of the pollutants from waste water. Silk, from the cocoons of silkworm moths, *Bombyx mori*, has been used for fabric for centuries. The red dye cochineal is obtained from the scale insects of *Dactylopius coccus* cultured on opuntia cacti. Another scale insect, the lac insect *Laccifer lacca*, is a source of a commercial varnish called shellac.

Benefits from insects are more than economic or environmental; characteristics of certain insects make them useful models for understanding biological processes in general. For example, studies on *Drosophila melanogaster* provided the foundations for our understanding of genetics and cytology, and these flies provide the experimental material for advances in the molecular biology, embryology and development. Studies on the social insects, notably hymenopterans such as ants and bees have allowed the understanding of evolution and maintenance of the social behaviours such as altruism and the development of field of sociobiology. Studies on the flour beetles have provided insights into the mechanisms governing the population regulation. Alfred Wallace and Charles Darwin deduced their theses based on tropical entomological observations. Theories concerning the many forms of mimicry and sexual selection have been derived from observations of insect behaviour. Lastly, the sheer numbers of insects means that their impact upon the environment, and hence our lives, is highly significant. Insects are the major component of macroscopic biodiversity and if only for this reason, we should try to understand them better (Gullan and Cranston 1999).

The systematic naming and recording of species began relatively recently, with Linnaeus' standard work, which in 1758 recognized some 9,000 species. Today the total number of living species named and recorded has been estimated at around 1.7 to 1.8 million. However, more than half (~56 %) of all names species are insects (May 2002). In India 59,353 insect species are found which corresponds to 6.83 % of world fauna (Varshney 1997).

The described taxonomic richness of insects is distributed unevenly among the higher taxonomic groups. Five orders stand out for their high species richness: the beetles (Coleoptera); flies (Diptera); wasps, ants and bees (Hymenoptera); butterflies and moths (Lepidoptera); and the true bugs (Hemiptera). Beetles comprise about 40% of all described insects (more than 3,00,000 species). The Hymenopterans have nearly 2,50,000 described species, with the Lepidoptera, Diptera and Hemiptera each having between 1,50,000 – 2,00,000 species. Of the remaining orders of living insects, none exceeds the 20,000 described species of the Orthoptera. Most of the 'minor' orders have hundreds to a few thousands of species (Gullan and Cranston 1999). There are approximately 5,000 dragonfly species; 2,000 praying mantis; 20,000 grasshopper; 1,70,000 butterfly and moth; 1,20,000 fly; 82,000 true bug; 3,50,000 beetle; and 1,10,000 bee and ant species (Gullan and Cranston 1999). Estimates of the total number of current species, including those not yet known to science, range from two to thirty million, with most authorities favouring a figure midway between these extremes.

1.2 Habitat and Diversity of Beetles (Coleoptera)

The beetles are the largest order including more species known to science than any other order not only in the class Insecta, but also in the entire animal kingdom (Animalia). The most authoritative calculations indicate that already now more than 3,50,000 species of beetles have been described in 190 families (www.zin.ru/Animalia/Coleoptera) across the world. In India, about 15,501 species (all except Archostemata) are found (Sengupta and Pal 1998). Coleoptera is the largest order of insects and contains about 40% of the known species in the Hexapoda. Estimates put the total number of species - described and undescribed - at between 5 and 8 million, one of every five living species is a beetle! These vary in length, from less than a millimeter (.30 -.80 mm in Nanosellinae) (Ptilidae: Featherwing beetles) (www.tolweb.org) up to 170 mm (*Titanus giganteus*, Cerambycidae). The beetles vary considerably in habits and are to be found almost everywhere.

Beetles are most abundant in the tropics; but at the same time they have got adapted to life at all latitudes and in nearly every habitat, to feeding on any substance of organic origin. They have not been found on the Antarctic continent yet, but inhabit the sub-antarctic islands, they have not been found in the open sea, but are abundant on sea coasts, they have not been found beyond the boundary of eternal snows, but very interesting species of beetles occur high in the mountains in the summer immediately close to this boundary. They may be found in almost every type of habitat in which any insect is found, and they feed on all sorts of plants and animals material.

Many are phytophagous; many are scavengers; others feed on fungi or mold, and a very few are parasitic. Some are subterranean in habit, many are aquatic or semi-aquatic, and a few live as commensals in the nests of social insects. Many species of beetles attain large numbers. The above explains why the beetles are so well known. Beetles are extremely diverse not only in size and colour, but also in body shape, sculpture of external cover, presence of various outgrowths, etc. Butterflies probably excel beetles in the splendour of colours; however, beetles have no match in the fantastic diversity of forms. Therefore, beetles are an inexhaustible source of inspiration for writers, sculptors, artists, ornamenters and pattern-designers. Perhaps for this reason and also due to the extreme simplicity of storage of dead specimens' beetles are favourite objects of collecting. One of the most distinctive features of Coleoptera is the structure of wings. The front wings are called the elytra, which is thickened, leathery, or hard and brittle, serves only as protective sheaths. The hind wings are the ones ordinarily used for the flight.

Many species are of great economic importance. Many species of beetles are serious pests of agriculture (Colorado potato beetle, *Leptinotarsa decemlineata*), forests (borers and miners), stored food, wood, leathers, furs, and fabric. Some of the phytophagous species are free feeders on foliage; some bore into the woods or fruits; some are leaf miners; some attack the roots and some feed on the parts of blossoms. Some type of beetle may feed upon any part of a plant. Other species, *vice versa*, are disturbed as a result of man's economic activity; they are permanently declining in numbers or become extinct. Some common species of beetles respond sensitively to the state of natural environment and may serve as convenient indicators of anthropogenic pollution. Therefore, knowledge of beetles is indispensable not only to professional zoologists, but also to plant protection specialists, agriculturists, arbor culturists, museum specialists and workers of food processing industry, ecologists, staff of reserves and specialists in many other areas. Many beetles are of value to human because they destroy injurious insects or act as scavengers. Certain species are agricultural pests in some areas while other species are important for control of agricultural pests, for example the lady beetles (Coccinellidae) consume aphids, fruit flies, thrips, and other plant-sucking insects that damage crops.

1.3 Taxonomic Indicator Groups of Biodiversity and Disturbance

The sheer degree of diversity around us is very evident. Scientists speculate that we have on the globe an estimated 13.5 million extant species approximately with only 1.75 million of these currently described (Gaston and Spicer 2004). More than half of these species are said to be restricted to the tropics. The tropics also include mainly developing countries where natural ecosystems are in serious risk from growing populations and rapid development. This has led to destruction and fragmentation of natural habitats. In a densely populated country like India the maintenance of biological diversity and its conservation in existing habitats is one of most pressing tasks that we face today. Identifying and setting aside areas of high conservation interest can require a lot of time and money (Soulé 1985).

Detailed inventories of taxa that are found in our country before they go extinct are near impossible owing to the fast rate of deforestation and degradation. As a result of this, biologists are interested in selecting an efficient, limited set of biological indicators for measuring and monitoring biological diversity (Kremen 1992, Pearson and Cassola 1992, Faith and Walker 1996, Pearson and Vogler 2001).

Now, how does one identify an indicator taxon that indicates habitat quality in landscape level? Indicator groups may be important tools with which to guide the selection of networks of areas for conservation. Nevertheless, the literature provides little guidance as to what makes some groups of species more suitable than others to guide area selection. Increasing the proportion of threatened, endemic, and range-restricted species in the indicator groups improves effectiveness of the selected area networks; in particular it improves the effectiveness in representing other threatened and range-restricted species. Further, changes in the number of genera and families only marginally affect the performance of indicator groups. Thus, focus on species of special conservation concern, which are legitimate conservation targets in their own right, also improves the effectiveness of indicator groups, in particular in representing other species of conservation concern. After a much careful study, ecologists have determined that the presence, condition, and numbers of the types of fish, algae, insects, and plants can provide accurate information about the health of a specific ecosystem like river, estuary, lake, wetland, stream, or a forest. These types of plants or animals are called the biological indicators (McCarty and Munkittrick 1996). An indicator is numerical value derived from actual measurements, has known statistical properties, and conveys useful information for environment decision making.

An ecological indicator is a measure, an index of measures, or a model that characterizes an ecosystem or one of its critical components. Use of taxonomic groups has two aspects. On one hand, a certain insect taxon may be used to identify the state or change in a landscape. It also detects how certain insect taxa are affected by a possible or an inevitable modification to the landscape. An indicator may reflect a change in biological, chemical, or ecological condition. The primary uses of an indicator are to characterize status and to track or predict significant change. With a foundation of diagnostic research, an ecological indicator may be also used to identify major ecological stress like habitat degradation, habitat loss, or habitat fragmentation. The class Insecta also has members, even within one order (e.g., Coleoptera) that operate at different trophic levels, therefore providing varied, sensitive indication of changes.

While long term monitoring gives variability (Samways 1990, Wolda 1992) since there is as such no ‘normal year’ for insect abundance. A short time study provides a fairly a true picture without having resort to long-term sampling (Owen and Owen 1990).This excludes the species that occasionally outbreak to enormous population levels, or show major range changes. The objective choice of insect indicator groups depends on various factors. For e.g., butterflies have been targeted for temperate regions as well as for the tropics (Ehrlich and Raven 1964, Gilbert 1980, Brown 1982, Pollard 1982, Murphy and Wilcox 1986, Erhardt and Thomas 1991, Ehrlich and Wilson 1991), because they are generally readily identifiable, there is a relatively good taxonomic knowledge of the group and they are sensitive to environmental changes in microsite and biotope characteristics. They are often highly plant specific for their growth development (Ehrlich and Raven 1964) and sometimes have close plant-pollinator relationships.

Pearson and Cassola (1992) have proposed the use of tiger beetles (Cicindelidae) as a good indicator group for identifying area for biodiversity conservation. Tiger beetles are well known, their biology is well understood, they occur over a broad range of biotope types and geographical areas and they also exist in remnant patches of appropriate biotopes. On a much small geographical scale, cicindelids are particularly useful as ‘fast indicators’ of biotope quality relative to disturbance (Clark and Samways 1992). Pearson and Cassola (1992) have shown that at a site in Peru it took only 50 hrs of observation to find 93% of the tiger beetle fauna, while to find out 90% of the butterflies species required nearly 1000 hrs of fieldwork.

Butterflies indicate change in environmental variation and also are affected by plant diversity since they are directly dependent on them (Breedlove and Ehrlich 1972). Some studies say that butterflies are affected by precipitation and other bioclimatic variables and they do not indicate minor changes in habitat quality (Hamer et al. 2003). Birds too serve as indicators of environmental change especially in the landscape level such as habitat fragmentation (Wilcove 1985). For the sustained conservation of biodiversity, now restricted to these degraded and patchy habitats it has become mandatory to protect and conserve these areas. But not all can be conserved and it is important to survey potential areas for conservation and prioritise them based on various criteria like the biodiversity (floral and faunal species), presence of rare or threatened species etc. Enumeration of biodiversity can be a daunting task due to the inherent variability and complexity of natural systems. Most enumeration efforts often need detailed field surveys requiring manpower, time and funds, which can both be limiting factors (Soulé 1985). Wood and Samways (1991) found butterflies (Papilionoidea) to be good indicators of biotope type and landscape pattern at a mesoscale (e.g., 50m X 50m), but cicindelids were much more sensitive indicators at a microscale level (e.g., 1m X 1m) (Clark and Samways 1992). Different developmental stages give different indications, often the larva being more sensitive at the smaller scale because of its relative immobility compared with the adult. Orthoptera can also be excellent bioindicators, as they can be recognized in the canopy at night without having resort to any trapping or landscape disturbance (Samways 1989b).

Various groups of invertebrates have been used in monitoring water quality and disturbance, the Ephemeroptera (Giberson et al. 1991), Plecoptera, and Trichoptera being particularly sensitive. The study of these groups helps in significant interpretation of causes of the environmental change. Lepidoptera are 12 times more responsive to environmental change than their food plants, while the ant *Myrmica sabutlei* was only 3 times as responsive (Thomas et al. 1989). Elliot (1991) has also examined the possibility of using aquatic insects as subject organisms being affected by climate change in Britain. Elliot (1991) has suggested long-term data should be available on the population dynamics of the selected species and on associated climatic variables. In addition, the eco-physiological information should be available on effects of climatic variables on the selected species (e.g., temperature). In addition, ecological information should be available on the functional role of the selected species within their ecosystem.

Unquestionably, insects are excellent indicators of environmental change, but the converse is that they are often readily subject to local extinction when environmental changes affect their biotope. Mobility can vary enormously even within one small taxon (Samways 1989a). This makes fragmentation of the landscape particularly significant, reducing the mobility of apparently quite mobile species, as in the case of some butterflies (Dempster 1991). This results in certain insects restricting themselves to small patches, and with closed populations (Thomas 1984) highly susceptible to natural and anthropogenic impacts. Insect behaviour is relative to the anthropogenic landscape modification, in the form of agricultural fields, plantations, and urbanisation. For example, insect mobility even though not selected for coping with the appearance of road, crop field, or building, may determine the survival or not of a species in the modified landscape. Thus, stenotopic low mobility Orthoptera (Samways 1989b), Coleoptera (Mader 1984), and butterfly (Wood and Samways 1991) species can be immediately and severely restricted by a new structure. Landscape fragmentation is thus taking the greatest and most rapid toll on relatively immobile, stenotopic species.

1.4 Indicator Species and Protected Area Management

There are now over 1,00,000 protected areas worldwide, covering over 12% of the Earth's land surface. These areas represent one of the most significant human resource use allocations on the planet. The importance of protected areas is reflected in their widely accepted role as an indicator for global targets and environmental assessments (Chape et al. 2005). Existing protected areas are generally not sufficiently numerous, large, or connected to maintain ecological integrity on their own (Newmark 1985, Noss and Harris 1986, Grumbine 1990 Newmark 1995, Rivard et al. 2000, McNamee 2002,). The protected area literature suggests that the maintenance of biodiversity involves conservation of genetic, species and ecosystem structures and processes in both protected and extensive areas (Shafer 1990, Soulé 1991, Noss 1990, Soulé and Terborgh 1999). For protected areas planning and management, a regional approach is necessary to accommodate critical large-scale spatial and temporal components such as representation of natural landscapes and population viability of focal species and other transboundary phenomena (Noss 1991, Noss and Cooperrider 1994, Brown 1997).

Applications of indicator species are thus of potential value and utility to managers of protected areas and surrounding lands. It is not necessary or desirable to consider every aspect of biodiversity: focal species and ecosystems warrant special consideration because they are functionally important, and/or sensitive to changes in habitat quality, quantity and configuration (Noss 1990, Lambeck 1997). Accordingly, a carefully chosen suite of species and ecosystems can provide a multi-element umbrella, which can aid decision-making and improve ecosystem-based management in both existing and proposed protected areas (Miller et al. 1999). The potential use of indicator species for conservation research can be divided in two basic categories (Kremen et al. 1993, Pearson 1994). Firstly, monitoring studies, to evaluate changes in habitats or ecosystems over time, such as successional stage or habitat degradation. Therefore, the choice of an indicator will be served best by a taxon that is sensitive to environmental change. Secondly, for inventory studies, to record distribution patterns of taxa or ecological units over geographical space, often with the purpose of identifying the areas for establishing nature reserves.

Bioindicators are the communication tools between environments and people. They focus and condense information about complex environments for management, monitoring and reporting uses. Since the indicator process can take account of social and economic information, properly designed indicators are useful tools for improving communication and management decisions. Protected area managers all face differing realities, though similarities exist. ; and protected area management is a cyclic process in which the community, policy makers, managers and scientists all participate, taking the lead at different stages. Bioindicators can help these groups, or an individual enterprise. Here we particularly assume that knowledge from science is required as one ingredient for success - as often it is.

The choice of indicators thus favours taxa whose distribution or abundance correlate, for example, with areas of high endemism or high species diversity (Erwin 1991). However, the vast majority of studies that rely on bioindicators have used taxa with little or no initial assessment of their adequacy as indicators. Many of these studies have focused on taxa that either are of high public concern (such as endangered species) or have been coincidentally the object of previous studies to use as indicators (Pearson 1994 and Shivshankar and Pearson 1994). Indicator or flag species are associated with a particular plantscape, biotope, or landscape, depending on the scale of measurement. However, a single species, which is highly sensitive to environmental perturbations, may simply disappear not because of a disturbance, but because of an intrinsic feature of population dynamics.

Bioindicators have proved to be a useful tool for monitoring and detecting changes in the environment. Since the time when canaries were used to detect carbon monoxide in mines, the use of indicators has increased to span both aquatic and terrestrial ecosystems covering a wide range of habitat alteration, from local disturbance to global climatic change (Spellerberg 1993). Despite the long history of use of bioindicators, there still are no unanimous definitions or criteria for selection of bioindicators. A bioindicator can be loosely defined as a species or a species group that reflects the abiotic or biotic state of the environment, represents the impact of environmental change on a habitat, community or ecosystems, or indicates the diversity of other species (McGeoch 1998). Many species fulfil at least one of these criteria. The use of bioindicators is based on a number of reasons. One of the most important ones is their cost-effectiveness. By using bioindicators it is possible to assess the impact of human activities on the biota, instead of examining the entire biota. Especially useful are species that provide early warning of change (Spellerberg 1993).

Bioindicators are also a good way to monitor the effects of toxic materials on organisms (Bridgham 1988). This might be difficult to assess through direct toxicity level assessment in nature. In biodiversity surveys, bioindicators are used to assess species richness of the community. Using only a few species groups and estimating diversity of total biota e.g. through extrapolation is a quick technique (Colwell and Coddington 1994). This is a great advantage especially in the tropics, where it is impossible to survey all species due to high species richness.

Indicator species need not always be amongst the rarest of species. Abundant species have value that they can be easily located. However, abundant species can also be generally more eurytopic than the rarer species, because stenotopic species are bound to be rare as their particular habitat is automatically defined. The highest level of endemism tends to occur in the most severe landscapes, which are predictably unfavourable (Greenslade 1983). Endemism is lowest in temporary and disturbed biotopes such as agricultural land, and the fauna shows high population variability and high dispersal ability. Diversity will be greatest in relatively stable, favourable biotopes. Thus, for the determination of impact at a single localized site, a stenotopic, endemic species (even just one of its life stages) may be appropriate. Nevertheless, for a large-scale survey, an abundant but biotope restricted species may be the best tool. The characteristics which will be monitored will include life history style, local or widespread abundance and distribution, availability and seasonality, sensitivity to disturbance for a complete biogeographical perspective. A series of criteria have been proposed for the objective selection of an indicator taxon (Noss 1990, Pearson and Cassola 1992, Pearson 1994). These criteria are:

- Taxonomically well known and stable, so that populations can be readily defined;
- Biology and natural history well understood – limiting resources, enemies, physical tolerances, and all stages of life cycle available to readily incorporate into hypotheses and experimental design;
- Populations readily surveyed and manipulated such that tests are logistically simple;
- At a higher taxonomic levels (order, family, tribe, genus), occurrence over broad geographical range and breadth of habitat types, so that results will be broadly applicable;

- At lower taxonomic levels (species, sub-species), specialization of each population within a narrow habitat is likely to make them sensitive to habitat changes;
- Some evidences that patterns observed in the indicator taxon are reflected in other related and unrelated taxa;
- Potential economic importance;
- Habits should be highly differentiated and larvae should possess the same general feeding habits; and
- Should be common and easy to find in almost all terrestrial ecosystems, including urban and rural landscapes.

On a global scale, Coleoptera meet most of these criteria. Their taxonomy is stable, their biology and life history have been the object of numerous studies. They have a worldwide distribution ranging from alpine meadows to desert grasslands and tropical rainforests. The species of different families are found in a wide variety of niches and there is a growing interest as its role as a natural predators and as controllers of certain crop pests. Since, protected areas are internationally recognized as a major tool for conserving species and ecosystems. The ecosystems they protect provide a range of goods and services essential to human well being. Bioindicators can help to safeguard natural resources and wild lands of cultural importance that local communities and indigenous peoples depend on. They also can play a key role in retaining habitat cover and therefore in helping to maintain species populations.

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CHAPTER 2
REVIEW OF LITERATURE

2.1 General

Insect conservation is fundamental to not only biodiversity conservation, but also to sustainable agriculture and a sustainable biosphere (Samways 1990, 1993). Conservation policy decisions must integrate an overwhelming number of biological and socioeconomic factors to prioritize conservation efforts adequately. In addition, economic and political pressures throughout the world should dictate that prioritization of these efforts be made quickly and efficiently. Ideally, the knowledge of biodiversity, habitat loss, and human impact is needed to make these decisions competently (Sisk et al. 1994). For biodiversity itself, great logistical barriers exist when we measure even obvious parameters such as species numbers and endemism (Gentry 1992, Colwell and Coddington 1994). Article 7 of the Convention on Biological Diversity (1992), to which over 157 countries are signatory, states that each contracting party shall, as far as possible and as appropriate identify components of biological diversity important for the long-term conservation and sustainable use of biodiversity (Glowka et al. 1994).

Among the recommended categories of such listed components are those with ‘importance for research into the conservation and sustainable use of biological diversity, such as indicator species’. Independently of the mandate set by the Convention, bioindicators have in the past and continue to be used today to determine the state of environmental health and to be tested as potential predictors of biodiversity and of the impact of environmental change on natural systems. The traditional approach to indicator studies, where the indicator taxon is monitored so that changes in environmental condition can be detected (i.e. environmental indication), has most commonly been applied using soil invertebrates as bioindicators of soil fertility and pollutant levels (such as pesticides, heavy metal and acidic pollutant levels) (Paoletti and

Bressan 1996). In comparison with aquatic environmental indication, this approach has seldom been applied using insects in terrestrial systems, with the exception of the use of pedofauna (Paoletti and Bressan 1996). Possible reasons for the above include that the type and degree of environmental change (such as air pollution, habitat alteration and fragmentation, invasions of exotic organisms) is commonly known prior to investigation in terrestrial insect indicator studies (Jones 1987 Kroupa et al. 1990). Using biota to indicate changes in physical or chemical environmental conditions, or vegetation, when the changes can be measured directly and far more accurately using instrumentation, or by other means, is futile (Kremen 1992). Also, when subtle, complex environmental changes occur direct measurement of the stressor is often more useful because it may be difficult to distinguish biotic changes as being either a direct consequence of anthropogenic infuence or merely part of the inherent dynamics of the system being examined (Underwood 1989, Stork and Samways 1995).

Several studies, including both insect and other taxa, have examined the possible indicator value of particular taxa for predicting the richness of one or more other taxa (Gaston 1996 a & b, Williams 1996). An example is the study by Beccaloni and Gaston (1995) where the Ithomiinae (Nymphalidae, Lepidoptera) were identified as a biodiversity indicator on the basis of their representativeness of the diversity of forest-dwelling neotropical butterflies. Conversely, Prendergast et al. (1993), using high species richness and rare species as criteria for site selection, found low coincidence of species-rich areas (hot-spots) and areas harbouring rare species for either plants, birds, butterflies or dragonflies. These studies (Oliver and Beattie 1993, 1996) are based on the so-called ‘hot-spot’ approach (Mittermeier 1988) and do not address the critical issue of complementarity that has been recognized as an integral component for markedly improving the efficiency of site-selection procedures (Kirkpatrick 1983, Ackery and Vane-Wright 1984, Collins and Morris 1985, Vane-Wright et al. 1991).

In certain instances, however, insect indicators remain potentially useful as signallers of change in environmental state (Zonneveld 1983). Direct measurement of disturbance often requires sophisticated procedures and equipment that are expensive to purchase and run. Environmental indicators may then be a more feasible alternative. In other instances, environmental changes in terrestrial ecosystems may be subtle and a result of complex interactions between abiotic and biotic components that cannot be measured directly (Zonneveld 1983, Spellerberg 1992, Stewart-Oaten 1993, Worthen et al. 1994). Occasionally, environmental changes can also be detected in biota long after physical or chemical traces of the impact are no longer directly measurable, or the biological indicator may reflect more accurately the presence and extent of a disturbance (Dallinger et al. 1992, Spellerberg 1992).

2.2 Research and Studies on Bioindicators - International Status

Insects constitute a substantial proportion of terrestrial species richness and biomass, and play a significant role in ecosystem functioning. This realization has led to extensive discussion and evaluation of the use of terrestrial insects as bioindicators, and the concept has been applied to a variety of taxa, habitats and environmental scenarios (Holloway 1980, Rosenberg et al. 1986, Kremen et al. 1993). Studies have included the use of single species, higher taxa, assemblages and communities of, for example, dragonflies, ground beetles, tiger beetles, moths (Kitching et al. 2000), butteries, sawflies and ants, in habitats such as forests, grasslands, sand dunes, soils, urban areas and mine sites. In spite of the apparent wide range of terrestrial insect indicator studies, little attention has been given to the definition or implicit goals of ‘bioindication’ using terrestrial insects. The term is often used loosely and has been adopted in a broad range of contexts, including the indication of habitat alteration, destruction, contamination and rehabilitation, vegetation succession, climate change and species diversity (and even to non-conservation related issues such as indicating past climates (Coope 1979, Coope and Lehmdahl 1996).

Questions concerning the protocols that should be used to identify indicator taxa and whether or not they can be designated objectively have also been raised (Stork and Samways 1995). On more than one occasion it has been suggested that the basis for insect indicator selection is often merely favoured or convenient taxa (Soulé and Kohm 1989, Woiwod and Thomas 1993, Williams and Gaston 1994). Numerous authors have listed *a priori* criteria for the selection of potentially effective insect indicator taxa and many studies have applied these to justify the suitability of particular taxa as indicators (e.g. Holloway and Stork 1991, Pearson and Cassola 1992, Pearson 1994).

However, there is little to be gained from ‘testing’ the suitability of potential indicator taxa against this list of *a priori* selection criteria. Guideline criteria merely minimize the chance from the outset of spending time and energy studying species that are unlikely to be successful candidates. Whatever the criteria for selection used, once identified as potentially suitable, taxa have seldom been formally tested for indicator value, let alone applied as such, and only very recently have more rigorous studies begun to appear. There is thus an imbalance between the considered ‘potential value’ and well-propounded *a priori* criteria for suitable terrestrial insect indicator taxa, and the actual testing and application of these taxa as indicators. Bioindication is essentially a sub-discipline of conservation biology (New 1995, 1999), and its primary goal is, therefore, the application of scientific knowledge to the management of ecological relationships, i.e. to maintain particular relationships between species and their distributions and abundances (Caughley and Gunn 1996). Research is not conservation biology if it has no practical implications for conservation (Murphy 1990, 1992) and, likewise, studies on the relationships between terrestrial insects and biotic and abiotic variables are not bioindication unless the potential applications of these relationships are elucidated.

As a result of undefined endpoints to indicator identification and selection (i.e. failure to identify and elucidate the specific applied value of a nominated indicator), there has often been a lack of rigorous testing of hypotheses and of the implicit assumptions made when a species, or group, of terrestrial insects is selected as a bioindicator. The use of bioindication in terrestrial systems, particularly using invertebrate indicators, has only gained momentum within the last two decades (Holloway 1980). Aquatic macroinvertebrates, however, have frequently been highly recommended as indicators of water quality (Hellawell 1986). The recommendation and use of aquatic invertebrates in both freshwater and marine systems dates back a number of decades and the literature in this field is extensive (Hellawell 1986, Rosenberg and Resh 1993). Although biological indicators have been used for far longer and far more extensively in aquatic than in terrestrial systems, the significant differences between aquatic and terrestrial ecosystems to some extent divide the fields of aquatic and terrestrial bioindication. Terrestrial systems tend to be more complex (e.g. have greater species richness) and variable, and terrestrial abiotic factors (e.g. air pollution, humidity) are often more difficult to quantify than aquatic abiotic ones (Steele 1991). Nevertheless the basic principles and methods used in terrestrial bioindication have their origin in the aquatic literature (Winner et al. 1980, Hellawell 1986, Landres et al. 1988, Rosenberg and Resh 1993, Clarke and Warwick 1994 a & b, Chessman 1995).

Methods to study and understand biodiversity must take into account the use of well-known bioindicators groups that are quickly and easily studied but whose patterns are likely to be representative of many other species (Landres et al. 1988, Noss 1990, Pearson 1994). Because many conservation decisions today are made at a large geographical scale (hundreds or thousands of square kilometers), indicator groups have become more useful. This assessment provides information for most useful resolving initial priorities (Kuliopulos 1990) especially in developing countries. An additional advantage is that patterns of biodiversity at large regional scales are generally the product of only a few factors; such as origination and extinction (Cracraft 1992, Rosenweig 1995) and may be generally represented by one or more indicator taxa.

Conversely, at small regional scales, biodiversity patterns are the product of these same factors plus numerous additional factors such as immigration and emigration (Gaston and Blackburn 1996). Thus, the greater number of varying factors makes resultant patterns less likely to be shared by different group at small geographical scales. In addition, at small scales, single habitats or ecosystems are often so unique that they are less likely to be broadly represented by a single or a small number of groups (Prendergast et al. 1993). Historically, studies with indicator taxa have focused primarily on vertebrates. However, their relatively long generation times, low population growth rates, and comparatively low habitat specificity, make them sub-optimal (though certainly charismatic) indicator species (Pyle et al. 1981, Rosenberg et al. 1986). Insects suffer none of these drawbacks, and have received increased recent attention as possible indicators. Insects in general are particularly suited for monitoring landscape change because of their abundances, species richness, ubiquitous appearance, and importance in the functioning of the natural ecosystems (Rosenberg et al. 1986).

So far only a discrete work for role of Coleoptera as bioindicators for biodiversity monitoring has been done. Only certain families have been taken into the consideration, since all the enlisted families of Coleoptera don't fit into the previously mentioned characteristics of indicator species. Kromp (1990) has shown the role of carabid beetles (Carabidae: Coleoptera) as bioindicators in biological and conventional farming in potato fields of Australia. Andersen (1997) has done study on using ants as bioindicators in land management. Paoletti et al. (1999) evaluated arthropods as bioindicators in agro-ecosystems of Jiang Han plains of Qianjiang city in China. Sommaggio (1999) has suggested the use of Syrphidae (Diptera: Hover flies) as environmental bioindicators, and emphasized the need of more research work towards the better understanding of environmental requirements of both the adults and larvae of hover flies. Iperti (1999) has reported on the biodiversity of predaceous Coccinellidae in relation to bioindication and economic importance. Vu and Nguyen (2000) studied the microarthropod community structures viz. Oribatei and Collembola in the Tam Dao National Park, Vietnam for its role as bioindicators of forest plant succession. McGeoch (2002) worked on the application of Scarabaeidae (dung beetles) as bioindicators in the Savannah ecosystem.

2.3 Research and Studies on Bioindicators - Status in India

Studies and research on bioindicators using animal models in ecology, environment and/or forest management is limited in India. Pearson and Ghorpade (1989) have proposed that the family of tiger beetles (Cicindelidae) can be used as an indicator for quickly and accurately determine areas of high diversity and endemism on the Indian sub-continent. The role of nematodes as bioindicators in marine and freshwater habitats using adult roundworms of genus *Rostellascaris*, in the river Ganges, Allahabad, and catfish, *Arius falcaris*, in the Arabian Sea at Goa has been studied by Geetanjali et al. (2002). Bhat et al. (2003) have studied the role of microbial biomass as bioindicators of forest floor degradation. Macroinvertebrates were studied as bioindicators (Coleoptera: Psephenidae) to monitor the water quality of wetlands (www.wgbis.ces.iisc.ernet.in).

Uniyal et al. (2007) undertook a major pioneering study on the ecological study on tiger beetles as indicator for monitoring biodiversity in the protected areas of the Shivalik landscape of north western Himalaya. So far, in India, not much of the work has been done on the bioindicators role of many abundant Coleopteran families. This research work gives an opportunity to explore an uninvestigated site to determine the spatial distribution of various families, species number and endemics of the order Coleoptera to apply it as its potential role as bioindicators, which will be thus an important technique for the preliminary decision-making of conservation efforts.

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CHAPTER 3
STUDY AREA

3.1 Simbalbara Wildlife Sanctuary, Himachal Pradesh

The study sites lie in Simbalbara Wildlife Sanctuary (WLS) (30°24’21”-30°28’13”N and 77°27’18”-77°31’26”E) in the southernmost Sirmaur district of Himachal Pradesh (Plate 1). This area is a representative of the lower *Bhabar* Shivalik region and lies in the confluence of the *Terai* plains and the main Shivalik system. The flora, fauna and physical features show affinities to western Himalaya, Punjab plains and upper Gangetic plains (Biogeographic zones 2B, 4A and 7A respectively, Rodgers and Panwar 1988), though it is present in the biogeographic province 4A (Fig. 3.1). The protected area spans over 19.03 sq. km. The sanctuary was notified as a game sanctuary for the first time on 8 February, 1958, under the Indian (Forest) Act 1927, the Punjab Wild Birds and Wild Animal (Protection) Act 1933, and other relevant acts. Prior to its notification, Simbalbara WLS was the hunting preserve of the former Maharajah of Sirmaur (Singh et al. 1990). A revised notification was issued in 1972, and the sanctuary was renotified on 27 March, 1974.

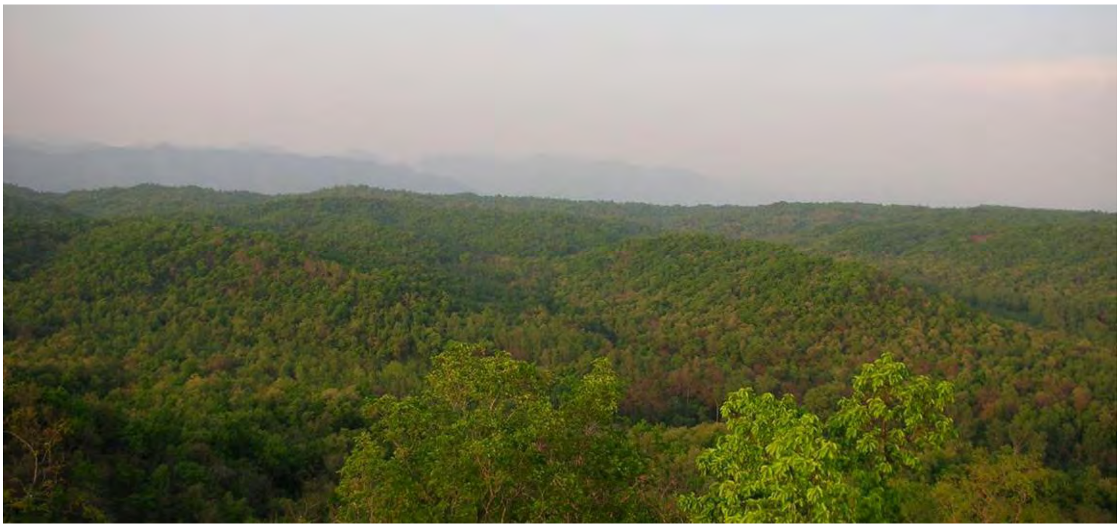
3.2 Physical Features

The altitudinal range is from 350m to 700m above msl. The hills are composed of unconsolidated sandstone and conglomerate that are extremely prone to erosion. The soil is extremely porous and thereby highly drained. However, in many low-lying areas springs emerge and create microhabitat for the invertebrate fauna like beetles and butterflies.

3.3 Climate

The temperature ranges from 10°C to 46°C with a mean annual rainfall of 1260mm (Singh et al. 1990). Most of the precipitation in this area occurs

Study area – Simbalbara Wildlife Sanctuary, Himachal Pradesh



Sal (*Shorea robusta*) dominated forests of Simbalbara WLS, Himachal Pradesh

A typical forest path inside the Simbalbara Wildlife Sanctuary

Cane (*Calamus* sp.) and *Ardisia solanacea* typify largely moist evergreen forest areas

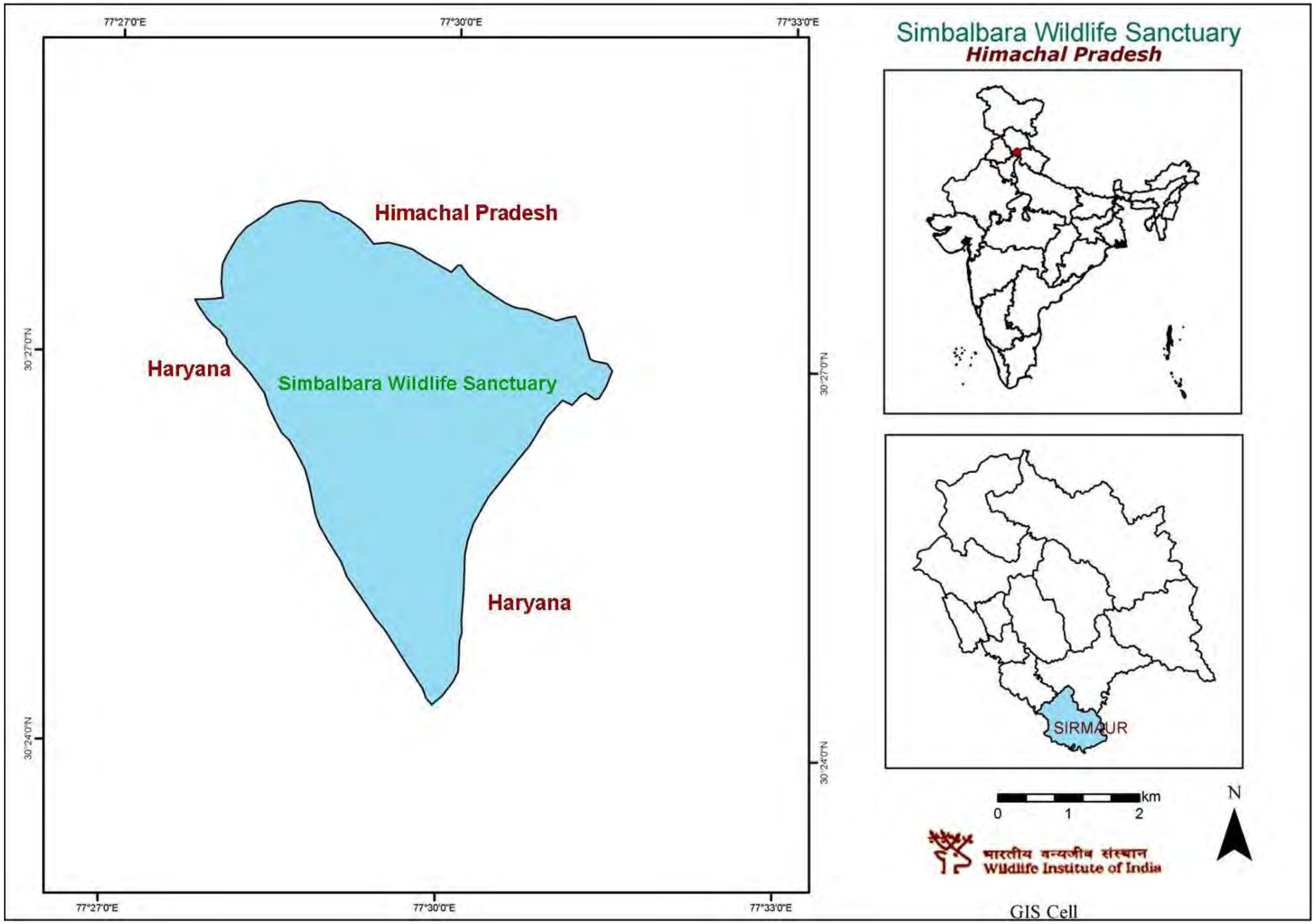


Fig. 3.1 Base map of Simbalbara Wildlife Sanctuary, Sirmaur, Himachal Pradesh

during southwest monsoon. Additionally, occasional winter rains also occur due to the western disturbance. Frost sometimes occurs during December and January. The relative humidity varies from 100% during monsoon to 26% in summer (Pendharkar 1993).

3.4 Flora

These forests are considered to be the westernmost limit of Sal *(Shorea robusta)* in protected areas of north western India. Moist and dry Sal bearing forests (3C1/C2) and northern dry mixed deciduous forests characterize the sanctuary (Champion and Seth 1968). Apart from these two major types, there are *Eucalyptus citrodora* mixed woodlands and riverine forests. The common species in the Sal-dominated forest include *Mallotus philipennsis, Terminalia alata (tomentosa), Ougenia oogeinensis, Cordia dichotoma, Ehretia laevis, Grewia tilaefolia* and *Bauhinia vahlii.* On the ridges, species such as Amla (*Emblica officinalis*), Gamhar (*Gmelina arborea*), *Anogeissus lalifolia,* Chironji (*Buchanania lanzan*)*,* Tendu (*Diospyros meanoxylon*) and *Boswellia serrata* are commonly found.

The sanctuary has some pockets of Khair (*Acacia catechu*) and bamboo plantations (*Bamboo bambusae* and *Dendrocalamus strictus*). Along the streams, species such as Jamun (*Syzigium cumini*) and Gular (*Ficus racemosa*) are prevalent. Plantations were undertaken in the past with the objective of improving wildlife habitat and cover an area of over 4 hectares. The introduced species planted include poplar (*Populus* sp.) (1983-84), bamboo like *Bamboo bambusae* and *Dendrocalamus strictus* (1966-68) and *Eucalyptus citrodora.* Some plantations of fodder species have been also carried out from 1983-84.

3.5 Fauna

The sanctuary area is home for many species of amphibians, reptiles, birds and mammals. Most of the mammals present have a wide geographical distribution and are not unique to the study area. A few representatives are common leopard (*Panthera pardus*), grey goral (*Naemorhedus goral*), chital (*Axis axis*), sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjak*), wild pig (*Sus scrofa*), hanuman langur (*Semnopithecus entellus*), rhesus macaque (*Macaca mulatta*), jackal (*Canis aureus*), black-naped hare (*Lepus nigricollis*), Indian pangolin (*Manis crassicaudata*) and porcupine (*Hystrix indica*). A breeding programme for chital, hog deer and barking deer was initiated in 1978, with plans of reintroducing chital. However the facility is no longer functional. Chital are known to migrate in the summer months from the plains of Darpur and Kalesar sanctuary, Haryana to the water holes in Simbalbara WLS. Tiger (*Panthera tigris*), jungle cat (*Felis chaus*) and leopard cat (*Prionailurus bengalensis*) are the rare inhabitants. Tiger (*Panthera tigris*) pugmarks were seen in the sanctuary and in adjoining Kalesar National Park (NP), Haryana in the year 2003. Elephant (*Elephas maximus*) from Shivalik Forest Division (FD) viz. Rajaji NP occasionally cross the Yamuna river and have been recorded many times in the sanctuary during the study period.

70 species of butterflies belonging to 54 genera in five families were recorded in the sanctuary (Kittur et al. 2006). 117 species of birds were recorded in the sanctuary area that included many winter migrants (Bhargav et al. 2007). The sanctuary is also the westernmost limit of distribution of 54 Himalayan bird species. Some of these include great slaty woodpecker, oriental pied hornbill, stork-billed kingfisher, blue-bearded bee-eater, drongo cuckoo, Indian nightjar, Syke's nightjar, emerald dove, lesser kestrel, Indian cormorant, bronzed drongo, spangled drongo, greater racquet-tailed drongo, maroon oriole, white-rumped shama, black-crested bulbul etc. The occurrence of all those mammals and birds such as Kaleej pheasant and red-billed blue magpie in the study area is indicative of the Himalayan influence on fauna of Simbalbara WLS. Similarly, presence of grey partridge, saker falcon, and imperial eagle is indicative of influence plains of India.

3.6 Land Use and Human Disturbance

There are no villages inside the sanctuary area. However, the surrounding area has 35 villages, many of which are inhabited by *gujjars with* large cattle holdings (Singh et al. 1990). Consequently, the forest faces a constant pressure due to fuel wood extraction, fodder collection, lopping, grazing by buffaloes and cattle, and also grazing by sheep and goats owned by nomadic *gaddis* in winter (Plate 2). A road passing through the sanctuary is used by *gujjars,* and other nomadic grazers. Visiting rights in relation to Kaludeo temple exists (Singh et al. 1990). Pilgrims visit this temple and also the *dargah* near the rest house. Hence, entry into the sanctuary is not regulated. The part of the sanctuary adjoining Kalesar National Park, Haryana is reported to be prone to poaching from across the border. In addition occasional cases of illegal felling and smuggling of *Acacia catechu* are also reported.

3.7 Study Period

The present intensive field research work was initiated in the Simbalbara WLS from October 2005 till August 2008. The research work focused primarily on beetles (Insecta: Coleoptera) towards understanding the nature of habitat association, diversity patterns and their potential role as bioindicators to monitor the human influence on forest ecosystems of protected areas as a type study. Sampling for beetles was carried out in different micro-habitat types present within and around the sanctuary area; delineated primarily on the dominant vegetation type of the sanctuary area during different seasons (Plate 3 to 7). The following microhabitats were delineated based on the dominant vegetation (tree species) in which sampling for the underlying objectives were undertaken.

1. Sal (*Shorea robusta*) forest (SFC): Habitat with the Importance Value Index (IVI, Curtis 1959) of over 175 for *Shorea robusta* was placed under this micro-habitat type. This tree species was found to be

Human disturbance in the study area

Grazing

Logging

Lopping

associated with *Mallotus philipennsis* (IVI=38) and other species such as *Terminalia alata* (IVI=16), *Ehretia laevis* (IVI=9), *Bauhinia malabarica*, *Careya arborea*, *Oogenia oogeinensis*, *Holarrhena antidysenterica* and *Cassia fistula*. *Clerodendron viscosum* was the most abundant shrub followed by *Murraya* koenigii and *Lantana camara*. The other major shrub found here was *Glycosmis pentaphylla.* Herbs were not abundantly found. The main herb found was *Ageratum conyzoides.* This micro-habitat was typically located within the sanctuary.

2. Sal (*Shorea robusta*) forest experiment (SFE): Habitat with the IVI of over 175 for *Shorea robusta* was placed under this micro-habitat type. *Clerodendron viscosum* was the most abundant shrub followed by *Murraya koenigii* and *Adhatoda sp.* The main herb found was *Ageratum conyzoides.* This micro-habitat was typically located outside the sanctuary with varying degrees of human interference like logging, lopping, grazing, fuelwood, MFP (minor forest produce) and NTFP (non-timber forest produce) collection.
3. Sal (*Shorea robusta*) forest fire (SFF): Habitat with the IVI of over 175 for *Shorea robusta* was placed under this micro-habitat type. This tree species was found to be associated with *Bauhinia vahlii*. These micro-habitats were typically located in the southwestern part of the sanctuary frequently predisposed to forest fires during the months from April to June.
4. *Eucalyptus* plantation mixed forest (EPC): *Eucalyptus citrodora* showed complete dominance in this micro-habitat type, since they are essentially monocultures. It had an IVI of 226. *Clerodendron viscosum Ardisia solanacea* and few *Colebrookea oppositifoila* and *Lantana camara* were recorded. *Cassia tora* was the most abundant herb species; few were *Sida acuta*, *Oxalis corniculata*. This micro-habitat was typically located within the sanctuary.
5. *Eucalyptus* plantation experiment (EPE): In this micro-habitat type also *Eucalyptus citrodora* showed complete dominance (IVI=216). *Murraya koenigii* was the predominant shrub species followed by *Clerodendron viscosum* and *Colebrookea oppositifoila*. *Cassia tora* was the most

Habitat types sampled for beetles in the Simbalbara WLS, Himachal Pradesh

1. Sal (*Shorea robusta*) forest control plot within the sanctuary

2. Sal (*Shorea robusta*) forest experiment plot outside the sanctuary

3. Sal (*Shorea robusta*) forest fire plot in southwestern part of the sanctuary

4. ***Eucalyptus citrodora*** **control plot within the sanctuary**

5. ***Eucalyptus citrodora*** **experiment plot outside the sanctuary**

6. Teak (*Tectona grandis*) plantation mixed forest

7. Khair (*Acacia catechu*) plantation mixed forest

8. Riverine area

Plate 5

9. Mixed forest

10. Jamun (*Syzygium cumini*) mixed forest

11. Bamboo (*Bamboo bambusae*) plantation mixed forest

Plate 6

12. Agriculture land

13. Pine (*Pinus roxburghii*) mixed forest

abundant herb species; few were *Carissa opaca, Sida acuta* and *Oxalis corniculata*. This micro-habitat was typically located outside the sanctuary with varying degrees of human interference like logging, lopping, grazing, fuelwood, MFP (minor forest produce) and NTFP (non-timber forest produce) collection.

6. Teak (*Tectona grandis*) plantation mixed forest (TP): Teak (*Tectona grandis*) has been planted in area contiguous with sanctaury boundary. This species showed dominance in all the seedling, sapling and tree layers. However, in such teak plantations with Sal forests, other species were found growing particularly near edges like *Mallotus philipennsis*, *Ficus* spp*.*, *Cassia fistula*, *Shorea robusta.* Teak had the maximum IVI of 85 followed by Sal (IVI=73). The major shrub was *Carissa opaca.*
7. Khair (*Acacia catechu*) mixed forest (KF): Khair was the most dominant tree species with an IVI of 140. The other tree species included *Rendia spinosa*, *Shorea robusta* and climber *Bauhinia vahlii. Carissa opaca* was the dominant shrub present with few *Zizyphus* spp. This micro-habitat was typically located within the sanctuary.
8. Riverine (RP): This micro-habitat showed the most diverse assemblage of tree species without any clear dominance of other species except Sal. Along the edges of riverine area tree species commonly found apart from Sal were *Ficus semicordata*, *Bauhinia malabarica*, *Litsea monopetala*, S*emecarpus anacardium*, *Toona ciliata*, *Oogenia oogeinensis*, *Lannea coromandelica, Ficus racemosa*; and relatively less common trees like *Acacia catechu, Ehraetia laevis, Grewia elastica, G. serrulata, Oroxylum indicum*, *Mitragyna parviflora*, *Aegle marmelos* were present. *Xanthium strumarium, Urena lobata, Caryopteris odora*, *Cassia occidentalis*, *Dicliptera* sp*., Solanum verbacifolium* were the common shrubs. *Milletia auriculata* was the common climber species. *Parthenium hysterophorus*, *Sida acuta* and *Ageratum conyzoides* were common herbs.
9. Mixed forest (MF): This micro-habitat was characterised by *Shorea robusta* with an IVI between 75 and 120. Sal had an overall IVI of 80. Among other dominant species were *Ficus racemosa*, *F. cunea*,

Mallotus philipennsis, *Terminalia bellerica*, *Syzygium cumini*, *Flacourtia indica*, *Embellia robusta*. Few less common species include *Bombax ceiba*, *Litsea monopetala*. The understorey was absent at many places due to thick canopy cover (>80%) and at few places of open canopy near the edges *Ardisia solanacea*, *Adhatoda* sp. and *Eupatorium adenophorum* as dominant shrubs were present. This micro-habitat was typically located within the sanctuary.

10. Jamun (*Syzygium cumini*) mixed forest (SY): It was characterised largely by the presence of *Syzygium cumuni* (IVI=66) and *S. operculata* with *Ficus racemosa* and *F. semicordata* at few places at the interface of riverine and Sal mixed forests. *Lantana camara* was the dominant shrub followed by *Murraya koenigii*. This micro-habitat was typically located within the sanctuary.
11. Bamboo (*Bamboo bambusae*) mixed forest (BF): It was characterised by tracts of *Bamboo bambusae* (IVI=61) plantation at the interface with Sal mixed forest. The understorey was dominated by *Lantana camara*. The dominant herbs were *Ageratum conyzoides*, *Oxalis corniculata* and various species of *Sida.* This micro-habitat was typically located within the sanctuary.
12. Agriculture/village land (AL): This micro-habitat was located outside the sanctuary limits. It was characterised by typical agriculture land set up of rural India with distinct cropping patterns of *kharif* and *rabi* growing seasons. The virtual objective of selecting this micro-habitat was to find out ‘any’ degree of overlap of beetle species with the forest species (pest or natural enemies) in diffferent sampling seasons. The micro-habitat was characterised by isolated plantations of *Populus* sp., *Eucalyptus citrodora*, *Mangifera indica*, *Psidium guajava*; and the riverine edges were largely dominated by wetland weed *Ipomea carnea.*
13. Pine (*Pinus roxburghii*) mixed forest (PM): This micro-habitat was located outside the Simbalbara WLS limits in the Darpur Reserve Forest (RF). It was characterised by *Pinus roxburghii* (IVI=53) interspersed with *Syzygium cumini*) mixed forest often at the edges of Sal forest. The understorey vegetation was largely absent. Few

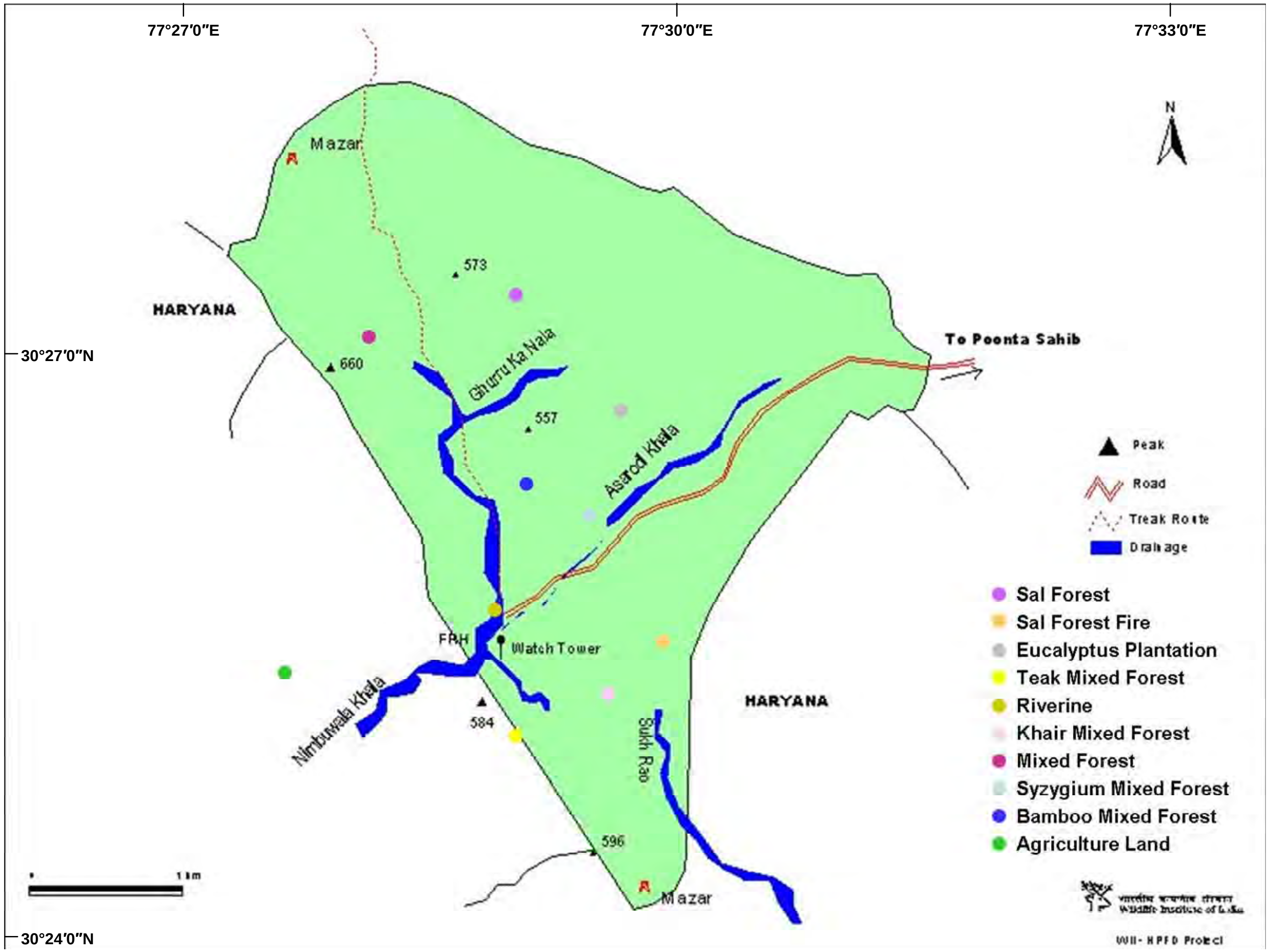


Fig. 3.2 Base map of Simbalbara WLS showing location of different sampling sites

seasonal herbs like *Cassia tora*, *Sida* spp. *and Solanum* spp. were present.

3.8 Objectives

The purpose of this research work were to examine, that how many families of Coleoptera promising as bioindicators on global scale are useful for monitoring and inventory study, on the more local scale in Sal (*Shorea robusta*) dominated forest ecosystems of Simbalbara Wildlife Sanctuary, Himachal Pradesh in the Shivalik landscape of western Himalaya. Field work for the study was conducted from October 2005 to August 2008 in different seasons to get consistent and reliable data. The key obectives undertaken in the study were:

1. To study the diversity patterns of beetles (Coleoptera) in Simbalbara Wildlife Sanctuary, Himachal Pradesh.
2. To determine the bioindicator families of Coleoptera and their taxonomy.
3. To assess the potential use of bioindicator Coleopteran families as indicator to monitor human influence on forest ecosystem.

CHAPTER 4

DIVERSITY PATTERNS OF BEETLES IN SIMBALBARA WILDLIFE SANCTUARY, HIMACHAL PRADESH

4.1 Introduction

Forests worldwide are known to be critically important habitats in terms of the biological diversity they contain and in terms of the ecological functions they serve. Taking species counts as an illustration of biological diversity, the number of described organisms totals some 1.75 million, and it is conjectured that this may be just 13% of the true total, i.e. actual species number perhaps 13.6 million (Hawksworth et al. 1995, Stork 1999). What fraction of this uncertain total resides in the world's forests is unknown. Wilson (1992) has suggested that perhaps half of all known species reside in tropical forests (Novotny and Basset 2000) alone, and WCMC (1992) conjectures that the majority of yet-to-be-discovered species are in tropical areas. Whatever the precise number, forests, and tropical forests in particular, are major locations for biological diversity. The values of forests therefore embody the values of the biological diversity they contain since it seems unlikely that the vast majority of the biological resources in question could occupy non-forest habitats. National and regional agencies for nature conservation, agriculture, and forestry have to monitor species diversity or other aspects of biodiversity, both before and after they spend tax money on subsidies or ecological compensation management, with the aim of enhancing biodiversity.

The Arthropods, most of which are insects, dominate many forest ecosystems in terms of species richness, biomass, and function. In addition to serving as an important vertebrate food source (Rosenberg et al. 1986, Borges and Brown 2004), many insect species also influence ecosystem processes, such as predation (Hammond and Miller 1998), decomposition (Moldenke and Lattin 1990), nutrient cycling (Asquith et al. 1990), herbivory (Wilson 1987), and pollination (Westman 1990). Insects are particularly useful bioindicators because of the large sample sizes that can be obtained using relatively unbiased methods, their relatively short generation times, and their sensitivity to local habitat changes (Refseth 1980, Pearson and Cassola 1992). Thus, insects can provide a rapid assessment of the effects of environmental change. Approximately 40% of all insects are beetles (order Coleoptera).

The order Coleoptera, the largest order of insects, has an estimated 3,50,000 species of beetles that are classified into 160 families (Elzinga 1992). These insects, with their thick and tough forewings, or *elytra*, have adapted to various habitats from aquatic to soil, to trees, foliage, and other aerial surfaces. They can range in size from 1 mm to approximately 75 mm in length (Borror et al. 2002). Although insects may seem to be small and inconspicuous compared with vertebrates (Greenwood 1987, Whitmore 1990), they are extremely important, arguably dominant elements within the ecosystems (Janzen 1987). Many insects respond rapidly and dramatically to changes in environmental conditions, making them potentially useful indicators of habitat condition.

Coleoptera comprise a diverse assemblage, including such major families as Scarabaeidae, Staphylinidae, Curculionidae and Carabidae. The distribution of beetles is often related to microhabitat features, such as soil moisture (Epstein and Kuhlman 1990, Niemelä et al. 1992, Rykken et al. 1997), litter depth (Michaels and McQuillan 1995), and habitat heterogeneity (Niemelä et al. 1996). Many beetles, especially those inhabiting stable ecosystems such as old growth forests (Purrington et al. 1989), have low dispersal ability, making their populations particularly susceptible to environmental disturbances (den Boer 1979). Environmental changes, such as logging for timber production and conversion of natural habitats for agriculture, human settlement, recreation, amenity or industry, greatly affect organism diversity (McNeely et al. 1995). Comparative studies have been conducted in on various insect groups, e.g. moths (Chey et al. 1997), dung beetles (Davis 1993), termites (Eggleton et al. 1997) and ants (Chung and Maryati 1996). They have generally found a decrease in diversity along the disturbance gradients.

Beetles have extreme diversity in form and function (Hammond 1995) and they are found in numbers in most vegetation types and can be easily sampled using a range of methods. Holloway (1998) emphasized that the high diversity of certain insect groups and the finer grain of their biogeographic and ecological patterns render them much more suitable than vertebrates as indicators of the state of forest systems and for monitoring the impact of changes. Beetles are used widely in diversity and ecological studies (Mawdsley and Stork 1997, Davis et al. 1997). In addition, more research needs to be carried out on such ecologically and economically-important groups. There is still a lack of taxonomical and ecological information on beetles in protected areas in India. Beetles are thus especially well-suited for monitoring effects of forest management practices on biodiversity, due to their relatively well-known taxonomy and relative ease of sampling. The overall aim of this chapter is to gain an understanding of the species richness, abundance, and composition of beetle assemblages in different habitat types in Simbalbara WLS, Himachal Pradesh. An understanding of these parameters is crucial to the conservation, land-use management and utilisation of the forest ecosystems of Shivalik Himalaya.

4.2 Sampling Methods

This study on key hyperdiverse group, beetles (Insecta: Coleoptera) was initiated in the study area to document the assemblage patterns of beetles in relation to different microhabitats. It is further extended to identifying key bioindicator families amongst recorded beetles and their use in conservation research for long term ecological monitoring of forest ecosystems in Shivalik landscape in light of anthropogenic induced landscape modification. There are many sampling techniques for the collection of beetles. These sampling techniques have no detrimental impact on longer-term trend of insect population, since no intensive sampling of a highly localized species was being done. The process involved sampling beetles by capture of the individual. Following were the methods used to capture beetles from different forest strata.

4.2.1 Sampling Subterranean Beetles

Hand Sorting

Hand sorting was employed in each sample plot on median axis to sample highly aggregated distributions of subterranean beetles that result from clumped ovipositional patterns, feeding preferences, and heterogeneous nature of the soil environment (Brown and Gange 1990). Thus, in any situation a large number of quadrats contained zero or very few beetles. Even though laborious, it is the most accurate method of extraction in the field (Penev 1992, Gange et al. 1991). A $25X25X10cm^3$ volume of soil was sampled for the estimation of density of subterranean beetles in the current study.

Flotation Methods

This method involved thorough mixing of the soil sample either with water, sugar, or salt solution to collect beetles from surface (Southwood and Henderson 2000); and salt was most commonly used (Goldson et al. 1988). The advantage of this passive technique is that it is inexpensive and relatively quick. It is the standard method for obtaining egg counts of a range of subterranean beetles (Elvin and Yeargan 1985, Blank et al. 1986) and useful for extraction of inactive stages like pupa and/or egg. The disadvantage of this method is that it is often difficult to get 'clean' samples of insects and that dead animals in the soil will also be extracted misleading the estimate of active population size for some species (McSorley et al. 1991). In such cases, magnesium sulphate was added to water to ease the separation of insects from soil material. In another extraction method, soil was mixed with a solution of water and hydrocarbon agent like benzene, and allowed to settle. The beetles were being found in hydrocarbon layer since cuticle of most species is lipophilic and shows hydrocarbon adhesion (Walter et al. 1987, Geurs 1991, Kethley 1989).

4.2.2 Sampling Nocturnal Beetles

Light Trap

A simple light trap made from a funnel, a collecting jar and a light source was used to capture nocturnal beetles. An incandescent light source (18W x 2) was held over a white sheet (1.8m x 1.2m) that acted as its background. The funnel was placed on the can and light source was suspended slightly above the funnel. Insects that fly into the light source fell down the funnel and were trapped in the can. The spout of the funnel was large enough to let the insects drop through it easily, but not so large as to let the insects fly out again. The can was filled with 70% alcohol with some preservative like ethyl acetate added to it to ensure insects do not escape.

Further, other beetles directly attracted to light held over sheet were captured directly using benzene-killing bottle; and they were preserved either dry, for large (>1cm) specimens; or wet in 70% alcohol, for small (<1cm) specimens This nocturnal light trap helped to determine the presence of primarily nocturnal species as well as nocturnal activity of otherwise diurnal species (Pearson and Vogler 2001). It was operated for one and half hour daily (1930h to 2100h) to maximize the capture size.

4.2.3 Sampling Epigeal Beetles

Pitfall Trap

Epigeal beetles were sampled using the pitfall trapping. The most commonly sampled epigeal beetles were ground beetles (Carabidae) rove beetles (Staphylinidae). These groups were characterised by highly active, mostly nocturnal polyphagous beetles (Greenslade 1973, Uetz and Unzicker 1976, Thiele 1977, Frank 1991). Their active nature means that while they showed habitat specificity, a spatially and temporally restricted sampling technique failed to catch many species because polyphagous predators are not associated with either a particular host plant, or specific prey species (Ericson

1979). Thus, any sampling strategy to target such an association would be also ineffective. In the present study, plastic jars measuring 10cm x 6cm filled with 50 ml of 10% ethyl acetate-saline solution were used as pitfall traps. Pitfall traps were left open and were monitored once in two days to check their functioning. Specimens were collected every third day and traps were restored with fresh solution.

The technique was first developed by Hertz (1927) and gives information on the structure of invertebrate communities (Hammond 1990), habitat associations (Honêk 1988), activity patterns (den Boer 1981), spatial distribution (Niemelä et al. 1990, Baars 1979), relative abundances, total population estimates, and distribution ranges and in pest monitoring programs. Since basic traps are cost effective and require no specialised manufacturing process, they are easy to transport and quick to install. The greatest advantage with them was that they sampled continuously, requiring only periodic emptying. Thus this technique not only removed biases associated with other techniques that sample at one point in time (Briggs 1960, Greenslade 1964, Topping and Sunderland 1992); it allowed large number of beetles to be caught over an entire season with minimal effort. It was also useful for sampling beetles occurring at low densities and to sample environmentally sensitive areas like sanctuaries since it caused low levels of disturbance, both physically and aesthetically.

4.2.4 Sampling Beetles from Forest Understorey Vegetation

Collecting insects from vegetation had two major aims; first, to generate a species list of the habitat and the second to obtain subsets or sample of the community those are representative of the whole.

Sweep Net capture

The sweep net capture was used in medium-height-vegetation for collecting beetles with specific plants or resources. It is an active sampling method suited to collect beetles associated to specific plant communities. It is a qualitative method, but was made semi-quantitative by standardising the number of sweeps to 100 in a given sample plot Gray and Treolar 1933). It is particularly effective for the insects present on the top of the vegetation, and in less dense vegetation, where insects can be easily knocked off into the net. Calibration was done in a pilot study in which netting was compared with the absolute counting method. Sweep net captures allowed collecting larger samples in a randomised manner from many locations, which is the essential requirement of parametric statistics. Thus, it collected samples that are completely representative of the population or community of beetles (Fichter 1941, Gadagkar et al. 1990, Krasnov and Shenbrot 1996).

4.2.5 Sampling from Tall Vegetation

Beating Trays

This is a qualitative method and was found reliable for constructing species lists and life cycle data for particular species like leaf beetles (Chrysomelidae) ladybird beetles (Coccinellidae), and it takes advantage of the fact that some of beetles are easily dislodged using a beating tray to give a relative estimate of population densities (White 1975). But the main bias in this technique lies in the selectivity with which insects will fall from vegetation, the strength of the beating action; so that larger beetles are preferentially collected from the vegetation; further from the sheet more active ones can escape. It was found to be more useful for collecting Chrysomelidae (leaf beetles). The beating method was found to be more effective than sweep net for estimating population densities but is more time consuming (Snodgrass 1993).

4.2.6 Sampling Beetles from Trees: Shoots, Stems and Trunks

Sampling beetles from the twigs, shoots and trunks of trees presents numerous problems as these include uneven population distributions over external and internal surfaces, and the frequently concealed and inaccessible nature of the life stages under investigation. During the present study, the most suitable method found was to collect beetles directly by hand picking in sampling sites; and emphasis was given to the evidences of insect activity concealed in the plant tissues, either currently or in the past to find out the beetle fauna. Damages caused by beetles, for example, periodic swellings along thin stems or twigs corresponds to boring by beetle larvae; heavy sap or resin exudation; creamy powder, dust or brown fine granules in bark crevices; engravings, tunneling etc correspond to the activity of beetles families viz. metallic wood borers (Buprestidae), borers (Cerambycidae), bark borers (Scolytidae), snout beetles (Curculionidae), and wood worms (Anobiidae).

4.3 Sample Plot

It was the most basic and smallest sampling unit grid with 50m X 50m dimensions i.e., an area of one fourth of a hectare (Fig. 4.1). Five such sample plots were marked on each linear transect measuring 300 m in length, in each habitat along open forest paths. Thus there was one transect containing five sample plots. The spatial distance between two transects in each was maintained at minimum 500m. The contiguous sample plots in each habitat were separated from each other by a distance of 10m that stood as 'no-sampling' zone to maintain adequate sampling distance between any two contiguous sample plots.

These sample plots were monitored for beetles during winter, summer, and monsoon months for three seasons from October 2005 to August 2008 to obtain consistent and reliable data. In each sample plot different collection methods (as described above in section 4.2) viz. beating trays, sweep net capture, and hand sorting were employed throughout the median axis of each sample plot. But pitfall traps (four in number) were strategically placed in each sample plot about 10m from the start point and 5m away from the median axis of the transect. The light trap was placed at the centre of each sample plot on median axis to sample beetles in each habitat during night time. Combining these different collection methods thus maximized the likelihood of our adequate sampling in different strata viz. subterranean, epigeal, low height and medium height understorey vegetation in the forests to understand habitat associations, spatial patterns and community structure of the beetles.

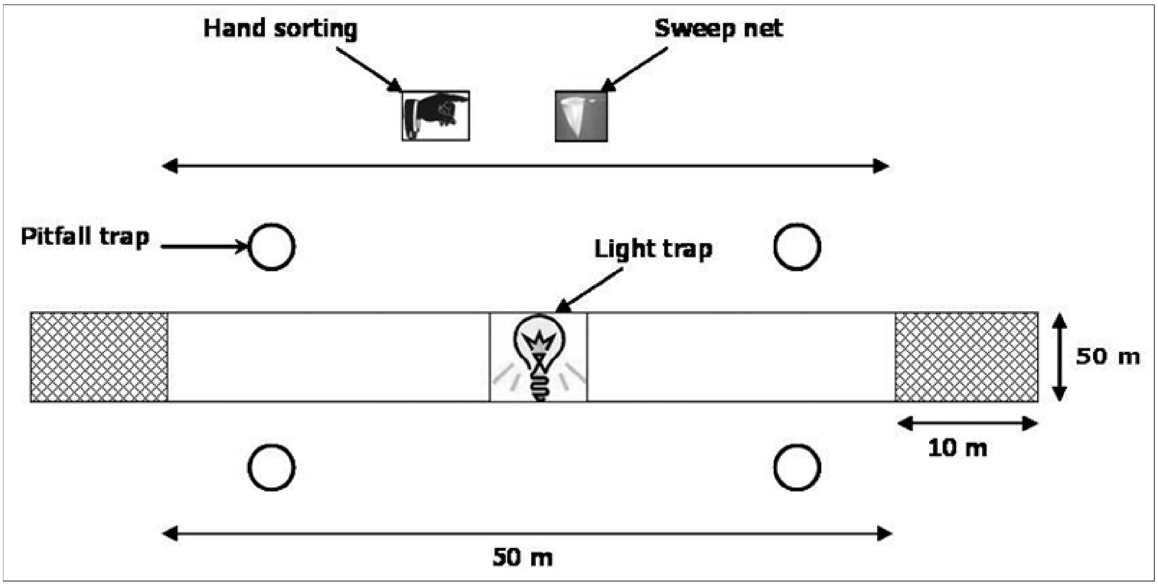


Fig. 4.1 Representation of a sample plot with various collection methods (Figure is not to scale)

4.4 Data Analysis

4.4.1 Species Richness and Diversity Pattern Analysis

Species Richness

Beetles captured by all the sampling methods were pooled for each site for quantitative analysis. SHE analysis was used first to test whether the data conform most closely to a log-normal, log-series or MacArthur's broken stick model using EstimateS (MacArthur and MacArthur 1961, MacArthur and Wilson 1967, MacArthur 1972, Colwell 2006). It finds the relationship between S (species richness), H (information, the Shannon-Wiener diversity index) and E (evenness as measured using the Shannon-Wiener evenness index, otherwise known as Pielou J) in the samples. It is therefore an approach to look at the contribution of species number and equitability to changes in diversity. SHE analysis follows the way these parameters changes with increasing sampling effort. It is also useful for identifying ecotones (regions where different ecological communities intersect, such as the edge of lakes) (Hayek and Buzas 1997).

Species richness was estimated for each habitat type, as well as for the regional data set using the non-parametric estimators Chao1 and Jacknife2. Accumulation curves were generated after 100 randomizations using EstimateS 7.0 (Colwell 2006). Chao1 gives an estimate of absolute number of species in an assemblage based on number of rare species (singletons and doubletons) in a sample. Chao1 estimate of species richness is recommended for inventory completeness values, completeness being the ratio between observed and estimated richness (Sørensen et al. 2002, Scharff et al. 2003, Buddle et al. 2005). Jacknife estimators in general, and Jacknife2 in particular, have been found to perform quite well in extrapolation of species richness, with greater precision, less bias and less dependence on sample size than other estimators (Palmer 1990, 1991, Baltanás 1992, Brose et al. 2003, Petersen et al. 2003, Chiarucci et al. 2003).

Measurement of α (Alpha) Diversity

Alpha diversity (α-diversity) is the biodiversity within a particular area, community or ecosystem, and is usually expressed as the species richness of the area. This can be easily measured by counting the number of taxa (distinct groups of organisms) within the ecosystem (eg. families, genera, and species). However, such estimates of species richness are strongly influenced by sample size, so a number of statistical techniques can be used to correct for sample size to get comparable values. Shannon index (H') was used to measure diversity across the selected micro-habitats. It provided the information entropy of the distribution, treating species as symbols and their relative population sizes as the probability. The advantage of this index is that it takes into account the number of species and the evenness of the species. The index is increased either by having additional unique species, or by having greater species evenness. Shannon J provided the species evenness that is the relative abundance or proportion of individuals among the species. Simpson's diversity index (D), which is a measure of diversity was used to quantify the biodiversity of a habitat (Simpson 1949). It takes into account the number of species present, as well as the abundance of each species. Thus, a habitat dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance. As species richness and evenness increases the diversity increases. D is thus measure of diversity, which takes into account both richness and evenness and it measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species). With this index, 0 represents infinite diversity and 1, no diversity; the bigger the value of D, the lower the diversity.

Rarefaction was carried out using the software program BioDiversity Pro (McAleece et al. 1997) to find out the expected number of species per sample size so as to compare the species number across the different habitat types. Data was log transformed to log (1+y) base 10 before analysis to reduce the weight of common species. Rarefaction thus ensured that all sample sizes are equal and the diversity is not dependent on sample size.

Measurement of β (Beta or Differentiation) Diversity

Beta diversity (β-diversity) is a measure of biodiversity that works by comparing the species diversity between ecosystems or along environmental gradients. This involves comparing the number of taxa that are unique to each of the ecosystems. Thus, it is the rate of change in species composition across habitats or among communities. It gives a quantitative measure of diversity of communities that experience changing environments. It is essentially a measure of how different (or similar) a range of habitats or samples are in terms of the variety (and sometimes the abundances) of species found in them. The fewer the species that the different communities or gradient positions share, the higher the β diversity will be. Together with diversity within a habitat, β diversity gives overall diversity of an area (Routledge 1977).

Kullback–Leibler information measure and Morisita-Horn index (Wolda 1981, Krebs 1989) were used as a measure of β-diversity. The former measures 'how' much the distribution of species within the communities differs from one another. The divergence is expressed as:

$$J\,(P{:}Q) = -\,H'_P - H'_Q + H'_{PQ}$$

where H'_P and H'_Q are Shannon H' for the communities P and Q respectively, and H'_{PQ} is a term for reciprocal information (Ludovisi and Taticchi 2006). It is very sensitive to shift in species dominance between two communities, i.e., it recognises two communities as very different if they are characterised by a high dominance of few but different species. It is also sensitive to the structure of the communities being compared, i.e., a given absolute difference in relative species abundance may result in different values of the divergence, depending on the equatiility of species distributions in the two communities. Further, its partitioning into different information terms (*H'_P, H'_Q and H'_{PQ}*) helps to show how different components of diversiy contribute to the resulting divergence.

Morisita-Horn index was calculated to find out the similarity between beetle populations from different habitats. Since the index is independent of sample size and diversity (Wolda 1981) it was an appropriate measure to compare the community structure pairwise in different habitats. The Morisita-Horn index was calculated using EstimateS (Colwell 2006) from:

$$\mathbf{MH} = \frac{\mathbf{2\ \sum n_{1\mathit{i}} n_{2\mathit{i}}}}{\mathbf{(\lambda_1 + \lambda_2)\, N_1 N_2}}$$

where MH is Morisita-Horn index of similarity between pairwise sampling habitats *j* and *k*, $n1_i$ = total number of individuals of species in *I* sample *j*, N_1 = the total number of individuals of all species in sample *j*, and λ_1 =

$$\frac{\sum \mathbf{N}_{1\mathit{i}}^2}{\sum \mathbf{N}_2^2}$$

4.4.2 Site Similarity and Cluster Analysis

Bray-Curtis similarity coefficient is a similarity coefficient used to determine site similarities based on organism abundances. It is widely employed in multivariate analysis of assemblage data. It reflects differences between two samples due both to differing community composition and/or differing total abundance. Bray-Curtis cluster analysis (single link) was performed to find out the clustering of habitats into distinct groups based on the species composition using software program BioDiversity Pro (McAleece et al. 1997). The similarity across sites was depicted as Bray-Curtis similarities (Krebs 1989) using both species composition and abundance across habitats. This similarity measure is an appropriate coefficient for exploring biological community similarities (Clarke and Warwick 2001). Single link clustering method was for hierarchical clustering that takes the similarity matrix as the starting point and successively fuses the samples into groups and the groups into larger clusters, starting with the highest mutual similarities then gradually lowering the similarity level at which groups are formed resulting in a tree diagram or dendogram plot (Clarke and Warwick 2001)

Multidimensional scaling (MDS) is a set of related statistical techniques often used in information visualization for exploring similarities or dissimilarities in data and can be considered to be an alternative to factor analysis. MDS is thus a special case of ordination. An MDS algorithm starts with a matrix of item–item similarities, and then assigns a location to each item in *N*-dimensional space, where *N* is specified a priori. Multidimensional scaling (MDS) plots were constructed based upon similarity values of species composition across habitat types in software program PRIMER (Clarke and Gorley 2001). MDS uses an algorithm which successively refines the positions of the points until they satisfy, as closely as possible, the dissimilarity between samples (Clarke and Warwick 2001). The result is a two-dimensional ordination plot where points that are close together represent samples that are very similar in composition. Points that are far apart correspond to samples with very different composition.

Analysis of similarities (ANOSIM, Clarke 1993) was performed between each pair of habitat types to determine whether there were significant differences between the beetle assemblages in the micro-habitat types. The ANOSIM procedure of PRIMER is a non-parametric permutation procedure applied to rank similarity matrices underlying sample ordinations (Clarke 1993). This method generates a global *R*-statistic, which is a measure of the distance between groups. An *R*-value that approaches one indicates strongly distinct assemblages, whereas an *R*-value close to zero indicates that the assemblages are barely separable (Clarke 1993). These *R*-values were used to compare beetle assemblages between habitat types.

Where ANOSIM revealed significant differences between groups, SIMPER analyses (PAST, Ryan et al. 1995) were used to identify those species that contributed most to the observed assemblage differences (Clarke and Gorley 2001). Similarity percentages (SIMPER) allowed identification of species and guild important in discriminating between groups that differed significantly from each other. SIMPER calculates the average Bray-Curtis dissimilarity between all pairs of inter-group samples. Because the Bray-Curtis dissimilarity measure incorporates the contribution of each species, the average dissimilarity between sites can be expressed in terms of the average contribution from each species. The standard deviation provides a measure of how consistently a given species will contribute to the dissimilarity between habitats. The species with the highest dissimilarity to standard deviation ratios were identified as good discriminators for each comparison as it contributes heavily to interhabitat dissimilarity (Clarke 1993).

4.4.3 Assemblage Patterns Using Multivariate analysis

The use of graphical methods was very useful for comparing the assemblages of several families of Coleoptera along with using various diversity indices. The rank-abundance and the k-dominance plot (Clarke 1993, McAleece et al. 1997) were used for the graphical representation of most diverse community. Upon plotting, the relative abundances on a graph gave a clear visible picture of the assemblages and communities. A rank abundance plot (or Whittaker plot) was used to visualize species abundance distributions. In this plot, the number of individuals of each species is sorted in descending order, and the proportion of the total number of individuals for each species is then plotted on the log scale against the species rank. Thus, shape of the rank abundance plot provides an indication of dominance or evenness; so steep plots signify assemblages with high dominance and shallower slopes indicate higher evenness. K-dominance plot displayed the cumulative proportion abundance against the log species rank. For this type of plot, more elevated curves represent less diverse assemblages.

DECORANA (DEtrended COrrespondence ANAalysis) a multivariate statistical technique is widely used to find the main factors or gradients in large, species rich but usually sparse data matrices that typify ecological community. For this data was analysed using PC-ORD (McCune and Mefford 1999, McCune and Grace 2002) and PAST (Ryan et al. 1995) by ordinating sites and species. DECORANA scales in units of average standard deviation of species turnover. Therefore a change of 50% in species composition occurs in about 1 standard deviation.

TWINSPAN (TWo-way INdicator SPecies ANalysis) however produced a classification of species list based on an ordered two-way table with each division into sub-groups characterised by indicator species. The process of classification is hierarchical in which samples are successively divided into categories, and species are then divided into categories on the basis of the sample classification. This technique had been successfully used for water beetle site list evaluation (Foster 1991).

4.5 Results

4.5.1 Species Richness and Diversity Pattern Analysis

SHE analysis plot (Fig. 4.2) that predicts average species abundance distribution depicted that beetles in the sampled sites have a Mac Arthur's broken stick model pattern of distribution, in relation to increasing sample size (N). It followed that the species richness (S) and the diversity (H') will tend to increase but the evenness (E) will remain constant; suggesting a relatively even distribution of beetle species.

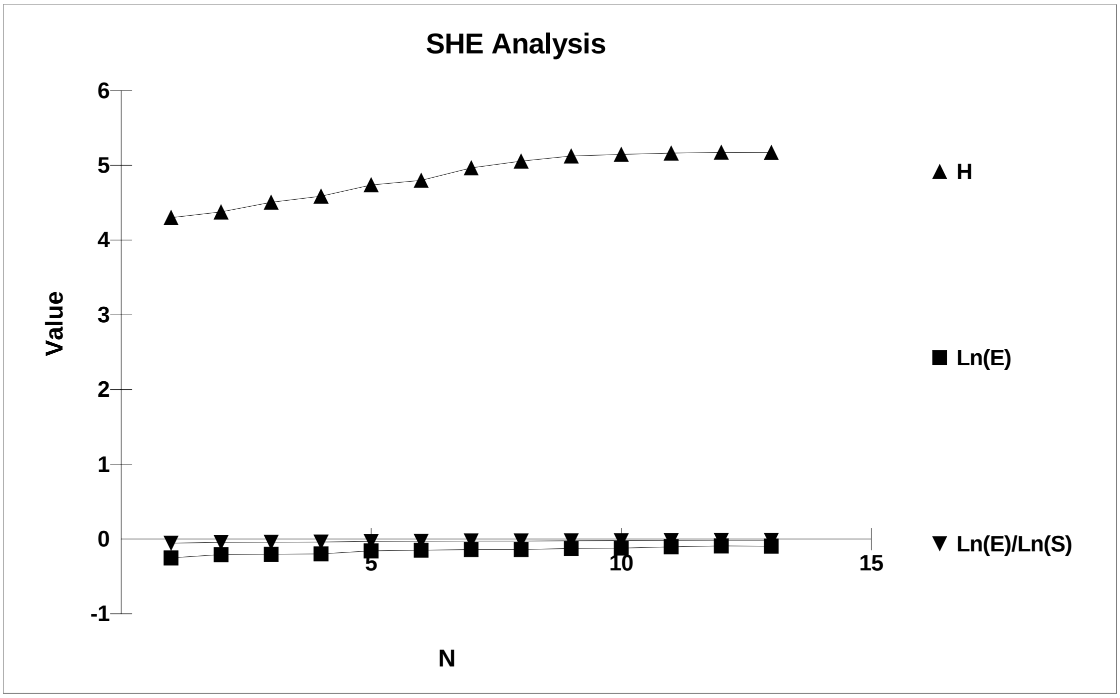


Fig. 4.2 SHE analysis plot showing average species abundance distribution of beetles in Simbalbara WLS

A total of 5404 adult beetles were captured representing 66 families, 95 genera and 194 species (including eight species identified till tribe and/or sub-family level designated as morphospecies and were included in the analyses), which represent ~1.13% of beetles species recorded in Indian mainland (Appendix 1). But this proportion included only five families of beetles' viz. ground beetles (Carabidae), tiger beetles (Cicindelidae), dung beetles (Scarabaeidae), rove beetles (Staphylinidae) and long-horned beetles (Cerambycidae). Only these families are included in the analyses presented here and subsequently; the virtual reason for selecting these families being their adequacy as bioindicators (Chapter 5).

The pooled species accumulation curve reached an asymptote for both Chao1 and Jacknife2 (Fig. 4.3), indicating that sampling was almost complete at regional level (Colwell and Coddington 1994, Colwell et al. 2004, Chao et al. 2005). The estimated total species richness using Chao1 was 206.88± 2.66 (SD), and using Jacknife2 216.32±1.55 (SD) for the complete sample. The ratio of observed to estimated (Chao1) number of species was 92% suggesting that at least 8% more species are expected in the area than were actually collected (Table 4.1).

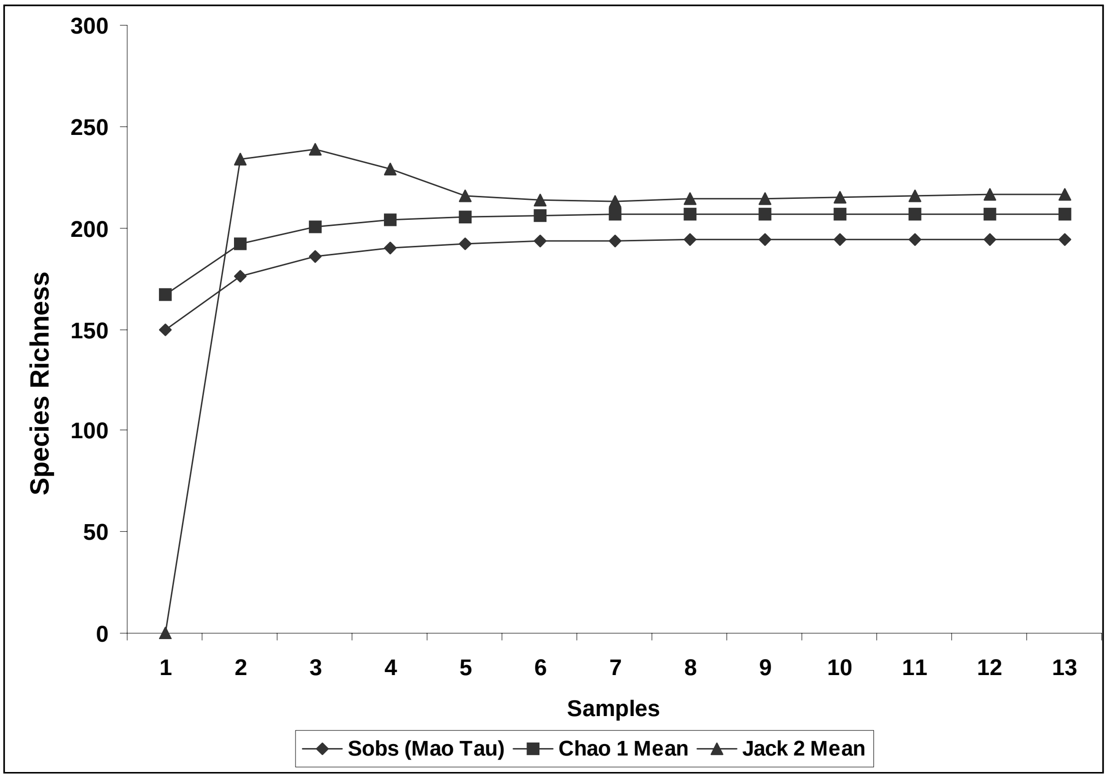


Fig. 4.3 Species accumulation curve and estimation curves at 100 randomizations for Chao1 and Jacknife 2, for the regional (pooled samples) dataset

Table 4.1 Measures of species richness estimates and inventory completeness for each habitat type and for regional dataset

S.No.	Habitats	No. of specimens	Observed richness	No. of singletons	No. of doubletons	Chao 1*	Jack 2*	% Completeness
1	SFC	766	153	7	1	183.07	186.34	84
2	SFE	324	175	14	6	196.29	206.8	89
3	SFF	570	171	11	4	201.73	208.03	85
4	EPC	705	156	9	0	198.64	211.09	79
5	EPE	496	169	3	5	193.17	213.48	87
6	TP	378	134	3	3	175.5	199.9	76
7	KF	144	138	10	7	170.45	195.81	81
8	RP	375	139	16	2	169.67	187.31	82
9	MF	808	179	8	2	201.25	207.37	89
10	SY	308	143	7	3	186.64	190.19	77
11	BF	312	120	7	4	160.14	166.83	75
12	AL	111	125	11	3	175.17	184.13	71
13	PM	107	147	3	2	199.13	204.1	74
14	**Pooled**	**5404**	**190**	**42**	**22**	**206.88**	**216.32**	**92**

***Richness estimator values (Chao 1 and Jack 2) represent the mean of 100 randomizations of sample order**

Measurement of α- Diversity

Rarefaction

The rarefaction plot (Fig. 4.4) showed that the sites were adequately sampled with curve for each habitat reaching the asymptote point suggesting that with the increasing effort there will not be any significant further addition to the species richness pool size. The ES(n) value peaked maximum for the bamboo mixed forest (BF) habitat and minimum for agriculture land (AL) habitat.

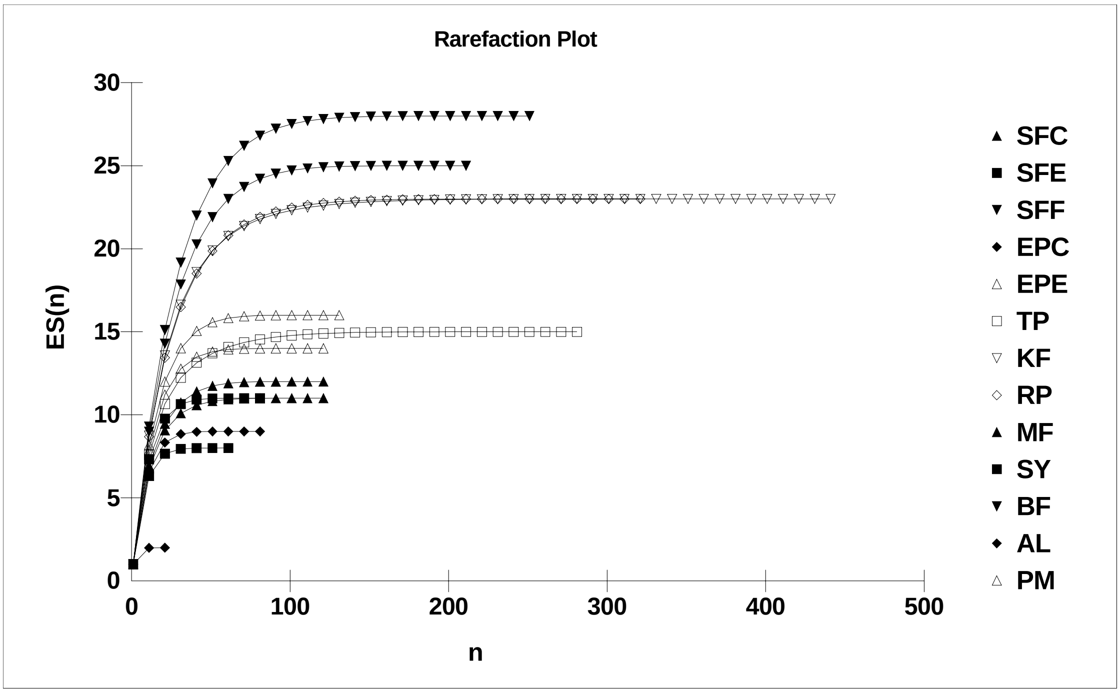


Fig. 4.4 Rarefaction plot showing the adequate sampling for beetles across thirteen micro-habitats of Simbalbara WLS

The alpha diversity plot (Fig. 4.5) (using Shannon H') was found maximum for the MF (1.935) and least for PM (1.53). Mixed forest habitats relatively showed a greater species diversity compared to pure stands and open areas sampled in and around the sanctuary. Experiment plots viz. SFF (1.877) and EPE (1.896) with moderate degree of disturbance also showed high species diversity. The evenness (Shannon J) ranged from 0.871 (KF) to 0.965 (EPE and SY) suggesting more or less even distribution of species across habitats. Further, the Simpson's diversity across habitats ranged from 0.012 (EPE) to 0.03 (PM) suggesting that the probability of getting two individuals of similar species was quite low. Consequently, the forest habitats of the sanctuary not only have a greater number of species present, but the individuals in the community are distributed more equitably among these species.

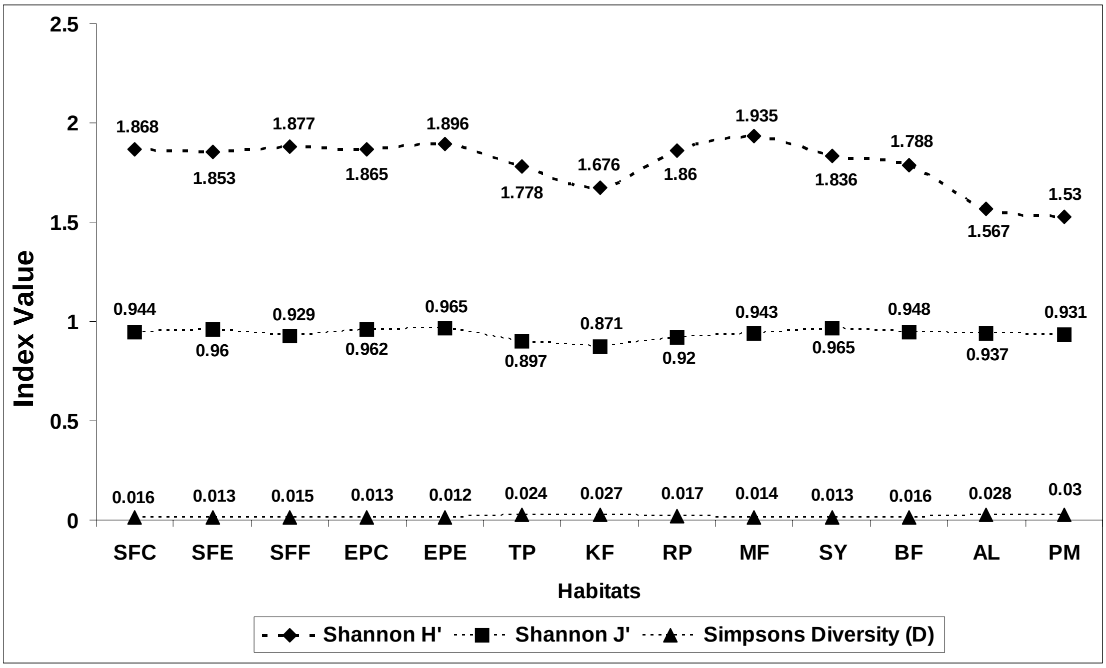


Fig. 4.5 Index values for Shannon H', Shannon J' and Simpson's diversity index (D) obtained for the sampled habitats across Simbalbara WLS

The cumulative species ricness plot (Fig. 4.6) showed the trend well known for insects and particularly for beetles. Long-horned beetles were completely not recorded during winter season, but remaining four families marked their presence with few species (two species in tiger beetles to twelve species in dung beetles). During summer season, all the families showed an upward trend that peaked maximum. In total, maximum of 66 species were recorded for dung beetles, followed by 52 for long-horned betles, 36 for ground beetles, 25 for tiger beetles and 15 for rove beetles. Fig. 4.7 shows the cumulatve proportion of total species richness recorded for beetles, pooled for all the seasons. MF, TP and RP were the most species dominant habitats while PM and KF supported least species.

Nevertheless, ground beetles were represented maximally in the KF with most (20) species, followed by RP and EPC each with 18 species and were least recorded in PM with only nine species. Tiger beetles were maximally recorded from the riverine area with 16 species, followed by 14 species in AL and 13 species each in SFC and EPC; and were least recorded in PM with only five species. Dung beetles were recorded maximally from mixed forest habitats viz. MF with 46 species, TP with 43 and BF with 38 species; and were least recorded in the PM with only five species. Rove beetles were least represented in all the habitats relatively but mixed forest habitats viz. MF with 14 species, TP with 10 species and BF with 10 species hosted most of the species; and in PM only two species and in SFF with only four species were recorded. Long-horned beetles one of the most important families of forest ecosystems was well represented in mixed forest habitats but was maximally recorded in MF with 46 species, followed by 43 in BF and 38 in TP; and were least recorded in AL with 12 species and in PM with only five species.

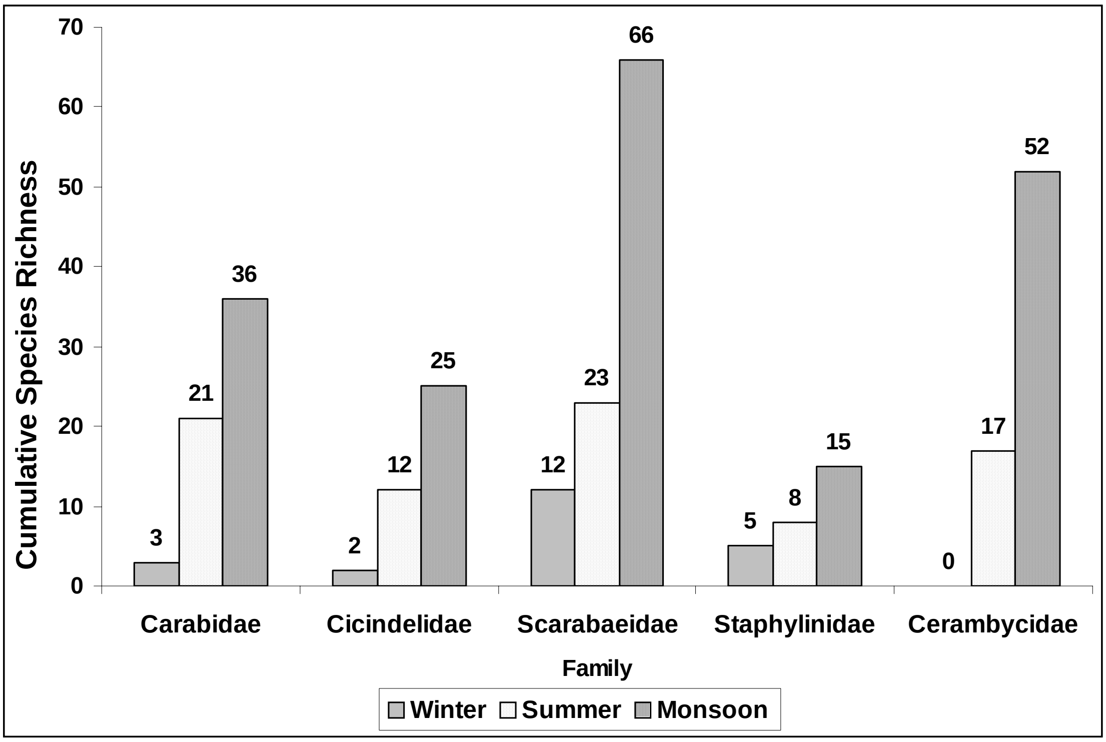


Fig. 4.6 Seasonal variation in the cumulative species richness of the beetle families

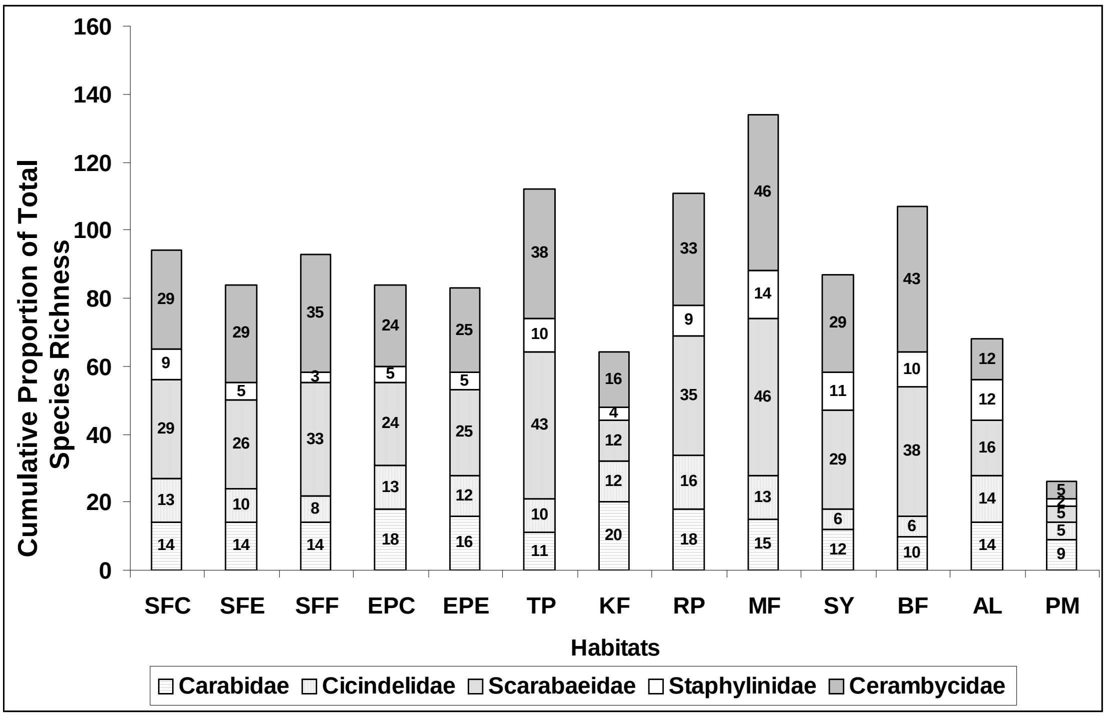


Fig. 4.7 Spatial variation in the cumulative species richness of beetle families across habitat types

β (or Differentiation) Diversity

β diversity plot as calculated from Kullback-Leibler information measures (Fig. 4.8 a & b) to find out the divergence of species richness assemblage in two subsequent years of sampling in 2006 and 2007. It is evident that $\hat{J}$ (*P*:*Q*) has quite similar values in the comparison between the habitat pairs in the in the same season along two subsequent sampling years. The values of the sum $\hat{H}'_p + \hat{H}'_q$ are also quite constant, indicating that the contribution of α diversity to $\hat{J}$ (*P*:*Q*) is similar in the different sampling years. The low values of $\hat{J}$ (*P*:*Q*) with respect to $\hat{J}(P{:}Q)_{max}$ and the resulting high values of similarity index S_j suggest that there are slight differences in between the habitats with respect to species richness in any given season in any given sampling year. Together with the high values obtained in the comparison of the habitats sampled in two years, they suggest that the species richness of the betles is highly homogeneous through the sampling years; and that the observed variaions in the richness do not show appreciable changes in assemblage structure in two years; but communities and their composition are varying across habitats.

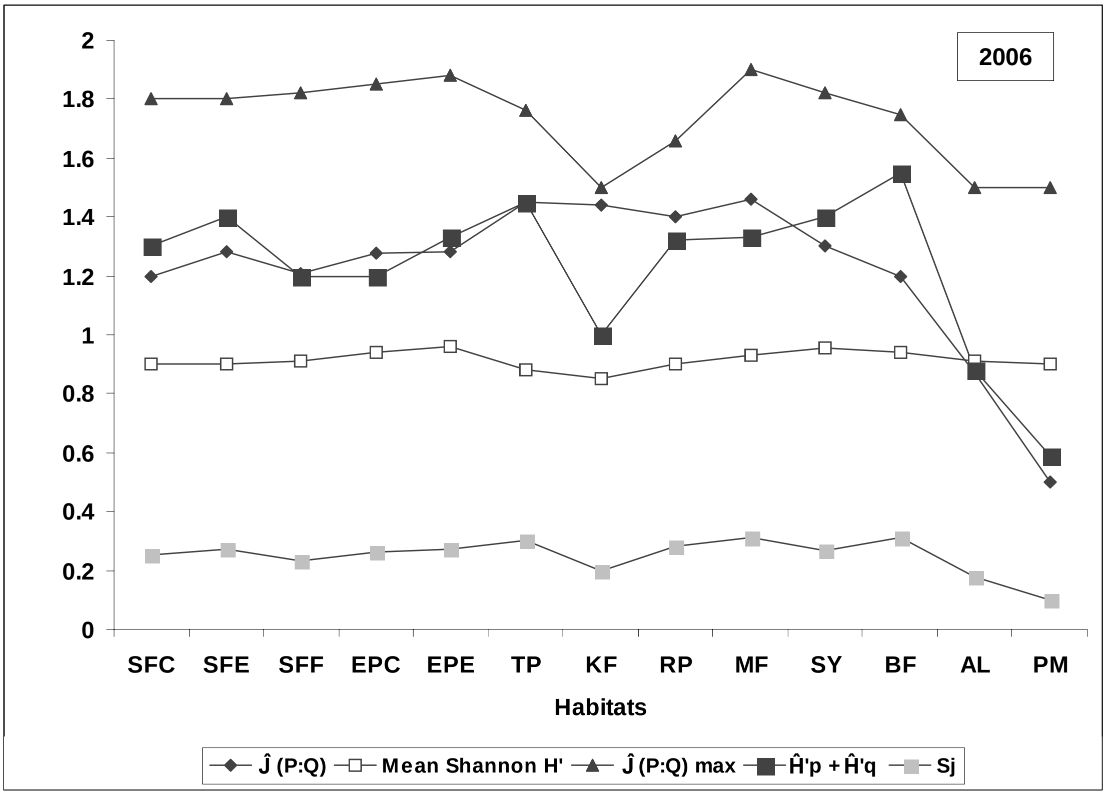


Fig. 4.8 a Beta diversity of beetle families across habitats in 2006 sampling season in Simbalbara WLS

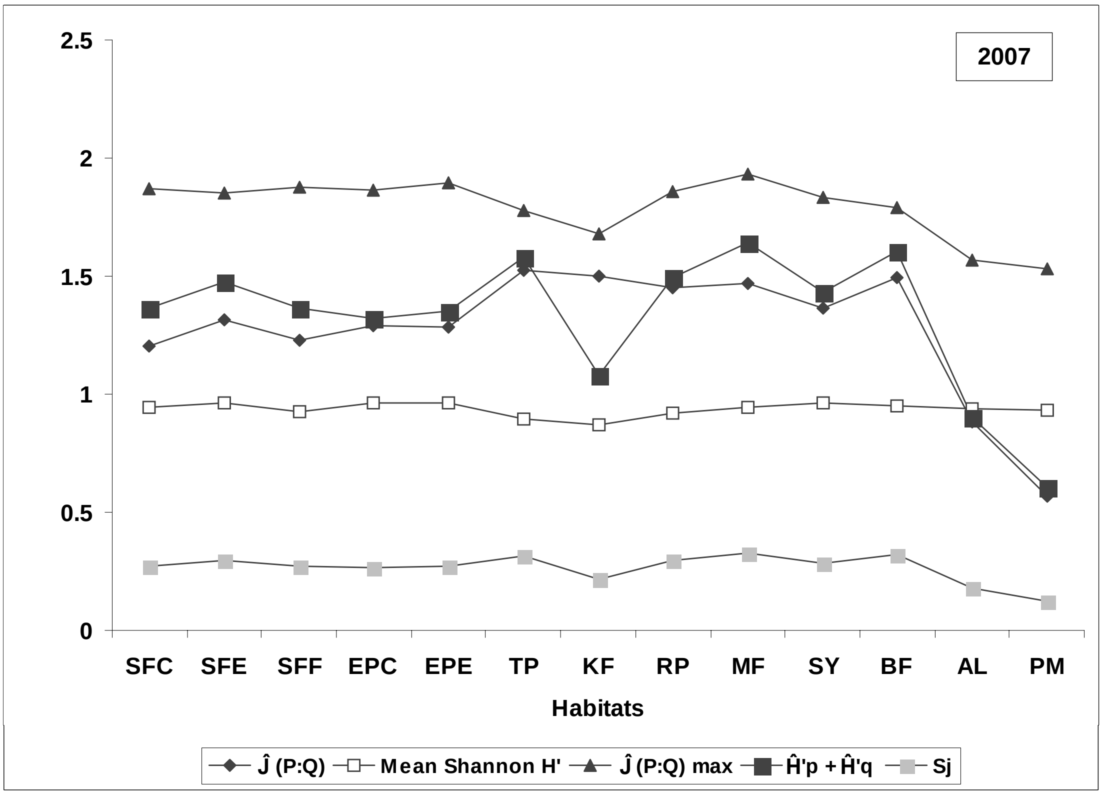


Fig. 4.8 b Beta diversity of beetle families across habitats in 2007 sampling season in Simbalbara WLS

Morisita-Horn index of similarity measure (Table 4.2) showed the degree of similarity between the habitats in relation to composition of beetle families. SFC and SFE habitats located within and outside the sanctuary were ≈78% similar; but the similarity between SFC and SFF was quite low at 58%; but the EPC and EPE were only ≈53% similar. The similarity of TP with other habitats ranged from ≈18% to ≈37%; and that of RP with other habitats ranged from ≈10 to ≈27%. Other mixed forest habitats had a similarity ranging from ≈20 to ≈40%; but KF stood out from the rest in having least degree of similarity (ranging from ≈6% to ≈27%) with other habitats. Few habitats like AL and PM had great difference in the degree of habitat similarity that ranged from as low as ≈2% to as high as ≈80% with some habitats.

4.5.2 Site Similarity and Cluster Analysis

Bray-Curtis cluster analysis performed with single linkage produced a plot (Fig. 4.9) segregating the thirteen habitat types into eight cluster groups based upon the percentage of similarity. SFC and SFE were the most similar; followed by PM and BF, followed by EPE and EPC. AL, SY and RP formed the single largest cluster with three habitats. KF was the least similar to the other sites. The majority of samples appear to have high levels of similarity (>50 % similarity).

Comparing different sites revealed that on an average, species composition was much more similar within the same habitat type than among different habitat types. MDS plot generated from relative abundances of different beetle species in pooled habitats showed that sampling sites from each habitat type were distinctly segregated (Fig. 4.10) and that the sampling sites of homogeneous Sal and *Eucalyptus* forests were well separated from their experiment and/or fire plots. Mixed forest habitats of MF, TP and BF were nearer in the ordination. KF, RP and PM were again the most separate habitats and showed little overlap with other habitat types. MDS ordination of five families according to habitat types mostly showed pattern of separation of species in habitat space with little degree of overlap.

Cumulative ANOSIM test (Table 4.3) showed most difference in species composition occurred between SFC and SFE (*R* = 0.89, *P* = 0.001) and between SFE and SFF sites (*R* = 0.35, *P* = 0.001), while the least difference was between AL and EPE (*R* = 0.0061, *P* = .011) and between SFC and MF (R = 0.0068, P = .013). Further, comparisons of dissimilarity in composition were made to identify the species contributing to the difference between groups of sites that differed most.

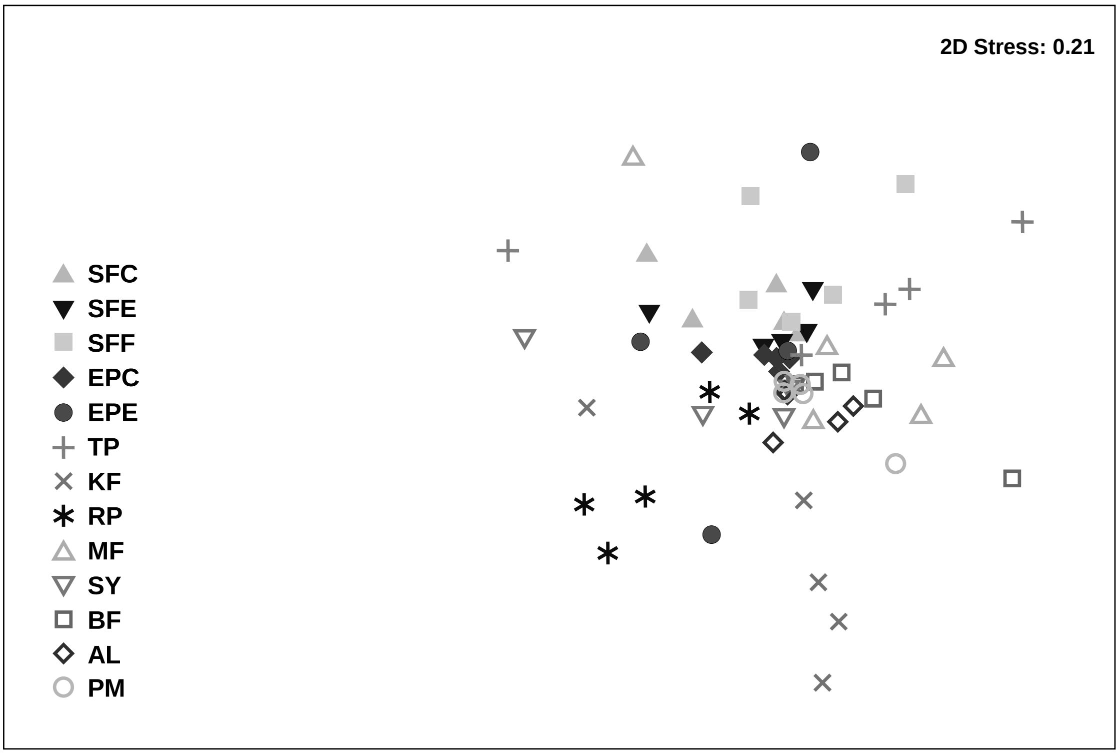


Fig. 4.10 MDS ordination of sampling sites in the Simbalbara WLS generated by species composition sorted according to habitat types (pooled)

Overall multi-group or cumulative SIMPER analysis (Appendix 2) revealed species that are primarily responsible for the observed difference between groups of samples (Clarke 1993). The overall significance of the difference was assessed by ANOSIM. The Bray-Curtis similarity measure is thus implicit to SIMPER. The overall average dissimilarity was found to be 87.44. Fifty species contributed around 50% to the difference between groups of sites. These species differed in mean abundance, which was reflected in the degree of group association. Some species of family Carabidae and Cicindelidae were almost absent from mixed forest sites and present in high abundance in

Khair mixed forest and riverine area respectively, whereas few species from Scarabaeidae were found in greater abundance in almost all mixed forest habitats compared to open and pure forest stands (Appendix 2).

4.5.3 Assemblage Patterns Using Multivariate Analysis

The distribution of species abundances across habitats was revealed by rank abundance plot (Fig. 4.12). A shallow gradient in most of the curves indicated high evenness of the species as the abundances of different species are quite similar in different mixed forest habitats as in KF, TP, RP and MF. Few habitats like SY, AL and SFF were dominated by abundances of few species.

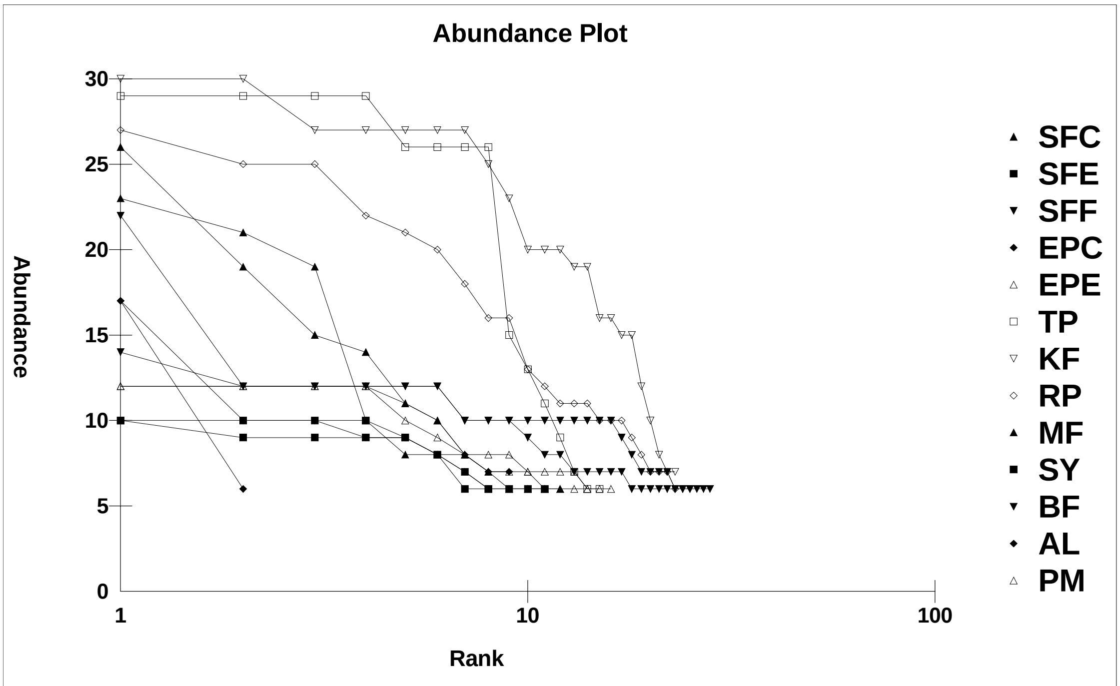


Fig. 4.12 A rank-abundance plot showing distribution of species abundance across habitat types in Simbalbara WLS

Table 4.2 β diversity between habitats as calculated from Morisita-Horn index of similarity measure

Habitats	SFC	SFE	SFF	EPC	EPE	TP	KF	RP	MF	SY	BF	AL	PM
SFC	0	0.789	0.557	0.526	0.351	0.213	0.098	0.22	0.221	0.24	0.261	0.026	0.127
SFE		0	0.532	0.506	0.402	0.203	0.077	0.215	0.336	0.26	0.32	0.042	0.125
SFF			0	0.482	0.261	0.366	0.069	0.25	0.247	0.157	0.361	0.051	0.147
EPC				0	0.532	0.237	0.1	0.227	0.22	0.332	0.319	0.055	0.162
EPE					0	0.182	0.095	0.26	0.293	0.389	0.192	0.145	0.07
TP						0	0.068	0.273	0.125	0.18	0.171	0.032	0.067
KF							0	0.101	0.1	0.219	0.15	0.108	0.174
RP								0	0.255	0.344	0.263	0.165	0.161
MF									0	0.401	0.391	0.572	0.225
SY										0	0.468	0.426	0.427
BF											0	0.334	0.795
AL												0	0.363
PM													0

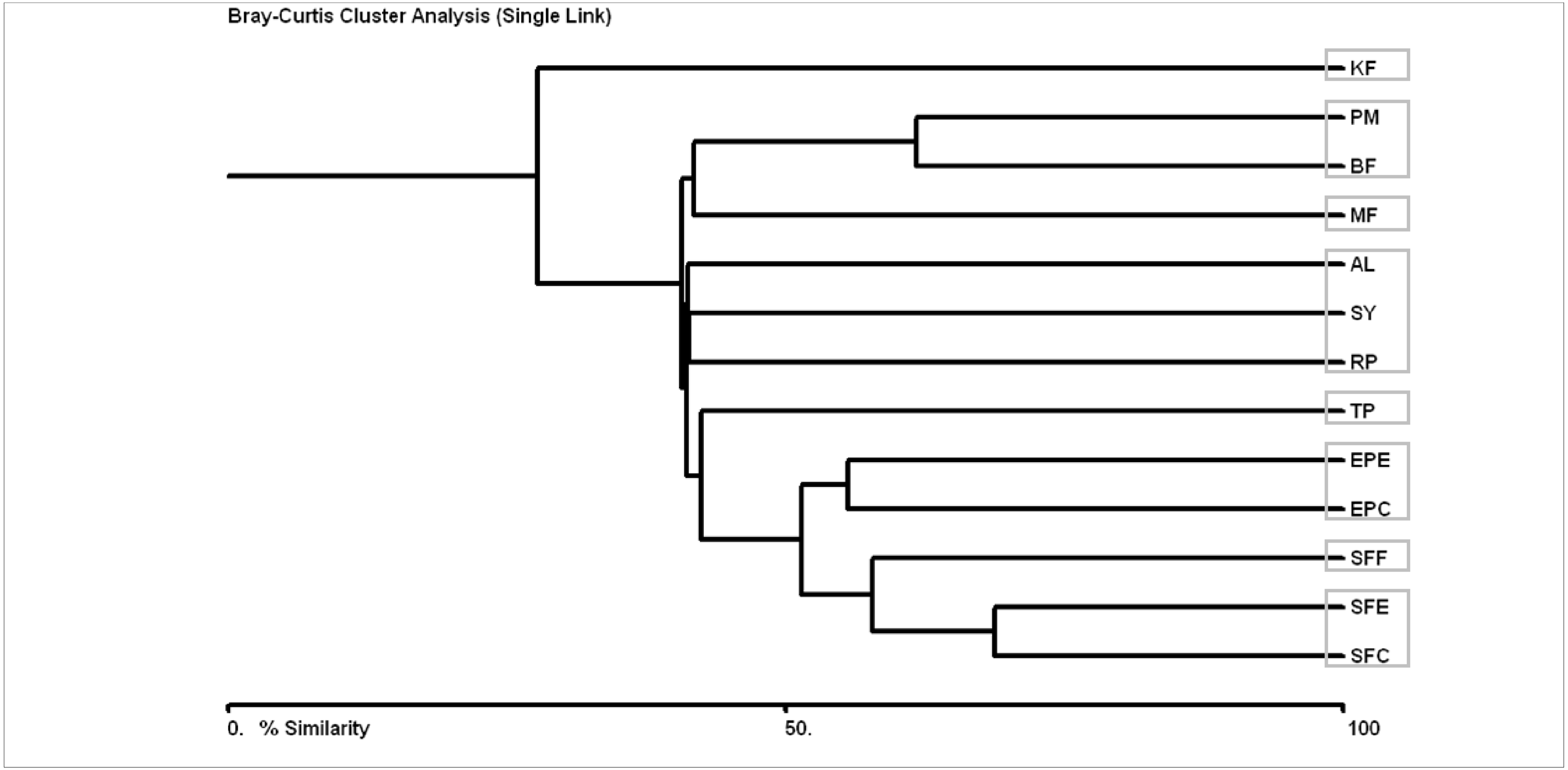
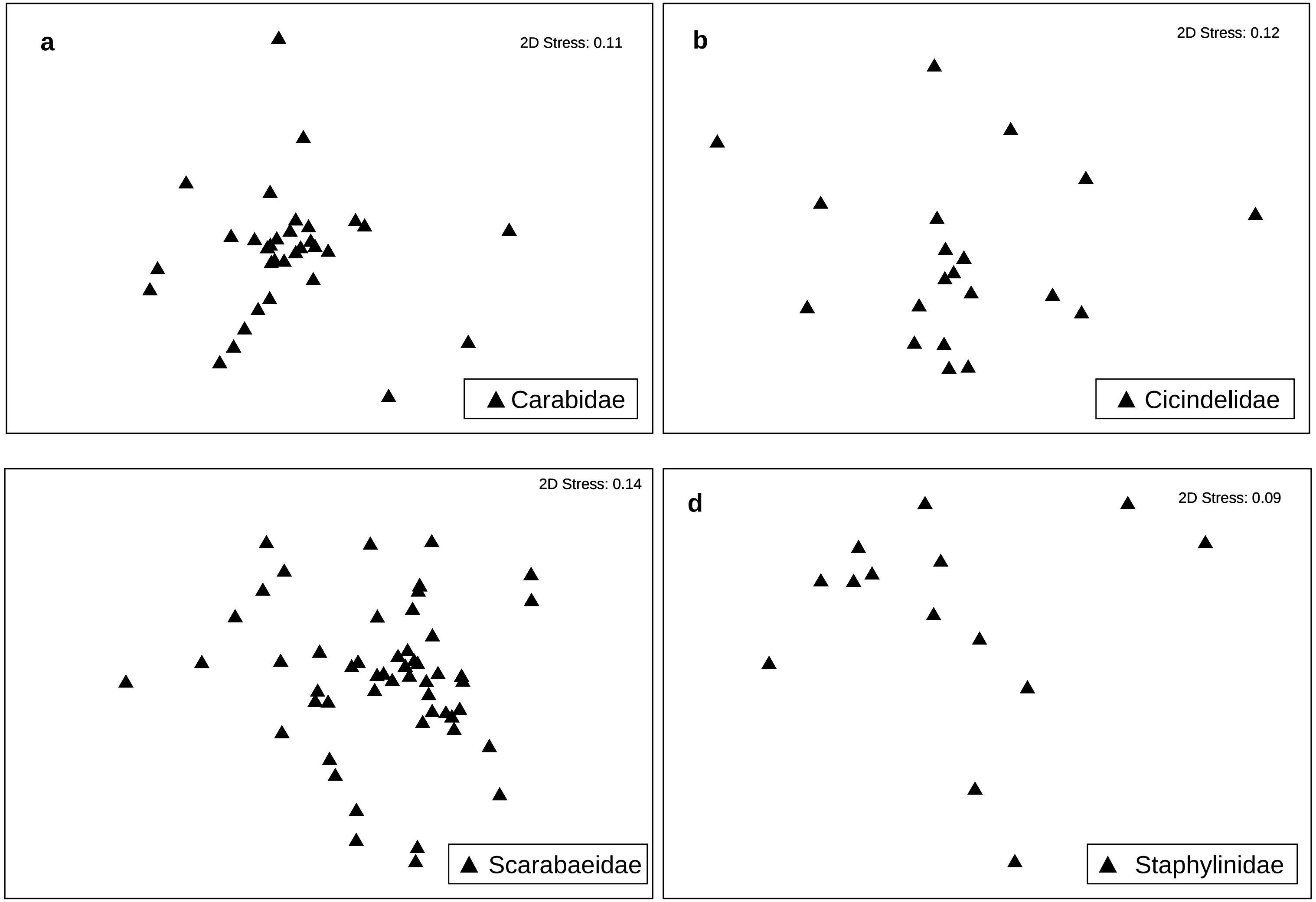


Fig. 4.9 Bray-Curtis cluster analysis (single linkage) dendogram showing the linkages between sampled habitats


a
2D Stress: 0.11
Carabidae
b
2D Stress: 0.12
Cicindelidae
2D Stress: 0.14
Scarabaeidae
d
2D Stress: 0.09
Staphylinidae

(Contd.)

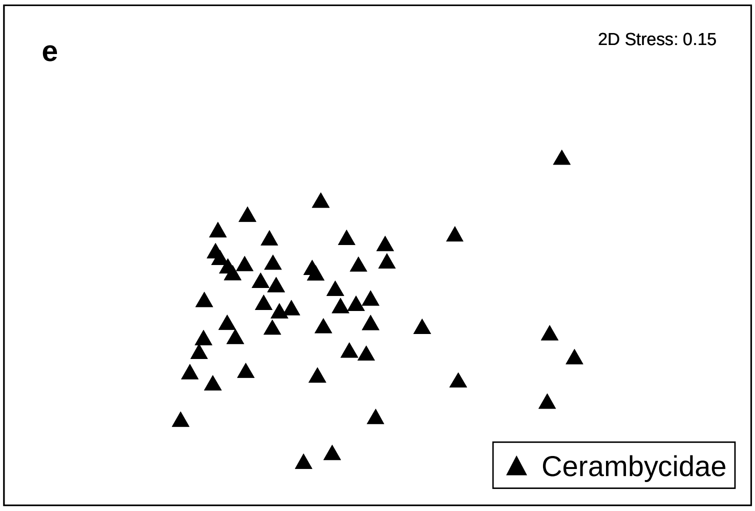


Fig. 4.11 a to e MDS ordination of families of beetles sorted by species composition in habitat space

Vertical distribution of diversity across habitats was represented by means of k-dominance plots (Fig. 4.13). SFF, BF, KF and RF which showed the lowest curves respectively were the habitats most diverse in the assemblage of beetles.

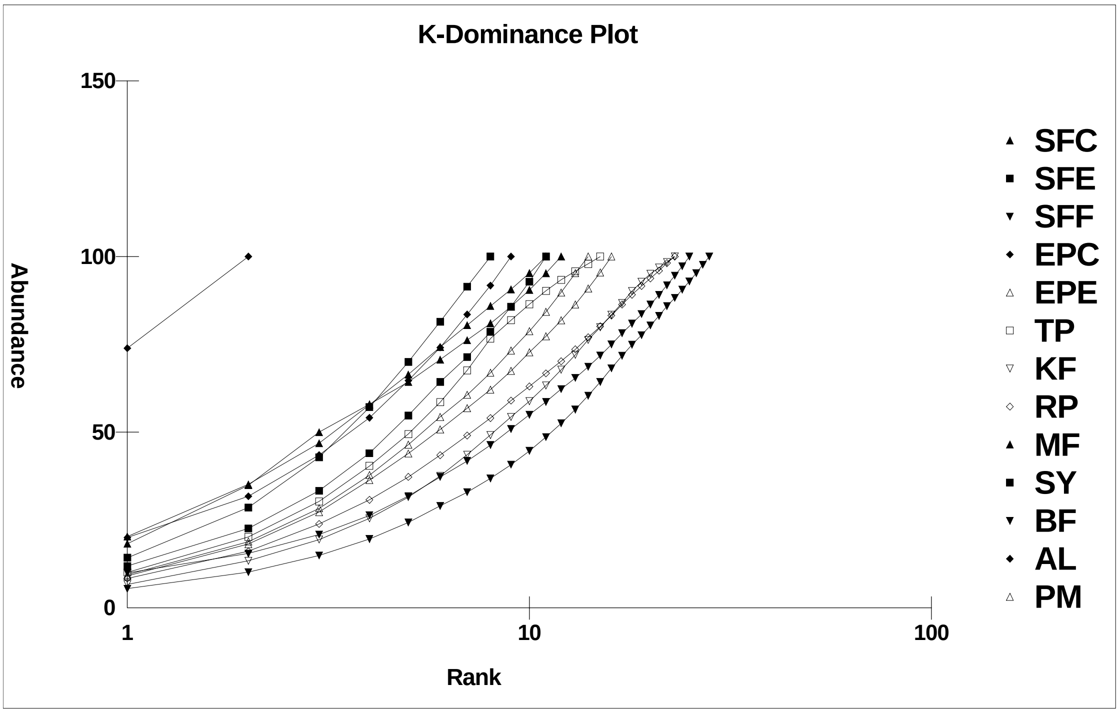


Fig. 4.13 A K-dominance plot showing distribution of species assemblage across habitat types in Simbalbara WLS

Table 4.3 Cumulative ANOSIM of habitats in relation to assemblage of species

HABITATS	Sal Forest Control	Sal Forest Exp.	Sal Forest Fire	Eucalyptus Plantation Control	Eucalyptus Plantation Exp.	Teak Mixed Forest	Riverine	Khair Mixed Forest	Mixed Forest	Syzygium Mixed Forest	Bamboo Mixed Forest	Agriculture Land	Pine Mixed Forest
Sal Forest Control	0	0.8916	0.5508	0.1316	0.0142	0.0095	0.0087	0.0071	0.0068	0.0071	0.0073	0.0091	0.0084
Sal Forest Exp.		0	0.3549	0.1408	0.0248	0.0075	0.0078	0.0089	0.0074	0.0084	0.0075	0.0085	0.0072
Sal Forest Fire			0	0.0385	0.0077	0.0085	0.0083	0.0084	0.0082	0.0076	0.0078	0.0083	0.0078
Eucalyptus Plantation Control				0	0.3419	0.007	0.0076	0.0069	0.0088	0.0081	0.0071	0.0077	0.0077
Eucalyptus Plantation Exp.					0	0.0079	0.0097	0.0084	0.0152	0.0398	0.0065	0.0061	0.0082
Teak Mixed Forest						0	0.0094	0.0077	0.0081	0.0083	0.0081	0.0085	0.0083
Riverine							0	0.0065	0.0078	0.0072	0.0074	0.0094	0.008
Khair Mixed Forest								0	0.0078	0.0071	0.0073	0.0082	0.0074
Mixed Forest									0	0.0241	0.0073	0.0175	0.0078
Syzygium Mixed Forest										0	0.014	0.0435	0.0565
Bamboo Mixed Forest											0	0.0074	0.2705
Agriculture Land												0	0.0094
Pine Mixed Forest													0

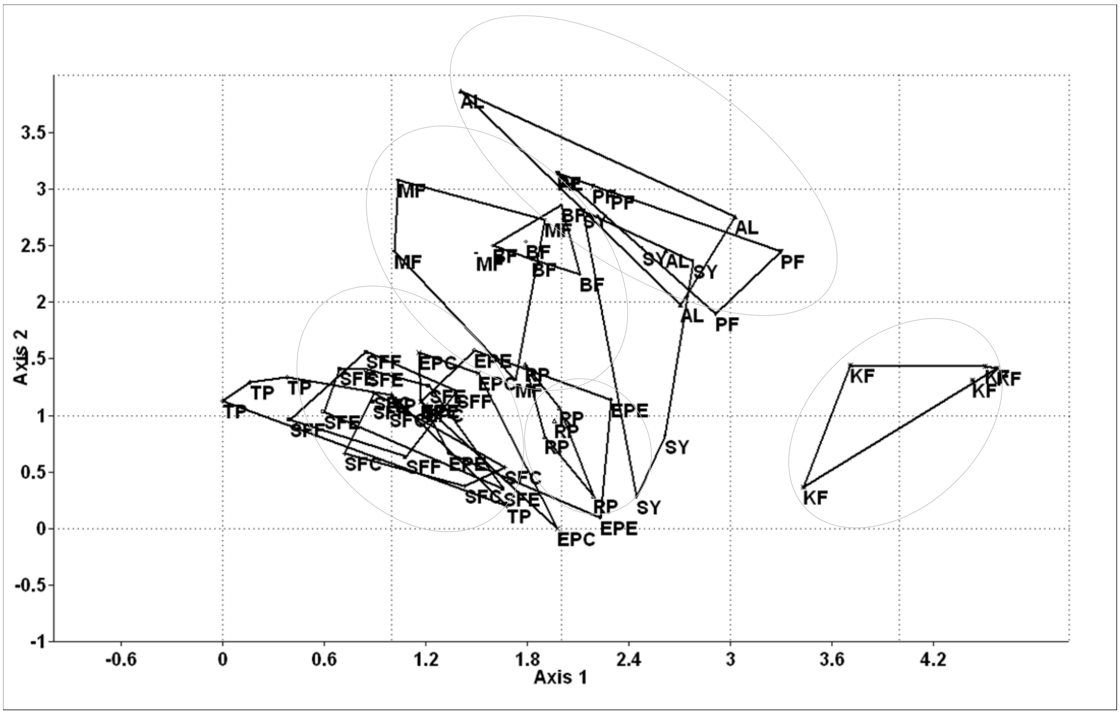


Fig. 4.14 DECORANA resulting from ordinaton of habitats and species

Table 4.4 DECORANA axis scores of ordination of habitats and species

DECORANA	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**
Eigen Value	0.6643	0.4407	0.2916	0.1783

DECORANA (Fig. 4.14) showed the separation of habitats into five distinct clusters in which KF is exclusively sorted and the remaining four show some degree of overlap. The mixed forest habitats of MF and BF were most related in one cluster; SFC, SFE, SFF, EPC, EPE and TP were most related in one cluster; and SY, AL and PM were segregated into fourth cluster. The difference in clustering paterns was explained by the species composition in habitat space by the eigen values (Table 4.4) in which the axis one explained 66%, axis two 44%, axis three 29% and axis four 17% of the variation in the clustering patterns of habitats.

The species data was primarily sampled on the basis of the dominant vegetation types. Later TWINSPAN classification was used to segregate the species data into various classes. Since, the habitat types provided for the stratification of the study area and helped in further intensive sampling, it was appropriate to segregate and analyse species data according to the vegetation types delineated on the IVI. Fig. 4.15 showed the segregation of species into communities with indicator species at every division for the cumulative species data in which strong divisions forming at the first level (eigen-value = 0.3946) a large group with *L. striolata, B. kara* and *M.undulata* as indicator species in riverine area and Khair mixed forests characterized by open spaces, little canopy cover and with acidic pHs of soils. At a second level of division (eigen-value = 0.4170) the plots were separated from the others in the first group and contained riverine and mixed forest species characterized by *M. melancholica* and *N.cameroni*. At a third level of division (eigen-value = 0.2939) the plots containing indicator species of mixed forest species *G.ruflcornis*, *N.cameroni*, *A.indicus* and *S.punctulata* were separated from the others. TWINSPAN classification with divisions and indicator species at each for the bioindicator families were identified suggesting high beta diversity among plots (Fig. 4.16 to 4.20).

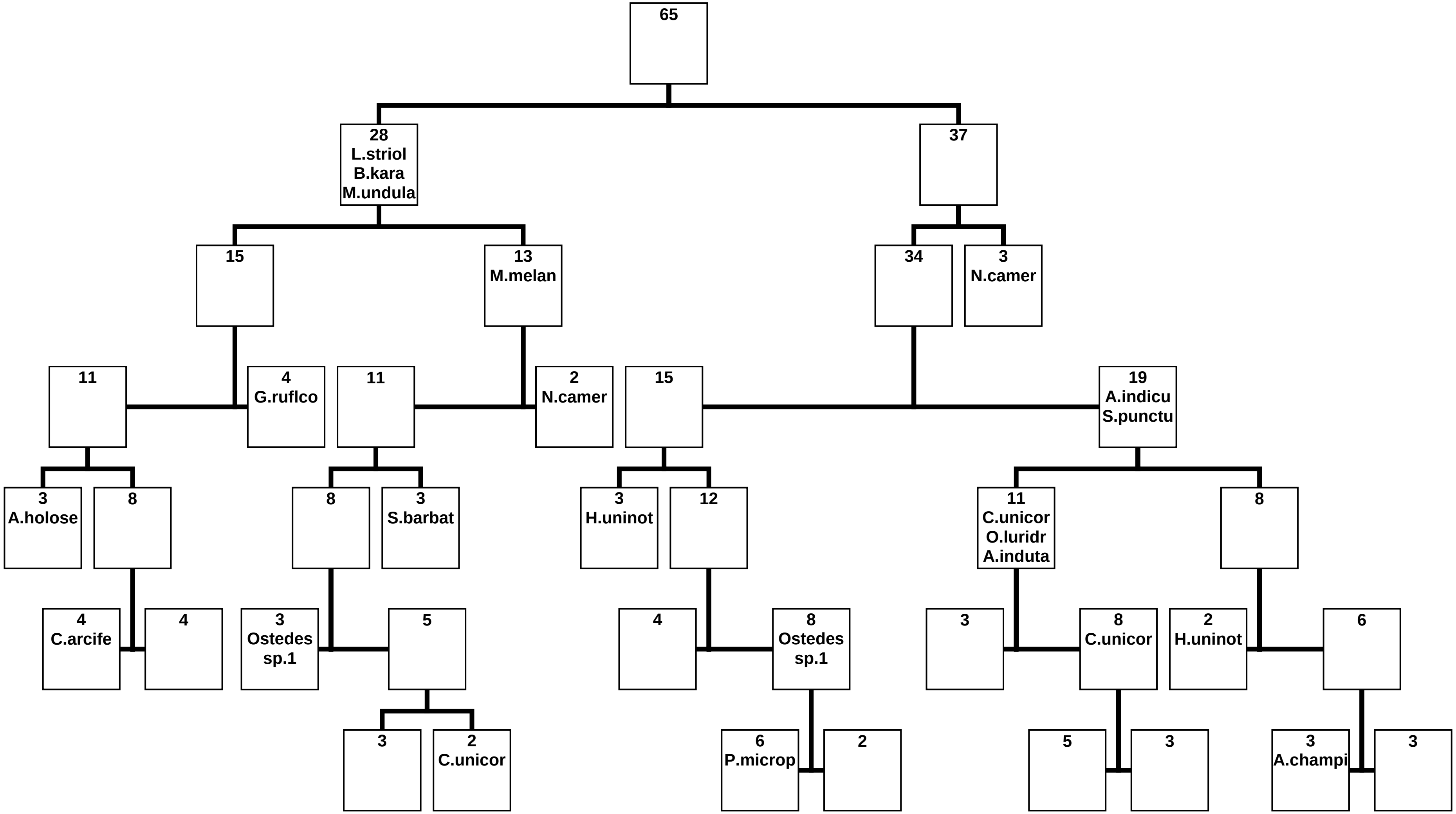


Fig. 4.15 Cumulative TWINSPAN classification for 65 sample plots of thirteen habitat types in Simbalbara WLS

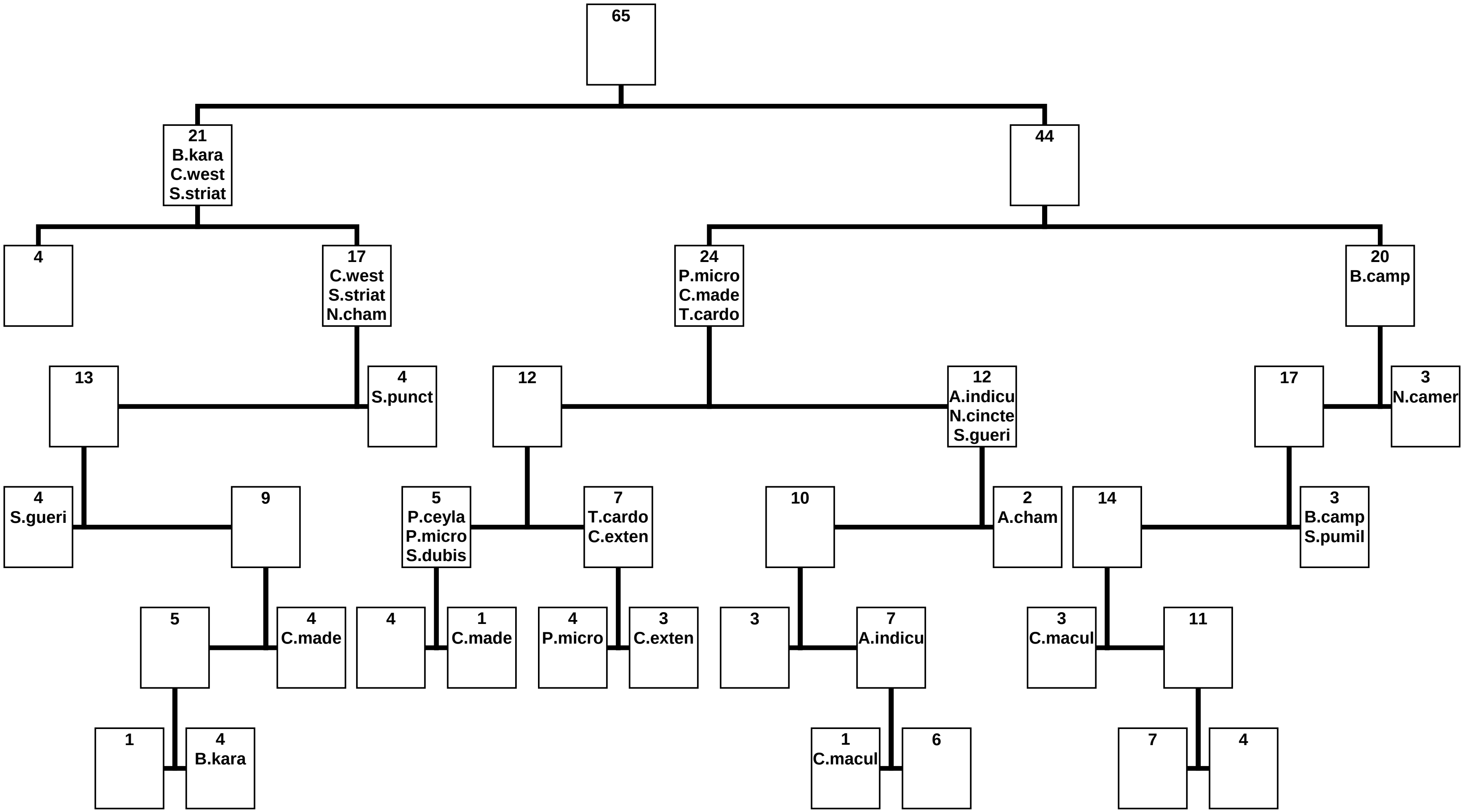


Fig. 4.16 TWINSPAN classification for Carabidae in 65 sample plots of thirteen habitat types in Simbalbara WLS

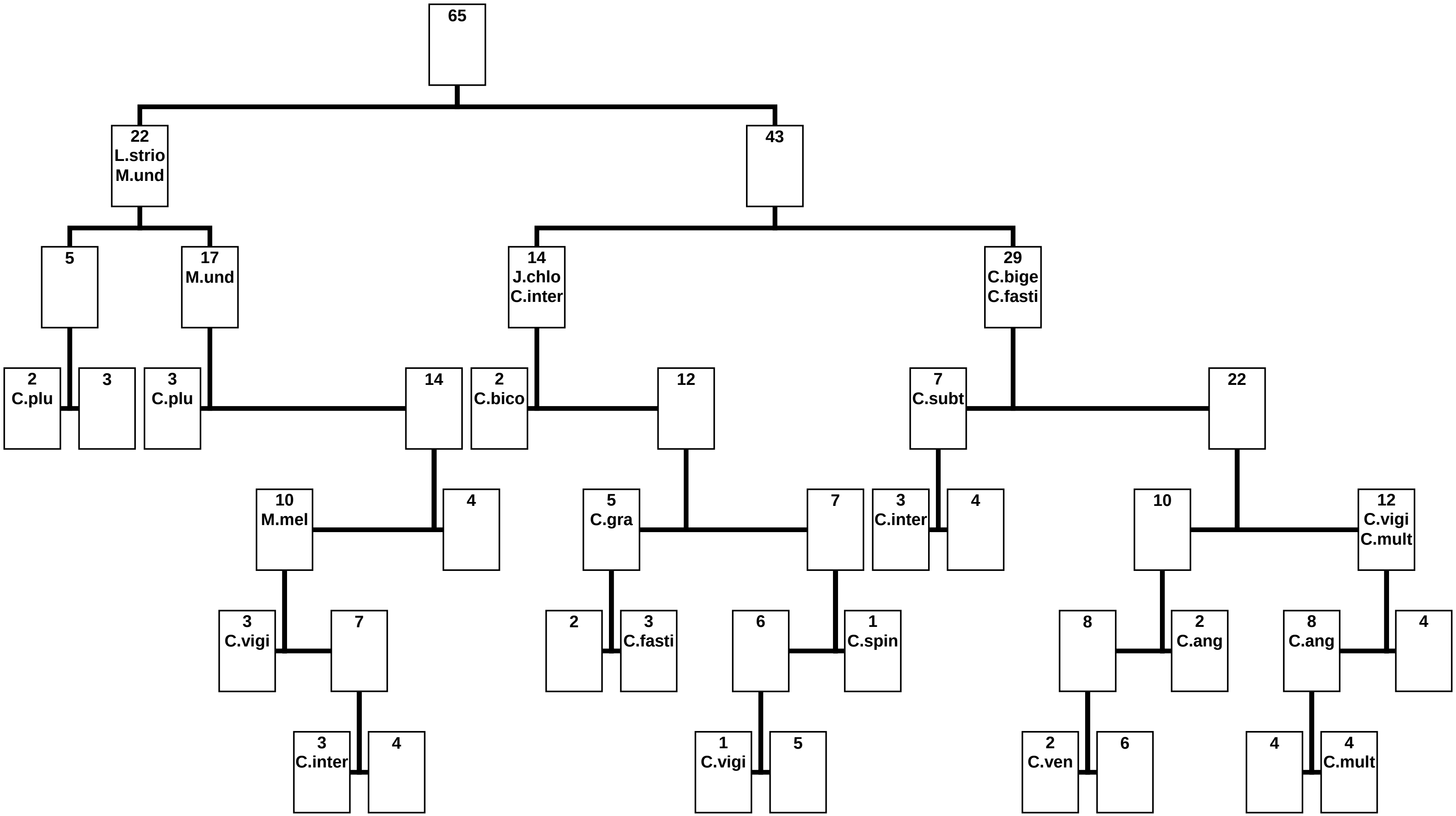


Fig. 4.17 TWINSPAN classification for Cicindelidae in 65 sample plots of thirteen habitat types in Simbalbara WLS

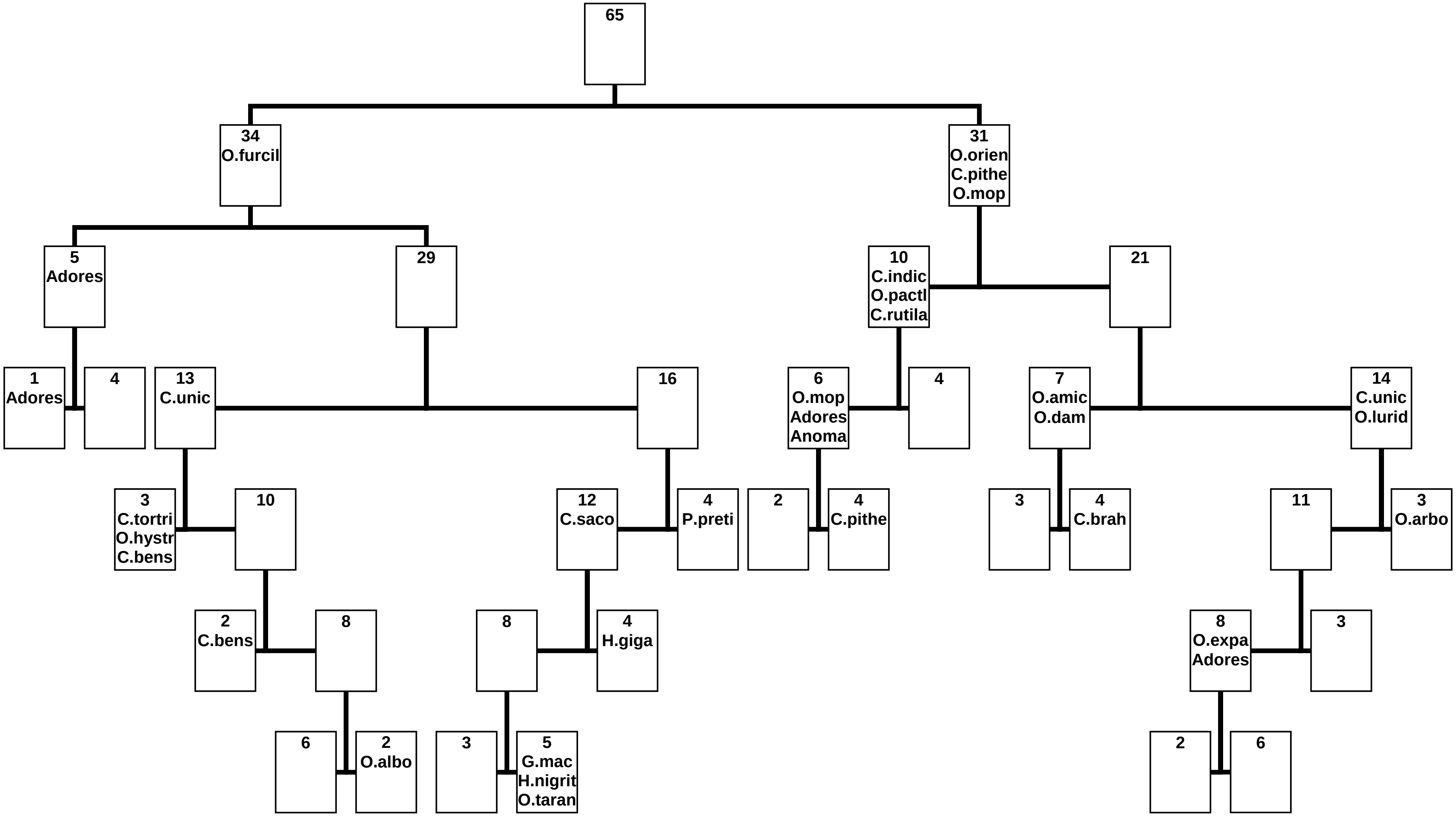


Fig. 4.18 TWINSPAN classification for Scarabaeidae in 65 sample plots of thirteen habitat types in Simbalbara WLS

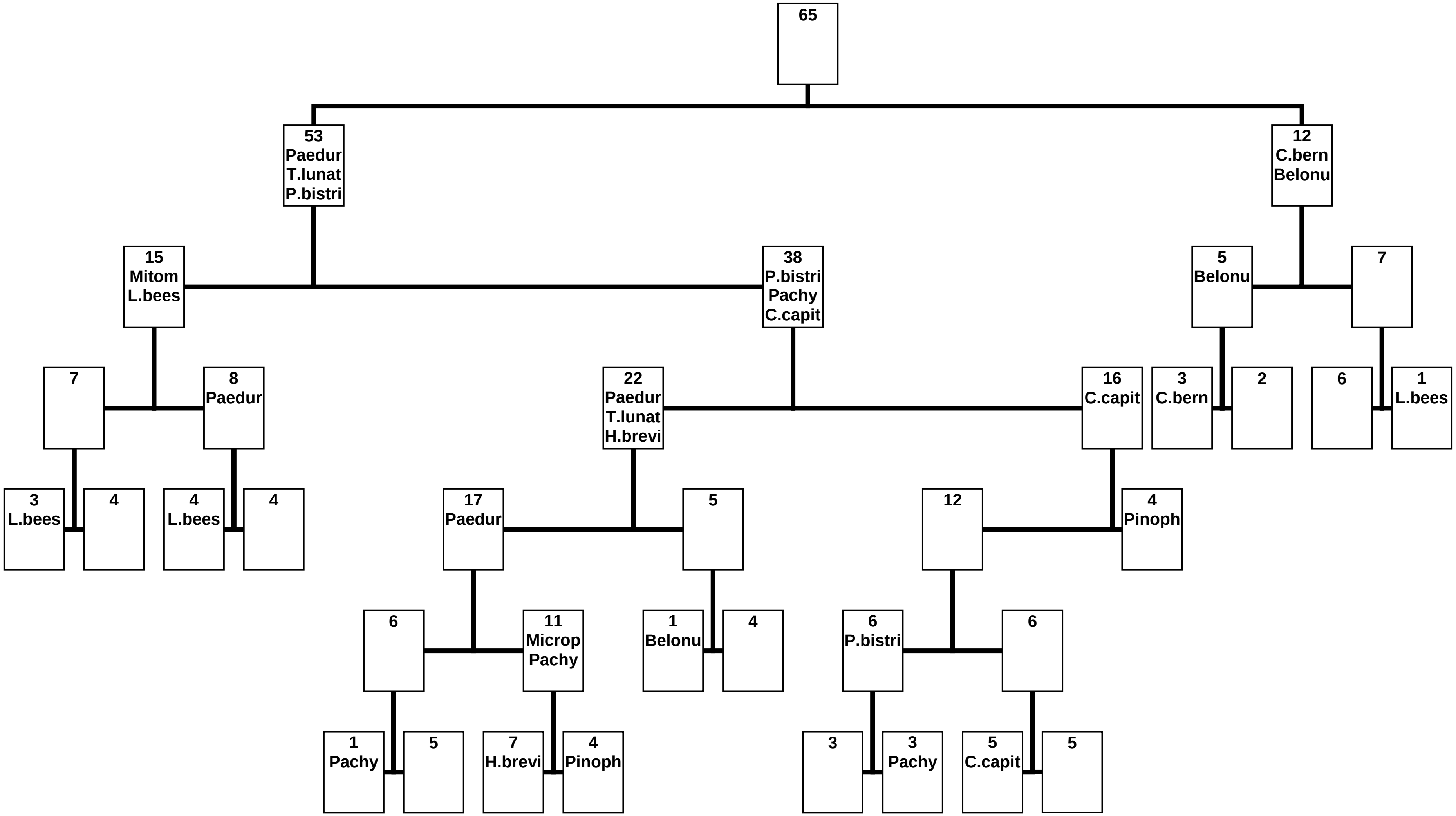


Fig. 4.19 TWINSPAN classification for Staphylinidae in 65 sample plots of thirteen habitat types in Simbalbara WLS

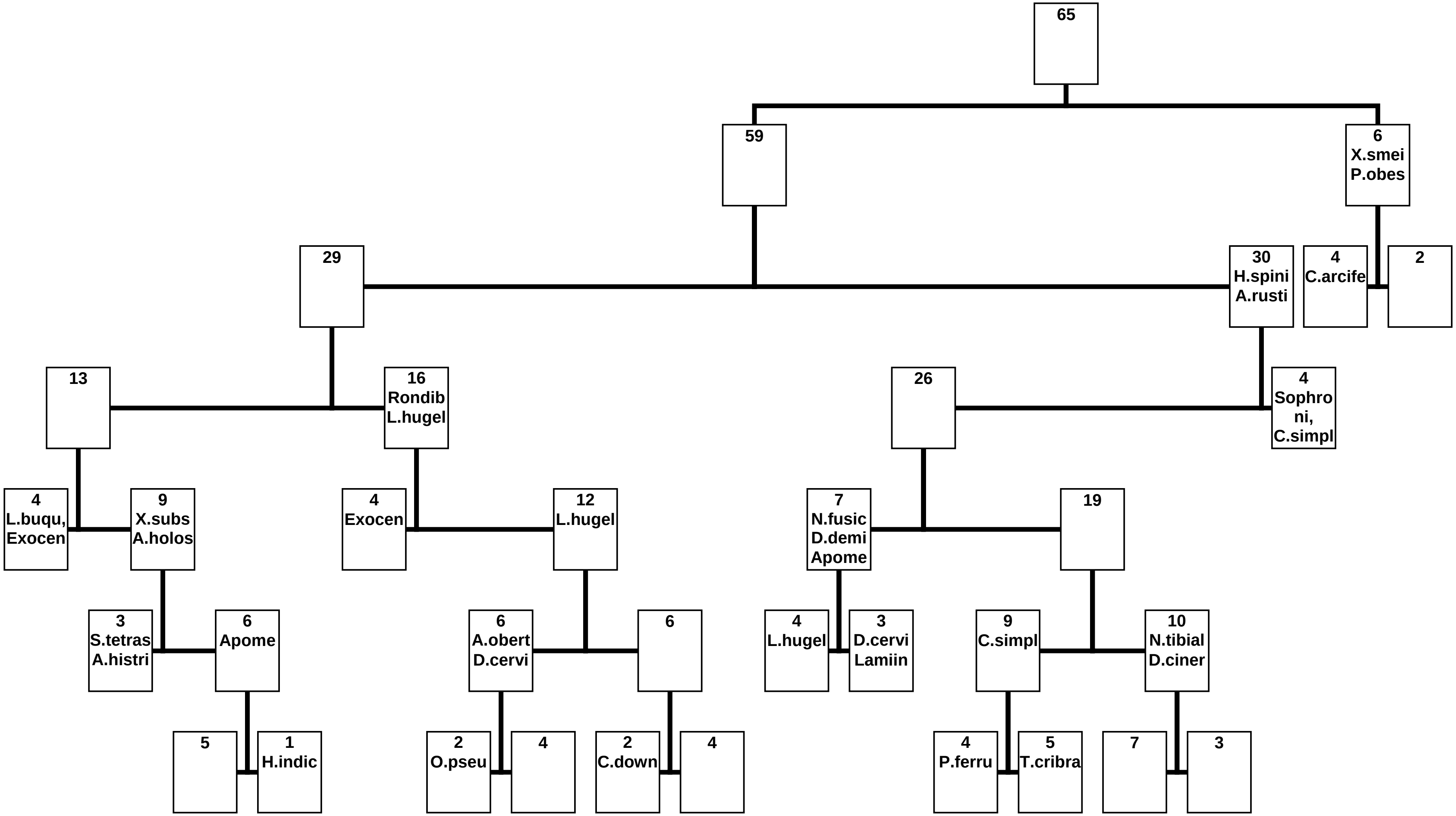


Fig. 4.20 TWINSPAN classification for Cerambycidae in 65 sample plots of thirteen habitat types in Simbalbara WLS

4.6 Discussion

Of the 166 families listed by Lawrence and Newton (1995) globally, 66 families (and 97 sub-families) or ≈40% were recorded in this study (Appendix 1). This proportion is very high considering that sampling was confined to selected micro-habitat site measuring one-fourth of a hectare. Dung beetles (Scarabaeidae), borers (Cerambycidae), ground beetles (Carabidae), tiger beetles (Cicindelidae), rove beetles (Staphylinidae), leaf beetles (Chrysomelidae), ladybird beetles (Coccinellidae), click beetles (Elateridae), stag beetles (Lucanidae), blister beetles (Meloidae), darkling beetles (Tenebrionidae), predaceous diving beetles (Dytiscidae), bark beetles (Scolytidae), branch and twig borers (Bostrychidae), powder-post beetles (Lyctidae), seed beetles (Bruchidae), metallic wood borers (Buprestidae), lightining bugs (Lampyridae), spider beetles (Ptinidae), weevils (Curculionidae), water scavenging beetle (Hydrophilidae), flat bark beetles (Cucujidae), soldier beetles (Cantharidae), flat-horned beetles (Paussidae) and bess beetles (Passalidae) were the twenty five most prominent families sampled throughout the study.

Most of the species of other families (Appendix 1) are still poorly known taxonomically and ecologically. The most abundant families in the study were the carnivorous, detrivorous, xylophagous and the ones associated with plants (Lawton 1983). The differences in family composition were mainly due to the sampling approach, as each method appeared to be sampling certain families or a specific part of the beetle assemblage in a particular stratum. The species richness and abundance of the dominant families in each sampling site increased from plantations to pure stand forests to mixed forest stands. Scarabaeidae and Cerambycidae dominated most of the sampled sites (most abundant in mixed forest sites) except for the abundance of Cicindelidae and Carabidae in the open areas like banks of streams and few sites like Khair mixed forest (Kegel 1990). Staphylinidae was the most abundant family in the mixed forests with lots of decomposing material like leaf litter, wet rotten wood, or moss. The difference between the 25 dominant families and rest others laid in the abundance of a few species. This represented the result of high stochasticity in the mixed forest ecosystems of the Simbalbara WLS (Sullivan and Sullivan 2001).

In this study, 194 species were recorded from 5,404 beetle specimens. There were little differences in the number of species and individuals sampled in some sites and trapping methods within the sampling period; as samples in 2007 season had significantly higher species richness and abundance compared to 2006 season. It was interesting to note that the abundance of soil and litter-dwelling beetles was higher in the primary forest compared with the logged forest and also other sites; overall high beetle diversity was recorded in the forest sites (Essen et al. 1992). Tropical forests are complex ecosystems that accommodate a wide range of living organisms within the ecosystem. Such an environment provides a variety of microhabitats and food for living organisms (Erwin 1982, 1983,). In some sites, light intensity and penetration was low where stands are older (>30 years) with high canopy cover. Hambler and Speight (1995) stated that low light levels at ground level correlates with high biomass of arthropods. With more canopy cover in the forest, the humidity is high and thus, more damp surface area for fungi which grow on plant surfaces, more substrate for microbes, more prey for predators, more hosts for parasites and overall a greater diversity (Basset 1991, Basset et al. 2001).

The plantations were once forested areas that were completely logged and converted into plantations. Extreme disturbance had occurred in these sites outside the sanctuary that has severely affected the fauna and flora within the area. Therefore, in monoculture plantations, the overall diversity was found low. This directly limits the choice for food and shelter for the animals. Populations of insects in monocultures tend to be taxonomically less diverse than insect assemblages in more diverse habitats but their populations may fluctuate enormously with subtle changes in the quality and availability of food (Lowman and Morrow 1998). Another possible reason for the low diversity in the plantations is the greater microclimatic variation in temperature, humidity and light intensity. This may be exceptionally important for the soil fauna. It is not surprising that beetle species richness and abundance were lowest in the khair plantation compared with *Eucalyptus* plantation as the latter still supported understorey vegetation and good organic matter. In total, 42 species (~ 22%) were singletons (i.e. species with only one individual collected throughout the sampling periods). The high number of rare species in the forest sites is typical for studies of tropical insect faunas (Mawdsley 1994, Basset and Kitching 1991). The species rank-abundance curves shows that the khair plantation, teak plantation and riverine area has the steepest curve, followed by mixed forests, then experiment plots forest and finally agriculture land and *Syzyium* plots. The khair plantation curve resembles the geometric series distribution where a few species (Carabidae) are dominant with the remainder fairly uncommon (Magurran 1988, 2004). This pattern is found primarily in species-poor or degraded environments. As environmental conditions improve, species abundance patterns grade into those of the log series distribution which appear to be portrayed by the mixed forest habitats curve. The shallower but protracted curves of such forests resemble the log normal distribution, indicating a large, mature and varied natural community (Magurran 1988, 2004).

In the present study, comprehensive and systematic record of selected bioindicator beetles' families is first of its kind in the protected area of Sal dominated forest ecosystems of north western India in the Shivalik Himalaya. As there is no species list available for Simblabara WLS, it is difficult to know precisely what proportion of the actual local and regional species was captured. However, based on estimated richness inventory was almost complete at the regional scale (92%). There may still be a good chance of finding species from *ad libitum* study (Hammond 1992). Sampling additional sites like canopy and using different methods like malaise trap, extraction methods (Winkler and Berlese), mist-blowing etc. would capture more species. Thus, the beetle species that predominantly or exclusively found in the canopy are under sampled. The sampling methods and sample plot design provides a strategically sufficient option to sample local and regional species to permit an accurate comparison of species richness in different habitat types in a time-bound scale (May 1994, MacNally et al. 2003).

The beetle diversity was not found similar in different habitat types. Comparatively, mixed forest habitats exhibit highly diverse assemblages, possibly due to higher structural complexity and heterogeneity. The relatively open and diverse overstorey and understorey structure of mixed forest habitats supported the highest number of beetle species while habitats with little understorey vegetation, canopy cover and ground leaf litter supported relatively few species. These mixed forest habitats are little subjected to fire, and other anthropogenic disturbance factors; which keep the area well under influence of natural ecological successional stage(s). These sites were also rich in soil organic matter and organisms, micro-and macro invertebrate fauna (Junk et al. 1989, Sparks et al. 1990, Richards et al. 2002).

The intermediate disturbance hypothesis (Connell 1978) might provide an explanatory framework for the pattern observed. According to this hypothesis species diversity is greatest in communities experiencing intermediate levels of disturbance; hence both very early as well as very later stages of recovery from disturbance should exhibit lower diversity. Because disturbance creates opportunities for species not found in undisturbed forest, the habitat mosaic resulting from patchy disturbance increases the number of niches available. Intriguingly, results showed high species richness and diverse assemblages at the interfaces of habitat types, due to high phenological and floristic diversity of the habitat types in different seasons. The beetle composition in disturbed habitats showed the most dissimilar assemblage in comparison with those of other habitat types. Possible reasons may be the increased human disturbance like logging, lopping, NTFP collection, and fire in addition to scarcity of understorey vegetation, single tree species dominance, and isolation from forested habitats, affecting the amount of different microhabitats available. Species richness and abundance of subterranean and understorey beetles were considerably lower in the plantations than in the forests. Understorey beetle abundances were lower in khair plantation compared with *Eucalyptus* plantation. Species composition was also significantly different between sites, but assemblages from the logged forests, experiment plots outside the sanctuary and plantation tended to be much more similar to each other than primary forest assemblages. The plantation beetles were, however, distinctly different from the rest of the sites. A few species in the plantation became numerical dominant despite its low diversity. This can be detrimental if the prevalent species is a potential pest; as some of the forest insects have become pests by increasing their population size and eating parts of commercially valuable tree species when faced with monocultures (Usher 1995).

The results from this study have indicated the loss of species richness and abundance of beetles, and changes in beetle composition in severely disturbed environment. Consequently, these results support the establishment or maintenance of forest patches in such environments (e.g. oil palm plantation). In conclusion, despite small distances between habitats studied, local ecological processes were strong enough to allow for a differentiation between beetles assemblages from mature forest and naturally disturbed sites. At disturbed sites beetles assemblage retained considerable diversity, partially even higher than in the mature forest, suggesting that landscape mosaics at the edge of nature reserves may support the survival of many of the more common species. Such areas could play an important role as buffer zones around protected areas (Soulé 1990, Soulé and Terborgh 1999, Schulze 2000). Since, species diversity of beetles was found to be higher at intermediate levels of disturbance, where the greatest landscape heterogeneity occurs (interfaces of forest-silviculture-agriculture landscape and grazing); such habitat heterogeneity is a determinant cause of species diversity in natural ecosystems, and therefore its preservation should be a priority when planning conservation strategies (Dennis et al. 1997, Bromham et al. 1999, Spence 2001). Since, habitat heterogeneity at the landscape scale acts as the main source of beetle diversity, management practices such as extensive poly-afforestation would help maintain the ever diminishing landscape heterogeneity and consequently local beetle diversity. Preservation of landscape heterogeneity therefore must be encouraged for adequate biodiversity conservation.

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CHAPTER 5
BIOINDICATOR FAMILIES AND TAXONOMY

5.1 Introduction

Bioindicators have proved to be a useful tool for monitoring and detecting changes in the environment. Since the time when canaries were used to detect carbon monoxide in mines, the use of indicators has increased to span both aquatic and terrestrial ecosystems covering a wide range of habitat alteration, from local disturbance to global climatic change (Spellerberg 1993). Despite the long history of use of bioindicators, there still are no unanimous definitions or criteria for selection of bioindicators. A bioindicator can be loosely defined as a species or a species group that reflects the abiotic or biotic state of the environment, represents the impact of environmental change on a habitat, community or ecosystems, or indicates the diversity of other species (McGeoch 1998). Many species fulfil at least one of these criteria. The use of bioindicators is based on a number of reasons. One of the most important ones is their cost-effectiveness. By using bioindicators it is possible to assess the impact of human activities on the biota, instead of examining the entire biota. Especially useful are species that provide early warning of change (Spellerberg 1993).

Bioindicators are also a good way to monitor the effects of toxic 488 materials on organisms (Bridgham 1988). This might be difficult to assess through direct toxicity level assessment in nature. In biodiversity surveys, bioindicators are used to assess species richness of the community. Using only a few species groups and estimating diversity of total biota e.g. through extrapolation is a quick technique (Colwell and Coddington 1994). This is a great advantage especially in the tropics, where it is impossible to survey all species due to high species richness. There are, however, several problems related to use of bioindicators (Landres et al. 1988). A difficult problem is the generalisation of results. For example, how well does one species or a species group represent the remaining biota? Species' ecological requirements can be very different, implying that the responses of species to certain environmental change might be opposite (Lawton et al. 1998, Jonsson and Jonsell 1999). As most species respond to changes in the environment, almost every terrestrial animal group has been used as some kind of indicator (Rosenberg et al. 1986, Roth 1993, Kremen et al. 1994). In many cases selection is based more or less on personal preference (Andersen 1995, 1999).

Sustainable forest management is a widely held international goal (McLaren et al. 1998, Mulder et al. 1999, Montreal Process 2000, UNCSD 2001) Monitoring indicators of sustainability has been proposed as a mechanism for assessing sustainability. The urgency with which meaningful, practical and immediate assessments of sustainability must be developed is highlighted by the fact that national and international sustainable forest management certification systems are expanding rapidly and influencing market demand (Kanowski et al. 1999) and the rate of timber harvesting in forests continues at substantial levels Monitoring a few indicator species is an intuitively appealing method of measuring the ecological sustainability of forest management because it is impossible to measure and monitor the effects of forest management on all species or environmental conditions of interest (Landres et al. 1988, Atlegrim et al. 1997).

Lindenmayer et al. (2000) defined seven types of indicator species that can be effectively classified into three classes of bio-indicators: (1) biodiversity, (2) environmental, and (3) ecological (McGeoch, 1998). Biodiversity indicators indicate the presence of a set of other species (Noss 1990, Gaston and Blackburn 1995, Flather et al. 1997), and therefore provide a descriptive function. Environmental indicators are also descriptive in that they indicate changes in the state of the abiotic environment directly. Both biodiversity and abiotic environmental change can be measured directly, although indicator species provide a cheaper method of doing so. Ecological indicators differ from biodiversity and environmental indicators in that they indicate functional change to systems. They demonstrate the effects of environmental change on the biotic systems including species, communities, and ecosystems (Meffe and Carroll 1994, McGeoch 1998).

Biological indicators of sustainable forest management are ecological indicators in that they must provide information on the effects of forest management on the functioning of the forest ecosystem to be useful. They can be keystone species, dominant species, sensitive species or species that reflect the ecological effects of a disturbance regime. To be most effective some must target anticipated stresses that are known to result from current or potential forest management approaches (Mulder et al. 1999, Venier and Pearce 2004). Thus, a single bioindicator species or assemblage is expected to be one component of a team of bioindicators to provide a multi-scaled and holistic assessment of sustainability. Conservation of the biodiversity will follow from maintaining ecosystem integrity.

5.2 Sampling methods

Beetles were collected by the various sampling methods viz. hand sorting, flotation method, pitfall trap, light trap, sweep net, beating trays as previously discussed (Section 4.2).

5.3 Data Analysis

For determining the bioindicator families, the degree of habitat specificity (habitat breadth or niche/micro site utilization) for each species of a family was calculated. This was quantified using Bulla's diversity index (Bulla 1994), a measure of the Habitat Breadth (*H*). The relative frequency of each species of a family in each habitat type of the site(s) will be used to calculate H, which consequently expresses breadth in terms of utilization of the available habitat spectrum.

$$\text{Eveness, } E = \frac{1 - 1/S + (S - 1)/N}{O - 1/S + (S - 1)/N}$$

$$\text{Habitat Breadth, } H = E \times S$$

Species restricted to one habitat type will have minimum habitat breadth, and are characterised by a value of *H* equal to zero. If a species were evenly distributed across all the habitat types, *H* would be equal to the total number of habitats.

Indicator Species Analysis (ISA) was also carried out to find indicator species and species assemblages characterizing habitats. It combines the species relative abundance with its relative frequency of occurrence in the different habitats (Lund 2002). This index has maximum value when all individuals of a species are found in a single habitat and when the species occurs in all sites of that group; it is a symmetric indicator. The statistical significance of the species indicator values is evaluated using a randomization procedure.

Contrary to TWINSPAN, IndicatorValue (IndVal) for a given species is independent of the other species relative abundances, and there is no need to use pseudospecies. Species can thus be grouped on the basis of their IndVal values for each clustering level, so the heterogeneous nature of species assemblages observed in any one site being well preserved. Such assemblages are usually a mixture of eurytopic (higher level) and stenotopic species (characteristic of lower level clusters) (Dufrêne and Legendre 1997). The IndVal technique of Dufrêne and Legendre (1997) assigns a value of 0–100 to each species according to how well that species can function as an indicator as determined by the species' specificity (maximum when only found at a given type of site) and fidelity (maximum when always found at a given type of site). It is calculated as:

$$\textbf{IndVal} = \textbf{Specificity} \times \textbf{Fidelity} \times 100$$

where,

$$\textbf{Specificity} = \mathbf{Nind}_{ij} / \mathbf{Nind}_{i}$$

and,

$$\textbf{Fidelity} = \mathbf{Nsites}_{ij} / \mathbf{Nsites}_{i}$$

where $N_{ind\,ij}$ is the mean number of individuals of species *i* across sites of group *j*, $N_{ind\,i}$ is the sum of the mean number of individuals of species *i* over all groups, $N_{sites_{ij}}$ is the number of sites in cluster *j* where species *i* is present, and N_{sites_j} is the total number of sites in that cluster. A high indicator value corresponds to a species that is found almost exclusively in cluster j and in almost every site within cluster j. The statistical significance of the indicator value of each species is statistically tested through a randomization procedure followed by two methods of determining significance. The IndVal is tested by calculating its z-value based on random permutations, and also by ranking their values in the ordered randomization results.

5.4 Taxonomy

Sound taxonomy is the foundation of all meaningful research in biology (Narendran 2001). Before undertaking any kind of research on any organism, it is essential to know its correct name. The name is a label using which various pieces of information on an organism are retrieved and stored. It has great relevance in various fields like biodiversity, ecology, agriculture, medicine, etc (Narendran 2001). Until date four orders, 166 families have been listed in the order Coleoptera (Lawrence and Newton 1995). The following taxonomic characters and keys wherever applicable were used in the identification of carabid beetles (Andrewes 1929, 1935), scarabaeid beetles (Arrow 1910, 1917, 1925, 1931, Kakkar 2008), cerambycid beetles (Gahan 1906), staphylinid beetles (Cameron 1930, 1934, 1932, 1939), cicindelid beetles (Fowler 1912, Singh 1991), Richards and Davies (1977), Crowson (1981), Lawrence and Newton (1995) and Borror et al. (2002).

Key characters

Head Characters: The principal head character used involves the development of a snout. It is more or less prolonged forward into a snout (Curculionoidea) or is poorly developed (Scolytidae and Platypodidae). The presence or absence and number of ocelli, also helps to differentiate some families.

Antennae: The antennae of beetles show considerable variations in different groups, and these differences are used in identification. It may be clavate, capitate, lamellate, serrate, filiform, or flabellate type. The number of flagellar segments and terminal antennal segments that form the club serves as a key character.

Thoracic Characters: The chief thoracic characters apparent in a ventral view important in identification are various sutures (prosternal and sternopleural), the shape of certain sclerites, particularly the sclerites which are are adjacent to the front and middle coxae.

Leg Characters: The coxae of beetles vary greatly in size and shape, and the coxal cavities may be present or absent. The number and relative size and shape of the tarsal segments are very important characters for the identification of beetles. The number of tarsal segments in most beetles varies from three to five and most beetles have a 5-5-5 tarsal formula.

The Elytra: The elytra vary principally in shape, length, and texture. They are usually parallel-sided anteriorly and tapering posteriorly. It may be variously sculptured, with ridges, grooves, smooth or pubescent. In some beetles it may be very hard and stiff or may be soft and pliable.

The Abdomen: The structure of the first abdominal segment serves to separate the two principal sub-orders of the Coleoptera, the Adephaga and Polyphaga. The number of visible abdominal sterna also varies in different groups and will be used in taxonomy.

Genitalia: The structure of the genitalia is a predominant character to differentiate between the species.

Other characters

Characters such as size, shape, or color were used to differentiate between different members of family. The term *base* is used to distinguish the two ends of body parts. When speaking of an appendage the base is the end nearest the body. The base of the head or pronotum is the posterior end, and the base of the elytra or abdomen is the anterior end. The segments of tarsi or antennae are numbered from the base distad.

5.5 Results

5.5.1 Bioindicator Families and Indicator Species Analysis

Beetle species were recorded in all of the habitat types but all were not equally rich. Mixed forests harboured more species than any other habitat. At the species level, each species tends to concentrate in one or few habitats. Thus, Bulla's diversity index was employed to measure the habitat breadth as prerequisite criterion of bioindicator taxon in relation to the habitat specificy of target species. It was vital to screen out and select suitable bioindicator families from the complete lot of 66 recorded families of beetles. Thus, all those families that showed the mean H' more than 11.00 were considered inappropriate to meet the criterion of a bioindicator taxon (Fig. 5.1 and Appendix 4).

Further, those families that were represented by one or few species though recorded in one or few habitats were also excluded from the analysis. Finally, five families viz. Carabidae Cicindelidae Scarabaeidae Staphylinidae Cerambycidae were selected out of 66 families as they met the aforesaid criterion. Their suitability was further validated using the indicator species analysis (ISA). All those recorded beetle families that showed the observed indicator value (IndVal) less than 10 were excluded from further analyses (Fig. 5.2 and Appendix 5). Of all, tiger beetles showed the maximum observed and mean IndVal followed by ground beetles, rove beetles, long-horned beetles and dung beetles.

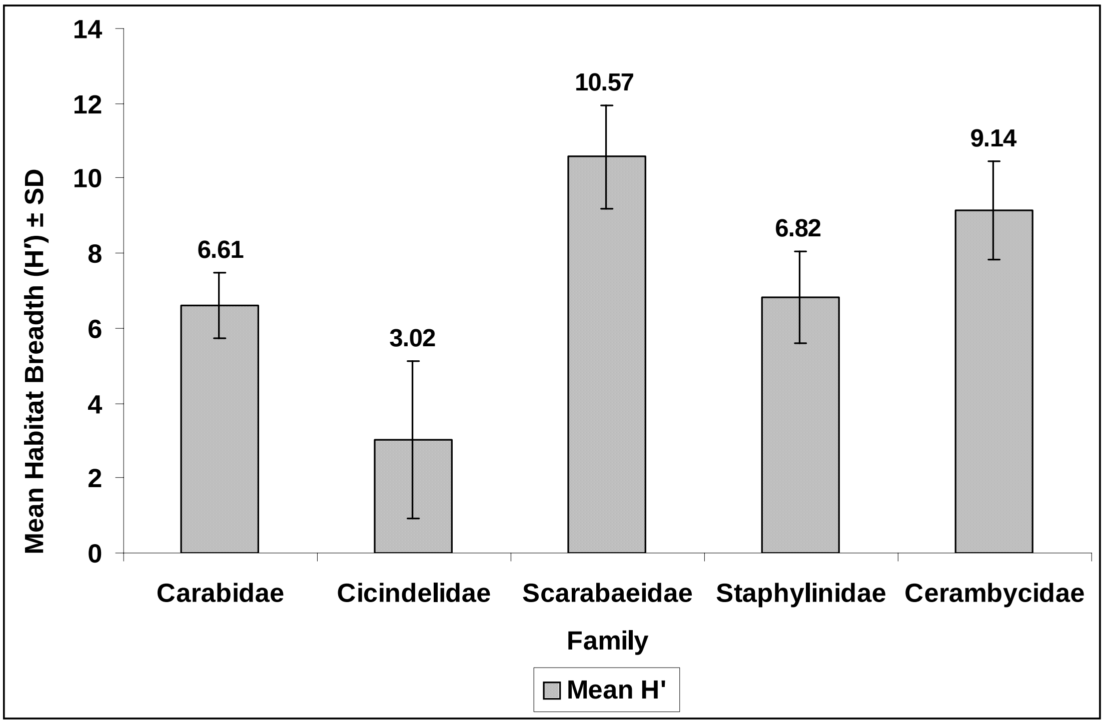


Fig. 5.1 Habitat breadth of bioindicator families recorded from Simbalbara WLS

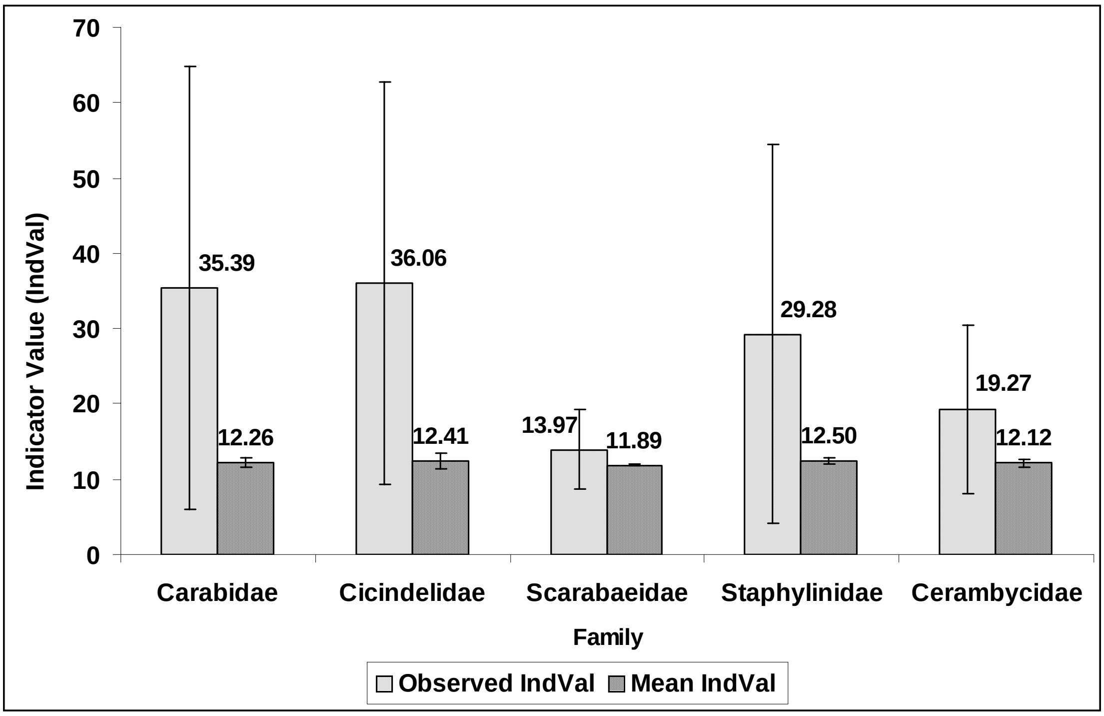


Fig. 5.2 Observed and mean Indicator Value (IndVal) of the bioindicator families

Table 5.1 Indicator species analysis computing indicator value (IndVal) coefficient of beetles in Simbalbara WLS

S.No.	Species	Observed Indicator value (IndVal)	IndVal* from randomized groups		P**	Indicator; Habitat Condition
			Mean	S. Dev		
Carabidae[1]						
1.	*Axonya championi*	44.4	11.9	5.08	0.001	Fragmentation; Forest-agriculture interface
2.	*Bembidion xanthacrum*	60	12.1	7.13	0.003	Fragmentation; Forest-agriculture interface
3.	*Calosoma maderae*	39.7	13.4	4.79	0.001	Fragmentation; Mixed forest
4.	*Hexagonia longithorax*	60	10.5	7.83	0.003	Fragmentation; Riverine-grassland interface
5.	*Hexagonia uninotata*	100	12.9	7.55	0.001	Fragmentation; Mixed forest
6.	*Nebria cameroni*	100	11.4	6.79	0.001	Fragmentation; Riverine-grassland interface
7.	*Neoblemus andrewesi*	80	12.2	7.09	0.001	Fragmentation; Riverine
8.	*Perileptus cameroni*	100	13.2	7.18	0.001	Fragmentation; Forest-agriculture interface
9.	*Perileptus ceylanicus*	100	11.6	7.14	0.001	Fragmentation; Mixed forest
10.	*Perileptus microps*	26.8	12.6	3.74	0.004	Fragmentation; Mixed forest
11.	*Scapterus guerini*	52.1	13.3	6.12	0.002	Fragmentation; Mixed forest
12.	*Scarites dubiosus*	48.8	13.1	7.31	0.003	Fragmentation; Low canopy cover
13.	*Tachys babulti*	60	12.1	7.13	0.003	Fragmentation; Agriculture land
14.	*Tachys cardoni*	22.2	12.2	4.36	0.033	Fragmentation; Agriculture land
Cicindelidae[2]						
15.	*Calochroa bicolor*	100	12.9	7.55	0.001	Biodiversity; High canopy cover
16.	*Calomera angulata*	100	12.9	7.55	0.001	Biodiversity; Riverine
17.	*Calomera plumigera*	72.2	12.4	6.25	0.001	Biodiversity; Riverine
18.	*Cicindela fastidiosa*	56.9	12.3	5.5	0.001	Biodiversity; Riverine
19.	*Cosmodela intermedia*	48.1	13.1	5.25	0.001	Biodiversity; Riverine-forest interface
20.	*Cylindera (Eugrapha) grammophora*	50.3	12.6	7.41	0.004	Biodiversity; Agriculture land
21.	*Cylindera (Ifasina) spinolae*	44.4	11.9	5.08	0.001	Biodiversity; Mixed forest

S.No.	Species	Observed Indicator value (IndVal)	IndVal* from randomized groups		P**	Indicator; Habitat Condition
			Mean	S. Dev		
22.	*Heptodonta pulchella*	60	12.1	7.13	0.003	Biodiversity; Pine
23.	*Lophyra parvimaculata*	100	13.2	7.18	0.001	Biodiversity; Mixed forest
24.	*Neocollyris (Neocollyris) bonellii*	60	12.1	7.13	0.003	Biodiversity; High shrub density
25.	*Neocollyris (Neocollyris) saphyrina*	100	11.4	6.79	0.001	Biodiversity; High shrub density
Scarabaeidae[3]						
26.	*Adorestes sp.1*	100	12.9	7.55	0.001	Urbanization; Agriculture-forestscapes
27.	*Adorestes sp.2*	100	11.4	6.79	0.001	Urbanization; Agriculture-forestscapes
28.	*Agerstrata orichalcea*	80	12.2	7.09	0.001	Urbanization; High leaf litter
29.	*Caccobius pantherinus*	100	13.2	7.18	0.001	Urbanization; Plantations
30.	*Caccobius tortricornis*	100	11.6	7.14	0.001	Urbanization; Plantations
31.	*Catharsius pithecius*	43.9	12.6	5.43	0.002	Urbanization; Mixed forest and litter
32.	*Cetonia bensoni*	48.8	13.1	7.31	0.003	Urbanization
33.	*Copris brahminus*	31.6	13.1	4.8	0.005	Urbanization; Dung
34.	*Copris sabinus*	60	11.4	7.62	0.003	Urbanization; Dung
35.	*Megalodacne consimilis*	48.8	12.4	5.71	0.003	Urbanization; Carrion
36.	*Onthophagus dama*	50.9	12	6.78	0.001	Urbanization; Dung
37.	*Onthophagus dynastoides*	48.6	12.3	6.03	0.001	Urbanization; Dung
38.	*Onthophagus expansicornis*	43.1	12.6	6.49	0.003	Urbanization; Dung
39.	*Onthophagus exquisitus*	73.3	13.1	7.16	0.001	Urbanization; Dung
40.	*Onthophagus fasciatus*	59.4	11.2	7.23	0.002	Urbanization; Dung
41.	*Onthophagus hamaticeps*	100	13.1	7.28	0.001	Urbanization; Dung
42.	*Onthophagus hystrix*	100	11.6	7.14	0.001	Urbanization; Dung
43.	*Onthophagus mopsus*	58.1	13.6	6.54	0.002	Urbanization; Dung
44.	*Onthophagus necrophagus*	48.8	13.1	7.31	0.003	Urbanization; Dung
45.	*Onthophagus sternalis*	60	12.1	7.13	0.003	Urbanization; Dung
46.	*Protaetia pretiosa*	34.3	11.8	5.15	0.004	Urbanization; Mixed forest

S.No.	Species	Observed Indicator value (IndVal)	IndVal* from randomized groups		P**	Indicator; Habitat Condition
			Mean	S. Dev		
Staphylinidae[4]						
47.	*Belonuchus sp.*	48.8	13.1	7.31	0.003	Land use; Mixed forest with litter
48.	*Cryptobium capitale*	100	11.6	7.14	0.001	Land use; Mixed forest with litter
49.	*Mitomorphus sp.*	31.6	13.1	4.8	0.005	Land use; Mixed forest with litter
50.	*Paedurus sp.*	43.1	12.6	6.49	0.003	Land use; Riverine
Cerambycidae[5]						
51.	*Cantharocnemis downesi*	36.9	11.9	5.65	0.004	Stand age; Mixed forest
52.	*Lophosternus buqueti*	60	11.4	7.62	0.003	Stand age; Sal forest
53.	*Olenecamptus anogeissi*	31.6	13.1	4.8	0.005	Stand age; Human influenced forest edges
54.	*Olenecamptus bilobus*	48.8	13.1	7.31	0.003	Stand age; Human influenced forest edges
55.	*Olenecamptus pseudostrigosus*	48.6	12.3	6.03	0.001	Stand age; Human influenced forest edges
56.	*Pyrestes pyrrhus*	60	12.1	7.13	0.003	Stand age; Human influenced forest edges
57.	*Trinophylum cribratum*	42.4	12.9	5.52	0.001	Stand age; Mixed forest
58.	*Xystrocera globosa*	73.3	13.1	7.16	0.001	Stand age; Mixed forest
59.	*Xylotrechus smei*	40.9	11.6	5.11	0.001	Stand age; Mixed forest

p*- proportion of randomized trials with indicator value equal to or exceeding the observed indicator value. p = (1 + number of runs ≥ observed)/ (1 + number of randomized runs)

****Monte Carlo test of significance of observed maximum indicator value for species at 999 permutations**

Indicative of key ecological processes and/or functions
1: Carnivory (Animal community structure: prey base availability)
2: Carnivory (Animal community structure: prey base availability)
3: Detrivory and saprophagy (Decomosition and nutrient recycling)
4: Detrivory and saprophagy (Decomosition, soil formation and nutrient recycling)
5: Xylophagy (Wood decomposer community)

5.5.2 Taxonomic Identification of the Species of Bioindicator Families of Beetles Recorded from Simbalbara WLS, Himachal Pradesh

Beetle species recorded from the five bioindicator families were taxonomically identified till species level. In those cases, where such level could not be met, specimens were identified and labeled as morphospecies of that tribe and/or sub-family level. In total 194 species (including morphospecies) were identified. Voucher specimens of each collected and identified beetle species are deposited at Wildlife Institute of India, Dehradun and entomology section of the Indian Agriculture Research Institute, New Delhi. The details of the taxonomic identification of the beetle species are as below:

I. Coleoptera: Carabidae (Ground beetles) (Plate 8 to 10)

Identifying characteristics for the family Carabidae include:

- First abdominal sternite *divided* by hind coxae (sub-order Adephaga)
- Head at eyes nearly always *narrower* than pronotum.
- Antennae threadlike, inserted *between* mandibles and eyes.
- 5-5-5 tarsi.
- Generally black and shiny with striate elytra, but sometimes metallic or colorful.
- They are commonly found under stones, logs, bark, or debris or running about on the ground. When disturbed, run rapidly, but seldom fly. Most species hide during the day and feed at night. Many are attracted to lights. Nearly all are nocturnal, secretive predators of other insects, and many are very beneficial.
- 40, 000 species described worldwide; 2,500 species in India (Gupta 2004).

Key to the Indian species of genus *Calosoma* Herbst

1. Elytra with the surface clearly imbricate, the striae clearly well defined

………. maderae, F., var. auropunctatum Herbst

1. *Calosoma maderae*, *F.*, var. indicum, Hope

Diagnostic characters

- Colour black, upper surface often with aeneous or cupreous tinge, the punctures on the primary intervals metallic green or cupreous; rather dull above, shiny beneath.
- Head with eyes only moderately prominent, clypeal suture obsolete, vaguely striate near eyes and across vertex, neck rather finely punctate, gula and mentum with a seta on each side, mentum very faintly punctate, lobes feebly bordered, mandibles rather finely punctate-striate, maxillary palpi with joint 3 half as long again as 4, antennae with joints 2 to 4 compressed, 1 to 4 carinate, 4 at base only.
- Prothorax much wider than head; more than half as wide again as long, a little more contracted behind than in front; base only slightly bisinuate, unbordered, apex emarginate, front and side borders rather fine (for the genus), side border reaching base, widened and rather reflexed behind, with two setae, sides strongly rounded, without sinuation behind, hind angles deflexed, rounded, projecting very little backwards; surface finely punctate, more coarsely and confluently along base.
- Elytra about half as wide again as prothorax, two thirds as long again as wide, very slightly serrate behind shoulder; striae more or less well marked, the punctures in them clearly visible on scutellary region only, intervals nearly flat, three between the primaries, which have 8 to 12 punctures, the surface imbricate, with cross-lines, more or less flattened, but rather more roughly sculptured behind shoulder, marginal channel widely and apex finely tuberculate.
- Sternum: sterna punctate, smooth along median line, proepisterna nearly smooth on outer half, prosternal process with border reaching apex, metepisterna distinctly longer than wide, a slight channel along outer margin. Venter: the segments with one seta, but sometimes several, along each side of median line.
- Legs: meso- and metatibiae strongly curved in ♂, slightly in ♀, a slight clothing of foxy hairs on outer margin of mesotibiae.
- Length, 18-30 mm; width, 7-11 mm.

Key to the Indian species of genus *Nebria* Andr.

1. Tarsi evidently, though not closely, pubescent on upper surface. Colour testaceous, with or without a dark apical spot on the elytra. Length about 11 mm

……… cameroni Andr.

2. Elytra with the pointed apex not produced, with wide flavous border. Length about 11.5 mm

……… cinctella Andr.

2. *Nebria cameroni*, Andr.

Diagnostic characters

- Colour testaceous-red, palpi joints, 1 to 4 of antennae, and legs (except tarsi) flavous; a vague triangular spot towards apex of each elytron, approximately from stria 2 to 7 (sometimes wanting), and a large patch on the underside, including meso and metasternum, with their episterna, base of ventral surface (narrowly), and meso and metacoxae black. Body winged.
- Head flat, wide and dull, neck inflated, with hardly a trace of constriction, smooth, and few fine striae near eyes, frontal foveae very shallow, clypeus slightly emarginate, finely rugose, clypeal suture very fine; gula with a row of four setae on each side; mentum with a deeply notched tooth, joint 2 of labial palpi trisetose, antennae stout, hardly reaching middle of elytra.
- Prothorax cordate, moderately convex, much wider than head, nearly a half wider than long, widest rather before middle, base bisinuate, a little narrower than apex, which is distinctly emarginate, sides bisetose, a little explanate, with a narrow reflexed border, darker than disk, strongly rounded in front, sharply contracted behind, sinuate at a fifth from base, front angles slightly rounded, adjoining neck, hind angles acute and projecting laterally; median line fine, transverse impressions and basal foveae all fairly deep, the foveae curved and produced a little on to disk, where they diverge somewhat, apical and side margins finely, base rather rugosely punctate, the disk smooth but dull.
- Elytra rather flat, short, and wide, with square shoulders, about half as wide again as prothorax, and rather more than half as long again as wide,

sharp and not separately rounded at apex; sides parallel, with narrow hardly reflexed border, very faintly sinuate behind shoulder and near apex; deeply punctate-striate, the striae not effaced behind, intervals smooth, shiny, and moderately convex, the apex of 4 to 8 raised into a short carina, 1 with a pore at base, 3 with two (sometimes three) pores, not far apart and about third from apex.

- Sternum: metepisterna half as long again as wide, coarsely punctate. Venter: the segments with a single seta on each side, anal segment (♂♀) with two setae on each side.
- Legs: tarsi rather strongly pubescent on upper surface, protarsi with 3 dilated joints, metatarsi with joint 4 very slightly produced at apex, metacoxae punctate, and unisetose at base.
- Length, 10.5-11 mm; width, 4.3-4.5 mm.

3. *Nebria cinctella*, Andr.

Diagnostic characters

- Colour flavous, tarsi and apical joints of antennae little darker; elytra black and rather shiny, with border to stria 8 and the apex (widely) flavous; a considerable black area on the underside, including base of prosternum, meso and metasterna, with their episterna, coxae, and base of venter.
- Head wide and rather flat, neck, without or with very slight constriction, surface smooth, frontal foveae shallow, clypeal suture fine, gula with two setae on each side, tooth of mentum clearly emarginate, joint 2 of labial palpi trisetose, antennae slender, reaching middle of elytra.
- Prothorax cordate, moderately convex, rather wider than head and a third wider than long, base bisinuate, a little narrower than apex, sides bisetose, with a narrow, slightly reflexed border, moderately rounded in front and sinuate at some little distance from base, hind angles right and sharp; median line fine, transverse impressions deep, surface smooth on disk, margins finely rugose-punctate, basal area more coarsely punctate.
- Elytra short and wide, with square shoulders, more than a half wider than prothorax, about a half longer than wide, border barely sinuate either at sides or behind, slightly dehiscent at apex, each one very sharp; strife deep and deeply punctate, striae long, intervals smooth and rather shiny,

the carina at apex not at all sharp, 1 with a pore at base, 3 with one or two small pores near apex. Microsculpture formed by meshes twice as wide as long.

- Sternum: metepisterna coarsely punctate, a half longer than wide. Venter: the segments with 1 or 2 setae on each side.
- Legs: tarsi almost glabrous above, though minute hairs are present at least on joint 1, protarsi with 3 dilated joints, joint 4 of metatarsi not produced beneath, metacoxae unisetose at base.
- Length, 11-12 mm; width, 4.75-5 mm.

Key to the Indian species of genus *Omophron* Latreille

1. Prothorax coarsely punctate punctures on elytral intervals visible only under a strong lens, front and intermediate testaceous patches united along interval 13

……… smaragdus Andr.

4. *Omophron smaragdus*, Andr.

Diagnostic characters

- Colour testaceous, sterna and front margin of prothorax piceous; back and sides of head, a wide transverse patch on prothorax, extending to base and covering its central third, extending also to a broad point at middle of apex, and an elytral pattern rather bright green. The base of the elytra is green to stria 15, as are intervals 1-2 to near apex; marginal channel, and occasionally internal 15 (or even 14) testaceous. On the green ground are two irregular fasciae and an apical patch testaceous. The front fasciae reaches shoulder and is fairly wide at margin, narrowing to stria 6, contracted and sometimes interrupted on interval 10; the hind fascia. also wide at margin, extends to stria 3, interrupted on intervals 6 and 10, the central and inner parts small, the central one rather in advance of the other two; apical patch comparatively small, with short arms projecting on intervals 3-5 and 7-9.
- Head flat, front nearly smooth, sides and back rather closely striate-punctate clypeus uneven, quadrisetose, indistinctly bordered, widely emarginate, suture with an angle at middle, lobes of mentum rounded,

epilobes not projecting, sub-ocular ridges extending little beyond fissure, area in front of them finely rugose-striate.

- Prothorax moderately convex, rather coarsely coriaceous, coarsely punctate along base, more finely on disk and along front margin, base only slightly sinuate near hind angles, sides a little rounded at about middle and faintly sinuate before angles, median line fine but distinct, not reaching extremities.
- Elytra oval, convex, base unbordered, sides rather strongly dilated behind shoulders; 15-punctate-striate, the punctures very distinct, intervals rather flat on disk, more convex at sides, a row of minute punctures down the centre of each. A fine microsculpture is present.
- Sternum: sterna at sides and prosternal plate with a few punctures, metepisterna practically as long as wide. Venter with a few coarse punctures at sides of base, segment 5 with a seta on each side.
- Legs: metacoxae with two pores.
- Length, 6-7 mm; width, 4-4.4 mm.

Key to the Indian species of genus *Siagona* Latreille

1. Body sub-convex, prothorax with lateral grooves not interrupted on disk, its sides rounded and evidently contracted in front, average length 10.5 mm

   ………. pumila Andr.

5. *Siagona pumila*, Andr.

Diagnostic characters

- Body winged, sub-convex, shiny, and covered with short pale pubescence. Colour piceous to black, palpi and legs ferruginous.
- Head moderately convex, clypeal suture clearly impressed, lateral ridges rather fine, rounded at the bend, generally uninterrupted, though sometimes vaguely interrupted, hardly diverging behind and not quite reaching hind-eye level, neck constriction deep; surface finely and fairly closely punctate, including the area immediately behind neck constriction, nearly smooth on vertex; mandibles small, but sharp, similar in the two sexes; supramaxillary plates conspicuous, with parallel sides, rounded in front; antennae stout, nearly reaching middle of elytra, joint 1 strongly

clavate.

- Prothorax about a sixth wider than head and a third wider than long, apex only slightly emarginate, sides rounded and evidently contracted in front; median line very fine, lying in a longitudinal depression, lateral grooves deep throughout; surface closely punctate, only a little more sparsely at sides of disk.
- Elytra only moderately flat, sub-ovate, with strongly marked shoulders, very little wider than prothorax, two-thirds longer than wide, surface rather closely and evenly punctate, with more or less cuneiform punctures, which are a little coarser in front and finer behind, suture raised, narrowly impunctate, humeral ridge just visible, the pores across shoulder very distinct. Microsculpture conspicuous on elytra and quite visible on head and prothorax. Stridulating apparatus wanting.
- Length, 10-11 mm.

Key to the Indian species of genus *Scarites* Fabricius

1. Head with joints 5 to 10 of the antennae transverse, elytral intervals very convex, even on disk, and without granulation along margins, average length 19.5 mm

   ………. conspicuus Andr.

2. Head moderately striate, impunctate, front transverse impression obsolete at middle, average length 28 mm

   ………. dubiosus

3. Mandibles smooth between scrobe and median carina, elytra twice as long as wide, sides nearly parallel, protibiae with two denticulations above upper tooth, length not exceeding 14 mm

   ………. subnitens Chaudoir

4. Surface dull, elytral striae fairly deep, protibiae with two denticulations above upper tooth

   ………. punctum Wiedemann

6. *Scarites inconspicuus*, Andr.

Diagnostic characters

- Head with the lateral truncature straight, the preocular angle not projecting laterally, frontal impression not very deep, moderately striate, together with clypeus and sides behind; neck slightly constricted at sides and faintly punctate, the punctures sometimes numerous and stretching right across; mandibles as long as head, moderately striate, median carina evidently, though not sharply carinate at middle, the carinae form upper edge of scrobe bent a little inwards at the same place, basal tooth in both mandibles more or less trifid; eyes rather flat, genae inconspicuous, much shorter than eyes; antennae moniliform, joints 5 to 10 wider than long; mentum faintly granulate and narrowly bordered at sides.

- Prothorax fifth wider than head and as much wider than long, base not produced, its sides straight, front angles slightly advanced and rather sharp, sides bisetose, nearly straight, but rounded close to front and hind angles, latter dentate; median line moderately deep, front transverse impression deep, hardly less so at middle, indistinctly crenulate, basal foveae obsolete, sides of base and basal channel somewhat granulate.
- Elytra very slightly dilated behind, about as wide as prothorax and twice as long as wide, sides of base curving gently backwards to shoulders, which have each a small tooth; striae deep, impunctate, 4 to 6 a little deeper near base; intervals convex, without granulation, 3 with four pores, which are often inconspicuous; surface shiny, nearly uniform, with a fine microsculpture, not quite obliterated even close to base, apex also microscopically punctate.
- Sternum: episterna more or less granulate metepisterna fully twice as long as wide.
- Leg: protibiae with 2 or 3 denticulations above upper tooth; mesotibiae with two sharp spurs, the upper shorter than the lower one.
- Length, 18-21 mm.

7. *Scarites dubiosus*

Diagnostic characters

- Head large, lateral truncature emarginate, preocular angle not projecting laterally, surface covered with moderate, rather wavy, longitudinal striae, which gradually disappear on neck, a small area near front angles smooth; mandibles stout, sharp, fully as long as head, rather lightly striate, median carina well developed, raised at base, bent outwards at middle, where the carina bounding the scrobe is bent a little inwards, so that only a narrow space is left between the two carinae, left mandible but constricted at middle, with a relatively small bifid tooth at base, another well-developed tooth not far from apex, and a third rather smaller one a little below and behind the apical one, right mandible with a single large bifid tooth, at about middle, without any carina on it; eyes moderately prominent, genae small and inconspicuous, sloping gradually to neck; antennae stout, not reaching hind angles of prothorax, joints 5 to 10 very nearly as wide as long; mentum sub-striate, sides rather widely bordered, the lobular sides of tooth much dilated. The left mandible is not constricted, but has a moderately large, emarginate, basal tooth, with a second very small one nearer apex; the right mandible has two fairly large teeth, separated by a deep indentation, the basal one somewhat rounded and more or less trifid.

- Prothorax a little wider than head, about a third wider than long, base not produced, evidently emarginate at middle, front angles projecting slightly forward, sides bisetose, forming with sides of base a continuous curve on each side, interrupted only by the small tooth at hind angle; median line and front transverse impression rather fine, the latter deeper near the angles, basal foveae, slight, granulate, the granulation extending vaguely along the basal channel.
- Elytra with sides practically parallel, as wide as prothorax, not quite twice as long as wide, sides of base curving gently back to shoulders, which are dentate; striae moderately impressed, a little deeper at sides, impunctate, 4 and 5 bent a little outwards at base; intervals moderately convex, with only traces of granulation along margins, 3 with 5 or 6 pores; surface smooth, but a little shagreened and with a faint microsculpture towards apex.
- Sternum: episterna and sides of sterna more or less granulate metepisterna twice as long as wide.
- Legs: protibiae with 4 or 5 denticulations above upper tooth; mesotibiae with two stout spurs.
- Length, 26-30 mm.

8. *Scarites subnitens*

Diagnostic characters

- Head with lateral truncature slightly emarginate, preocular angle not projecting laterally, frontal impressions moderately deep, finely striate on their outer side, the striae, generally carried forward on the clypeus, some more evident striae near eyes and a few vague ones across neck; mandibles as long as head, smooth except for a little striation on the basal tooth of left one, median carina gently curved, basal tooth in both mandibles irregularly jagged, the carina on front tooth not joining central one or reaching base; eyes with genae rather prominent, latter shorter than and not projecting as far laterally as eyes but contracted sharply to neck; antennae moniliform, barely reaching hind angles of prothorax, joints 5 to 10 as wide as long; mentum uneven but nearly smooth, its sides narrowly bordered.
- Prothorax slightly wider than head and also a little wider than long, base not produced at middle, its sides straight, front angles projecting a little forwards, sides bisetose, nearly straight, a little rounded close to front and hind angles, latter dentate; median line and front transverse impression not very deep, latter a little deeper near the angles and minutely crenulate, basal fovea just visible and faintly granulate.
- Elytra with parallel sides, only faintly contracted near base, as wide as prothorax and fully twice as long as wide, sides of base only sloping backwards close to shoulders, which are sharply dentate; striae, fine and shallow, minutely and often indistinctly punctate, 5 and 6 bent a little outwards and also a little deeper just behind shoulder; intervals only slightly convex, without granulation, 3 with three pores; surface smooth and shiny, with a microsculpture which in front is visible only in the striae.
- Sternum: sterna practically smooth, metepisterna more than twice as long as wide.
- Legs: protibiae with two very small denticulations above upper tooth; mesotibiae with a single spur.
- Length, 13-14 mm.

9. *Scarites punctum*

Diagnostic characters

- Head with lateral truncature straight, preocular angle not projecting laterally, frontal impressions moderately deep, the whole surface finely striate, very irregularly behind, basal half also finely punctate, a slight depression along the course of the clypeal suture; mandibles slender, as long as head, finely striate, median carina faintly sinuate at basal third, basal tooth in both mandibles more or less bifid, hind cusp of the right one raised, much larger than front cusp, the carina very short; eyes rather flat, genae inconspicuous; antennae moniliform, barely reaching hind angle of prothorax, evidently dilated towards extremity, joints 5 to 10 about as long as wide; mentum faintly striate, the sides finely bordered.
- Prothorax a fifth wider than head but only a trifle wider than long, base not produced at middle, its sides straight, front angles fairly sharp and slightly advanced, sides bisetose, nearly straight, parallel, curving inwards a little in front and behind, hind angles each with a small tooth; median line fine, front transverse impression sub-crenulate, moderately deep, hardly deeper at sides, basal foveae obsolete, their site hardly perceptibly granulate, surface covered with very faint wavy striae, some evident longitudinal striation along front margin.
- Elytra with sides nearly parallel, but very gently contracted in front, barely wider than prothorax and twice as long as wide, sides of base sloping gently back to shoulders, which are minutely but sharply dentate; striae very fine, hardly impressed and formed chiefly by minute punctures, obsolete; intervals flat, 3 with three very conspicuous pores; surface dull, with a very clear microsculpture, which covers elytra and prothorax and extends to, though it is less visible on head.
- Sternum: episterna and sides of sterna vaguely rugose granulate metepisterna more than twice as long as wide.
- Legs: protibiae with a single denticulation above upper tooth; mesotibiae with only one spur.
- Length, 11.5-14 mm.

Key to the Indian species of genus *Scapterus* Dejean

1. Prothorax with median part of base evidently emarginate at middle and angulate at sides, elytra deeply striate but not sulcate, average length 17 mm

……… guerini Dejean

10. *Scapterus guerini*, Dejean

Diagnostic characters

- Colour black. Head wide, clypeus very short, surface somewhat irregularly and fairly closely longitudinally striate, neck nearly smooth, a well marked elongate tubercle on middle of front, projecting slightly over clypeus, eyes projecting very little, the genae enclosing them to some extent behind, but not projecting so far laterally.
- Prothorax about a fourth wider than head and as long as wide, base truncate at sides, with a moderately deep emargination at middle, which is obtusely angulate at sides, apex slightly but widely emarginate, front angles dentate and projecting forwards, sides parallel, with a fine, faintly crenulate border, hind angles sharply rounded; median line moderately deep, front transverse impression and the channel within the basal border both deep, and both broken up by a series of minute longitudinal ridges, basal foveae rather short and wide, uneven, diverging a little forwards, an irregular row of coarse punctures extending on each side between them and front angles, surface otherwise smooth.
- Elytra as wide as prothorax and twice as long as wide, rather sharply rounded at apex, shoulders without tooth, sides finely bordered, crenulate, almost parallel, though faintly dilated behind middle; striae fairly deep, punctate, intervals convex, much more convex at sides, their surface rather broken up near apex, 8 carinate on basal half, 9 very narrow, commencing behind shoulder and joining 8 before apex, no dorsal pores.
- Length, 15-19 mm.

Key to the Indian species of genus *Sparostes* Putzeys

1. Elytra convex, border behind entire, 7 striate

……… striatulus Putzeys

11. *Sparostes striatulus*

Diagnostic characters

- Colour black. Palpi, joints 1 to 3 of antennae, and legs very dark red. Form elongate and parallel.
- Head just narrower than prothorax, clypeus with its front margin depressed and truncate, inner margin of wings straight, outer margin rounded, their surface a little striate, frontal plates obliquely truncate in front and sharply rounded close to eye; clypeal ridge slightly raised, suture wanting, frontal foveae wide and shallow, covered by longitudinal striation; facial carina and groove short but strongly developed, the former interrupted behind by the hind supraorbital pore, so that its extremity forms a distinct tubercle, no neck constriction; middle of front with a longitudinal furrow, surface otherwise very smooth and shiny.
- Prothorax slightly narrower than elytra, surface almost vertical behind, where middle of base is very strongly constricted and a little produced, apex widely and deeply emarginate, front angles prominent but rounded; sides parallel, with a moderately deep marginal channel extending between the two lateral pores, of which the front one is not far from apex, the hind one close to the angle, indicated by a small tooth, sides of base nearly straight and very finely bordered; median line fine, front transverse sulcus only just visible close to front angles, surface smooth and shiny.
- Elytra elongate, base truncate, sides nearly parallel, not quite twice as long as wide, slightly contracted behind shoulders, which are minutely though evidently dentate; striae rather fine and finely punctate, 1 to 5 free at base, 6 and 7 joining at shoulder; intervals somewhat raised on the nearly vertical base but hardly forming tubercles, 8 carinate at shoulder, but not at apex, 7 almost cariniform at both extremities, 3 with a series of half a dozen small setiferous pores adjoining stria 3.
- Length, 16-22 mm; width, 4.5-6.5 mm.

Key to the Indian species of genus *Coryza* Putzeys

1. Colour bronze-black, elytra sometimes red at extremity or vaguely brown, head without transverse ridge in front of neck constriction, elytra with basal tubercles well developed, humeral tooth rather slight

………. maculata Nietn.

2. Colour black, basal half of elytra red, head with a transverse ridge in front of neck constriction, elytra with basal tubercles well developed, humeral tooth well developed

………. semirubra Andr.

12. *Coryza maculata*, Nietn.

Diagnostic characters

- Colour black, often with a greenish or bluish tinge, elytra sometimes more or less dark brown; palpi, joints 1 and 2 of antennae, and legs (excluding profemora) ferruginous; profemora and rest of antennae piceous.
- Head: clypeus with its front margin conspicuously quadridentate, the central emargination nearly as deep as the lateral ones, both the median and oblique carinae very distinct, neck constriction coarsely punctate, surface generally very uneven.
- Prothorax about a third wider than head, hardly wider than long, a slight but generally distinct tooth at hind angles; median line very deep, passing through the front transverse impression, sometimes without quite joining it but not reaching front margin, the impression fairly deep and crenulate.
- Elytra elongate oval, a third wider than prothorax and quite a half longer than wide, widest just behind middle, shoulders clearly dentate; punctate striate, the striae fairly deep, the punctures deep in front, gradually disappearing towards apex, 1 rather deeper than the rest; intervals moderately convex, 1 slightly raised.
- Legs: protibiae with the spines well developed, apical digitations curved, moderately sharp, a little thicker than lower spine and longer than spur.
- Length, 3.45-4.80 mm.

13. *Coryza semirubra*, Andr.

Diagnostic characters

- Colour black. The basal half of elytra red; underside, profemora, and apical joints of antennae more or less piceous; mandibles, legs, and sometimes venter ferruginous; palpi, basal joints of antennae and tarsi more or less piceous.

- Head: clypeus with front margin quadridentate, but with the central emargination shallower, sometimes much shallower, than the lateral ones, the median carina extending forwards and dilated at extremity, but not reaching front margin, becoming finer behind though reaching neck constriction, the oblique lateral carinae much slighter than the central one, sometimes indistinct, the space enclosed between them somewhat flattened bounded behind by a slight ridge in front of the neck constriction, and sometimes nearly smooth.
- Prothorax a half wider than head, but very little wider than long, front angles a little advanced, sides slightly indented by the pores of the front lateral setae, the tooth at hind angle well developed; median line deep, passing through the front transverse impression, but not, or only indistinctly, joining it, the impression coarsely punctate.
- Elytra not quite a half wider than prothorax and about as much longer than wide, shoulders distinctly dentate, basal tubercles very small and inconspicuous; striae punctate and fairly deep, 1 a little deeper than the rest, interval 1 slightly raised.
- Leg: protibiae with strongly developed spine, the minute spine near base generally visible, apical digitations a little longer and blunter than in *maculata*.
- Length, 3.75-4.50 mm.

Key to the Indian species of genus *Clivina* Latreille

1. Eyes prominent, middle of front sub-rugose and minutely punctate, elytral intervals moderately convex

   ………. westwoodi Putz.

2. Head convex behind, with a long longitudinal sulcus on vertex, prothorax evidently longer than wide, body very long, narrow and cylindrical

   ………. extensicollis Putz.

14. *Clivina westwoodi*, Putz.

Diagnostic characters

- Colour piceous: palpi, joints 1 to 3 of antennae, and legs testaceous. Head with prominent eyes, clypeus truncate, with its median part in advance of the wings, the angle on each side projecting forwards as a small tooth, wings small, with the outer angle somewhat obtuse, separated from median part by a slight ridge; frontal plates with an obtuse angle at sides, separated from wings by a slight notch, surface irregular but convex; clypeal ridge slight, with a small raised knob at each end; frontal impressions deep, suture obsolete; middle of front irregularly strigose-rugose, with a large pore on vertex, neck constriction entire, punctate, joined on each side by the facial sulci, surface sparsely and minutely punctate; labrum 7 setose, mandibles short and wide; mentum swollen at base, the tooth a little longer than lobes; antennae rather fine, joint 2 sub-clavate a little longer than 3.

- Pronotum slightly transverse, convex, quadrate, sides nearly straight, parallel, the front angles hardly advanced, hind angles with a short obtuse tooth; median line joining front transverse sulcus, which is uninterrupted and practically reaches margin at extremities, surface with a punctate figure Y on each side, sometimes obsolete.
- Elytra twice as long as wide, convex, parallel; striae moderately impressed and finely crenulate, 1 to 4 free at base, 5 joining 6, 7 ending behind shoulder, striae vestigial; intervals slightly convex, 3 with four small punctures adjoining stria 3, 8 slightly carinate at apex; narrow but not carinate behind shoulder.
- Sternum: prosternal ridge rather narrow and slightly sulcate. Venter smooth, the two pores on each side of last segment distant.
- Legs: protibiae, with a slight sulcus on basal half, 4-digitate, the uppermost denticulation very small; mesotibiae finely crenulate, with few but rather long bristles, a small spur a little above apex.
- Length, 6-7 mm.

15. *Clivina extensicollis*, Putz.

Diagnostic characters

- Colour black, shiny; palpi, antennae, and two hind pairs of legs more or less ferruginous, front legs piceous.
- Head with the eyes moderately prominent, clypeus with the wings and median part completely fused, widely and slightly emarginate, bordered;

frontal plates separated from clypeus on each side by a slight indentation, their sides obliquely truncate, the surface a little convex behind; clypeal ridge formed by a slightly raised, transverse, oval area, behind which is the short, wide, and fairly deep clypeal suture; facial sulci fairly deep, uneven, joining the clypeal suture in front; vertex with a vaguely defined, though fairly deep longitudinal sulcus, the surface uneven and punctate, but without neck constriction, one or two transverse rugae on each side of front; labrum bisinuate, 7-setose; mandibles wide, very short and blunt; mentum rather concave, sides nearly parallel, a carina at middle, the tooth wide and not very sharp; antennae short, moniliform, dilated towards apex, joint 2 longer than 3.

- Prothorax very convex, a third wider than head and quite a fourth longer than wide, sides straight, converging very gently in front, widest at hind angles, which are without tooth, front angles rounded and inconspicuous; median line moderately deep, though rather fine behind, joining and crossing the front transverse impression, which is deep, impunctate, and reaches the front margin; surface smooth, but with some fairly conspicuous transverse striae, particularly near the sides.
- Elytra convex, as wide as prothorax and rather more than twice as long as wide, sides parallel, apex somewhat pointed; striae moderately deep, punctate, 1 to 3 free at base, 4 to 7 converging and meeting near shoulder, striae vestigial; internals convex, 3 with three pores, one in front and two towards apex, all adjoining stria 3, 8 carinate behind shoulder.
- Sternum: prosternal ridge narrow, only faintly sulcate, proepisterna with some transverse wrinkling at sides. Venter with the apical segment finely punctate, the two pores distant.
- Legs with the profemora strongly dilated, the end of the trochanter protruding as a tooth beneath, protibiae not sulcate, with very short digitations, mesotibiae with a spur above apex.
- Length, 5.5-6.25 mm.

Key to the Indian species of genus *Dyschirius* Panzer

1. Head with a transverse impression across neck, elytral striae impressed to a fourth from the apex, two apical pores

………. constrictus

16. *Dyschirius constrictus*

Diagnostic characters

- Colour dark brassy: palpi, joints 1 to 3 of antennae (rest fuscous), and two hind pairs of legs ferruginous; front legs and apex of elytra (narrowly) more or less brown.
- Head: clypeus convex, uneven and somewhat depressed in front, margin sub-arcuate, lateral teeth rather blunt and very little advanced, connected with front by a median ridge, on each side of which is an uneven rounded depression occupying the position of the clypeal suture, a short, transverse, often asymmetrical furrow across vertex, and a deeper rather longer one behind it across neck, facial sulci deep, diverging behind and ending in a punctate area behind eye, the punctures extending a little inwards on to neck, surface very uneven at sides.
- Prothorax globose, a third wider than head, but hardly wider than long, border entire to hind lateral pore; median line very fine, transverse impression moderately deep, sub-crenulate.
- Elytra ovate, shoulders square, base unbordered, a fifth wider than prothorax and a half longer than wide; striae punctate and moderately deep to apical third, then gradually disappearing, but sometimes just visible to near apex, 1 entire arising in basal pore, the other striae shortening a little outwards, 5 generally reduced to two or three pores near base, deep close to apex, two apical and three post humeral pores; intervals moderately convex, 1 raised 3 with three pores on the interval.
- Legs: protibiae with upper spine obsolete, lower one short but sharp, apical digitations nearly straight, longer than the spur.
- Length, 2.3-2.7 mm.

Key to the Indian species of genus *Hexagonia* Kirby

1. The fovea on each side behind the eye connected by a shallow groove with the post-orbital pore; prothorax angulate at sides. Length 8-9 mm

………. terminata Kirby

2. Eyes shorter than genae; vertex impunctate, prothorax punctate only in the basal foveae and lateral channels. Length 8-10.5 mm

……… longithorax Wied.

3. The groove between the eye and post-orbital pore moderately deep, elytra ferruginous, with a piceous oval spot on apical half, the striae only moderately impressed and finely punctate

……… uninotata

17. ***Hexagonia terminata***

Diagnostic characters

- Colour ferruginous, the underside sometimes piceous, head and prothorax usually piceous or black, joints 4 to 11 of antennae, fuscous, apical two-fifths of elytra black, the black extending a little forward along sides and suture.
- Head large, pentagonal, longer than wide; frontal impressions wide and shallow, bounded on each side by a slight ridge, hardly extending beyond mid-eye level, a few fine punctures within them; genae as long as eyes, curving inwards very sharply to neck; the deep lateral sulcus, which runs on each side between the eye and the front supraorbital, extending back in a straight line to a point a little behind the eye and ending in a fovea, then continuing as a shallow groove to the hind supraorbital pore; antennae just reaching base of elytron.
- Prothorax moderately convex, sub-hexagonal, slightly wider than head and slightly wider than long, base gently arcuate, slightly narrower than apex, widest a little before middle, where the sides are obtusely angulate, front angles rounded, sides practically straight both in front of and behind the angle, sinuate at a sixth from and falling vertically on base, so that the hind angles are right and fairly sharp, a seta at the lateral angle but none visible at the basal angle; median line deep, basal foveae fairly deep, diverging in front and extending to the front margin on each side as a faint impressed line, lateral channels bounded inwardly by a fairly stout ridge; surface irregularly and finely punctate, nearly smooth on disk, basal area rather more coarsely punctate.
- Elytra rather flat, a little less than twice as wide as prothorax, nearly two-

thirds longer than wide, sides slightly dilated behind, basal border entire, forming a very obtuse angle opposite interval 5, margin faintly sinuate on each side before apex; striae moderately impressed and finely crenulate, a little deeper towards apex, scutellary striole long and rather deep, 1 and 2 arising in an umbilicate pore; intervals rather flat, more convex at sides and near apex, 8 and 9 narrower than the rest, 3 with three pores, the front one not far from base, adjoining stria 3, the second and third on the interval though nearer stria 2 than stria 3, at three-fifths and five-sixths respectively, 5 with a single pore near stria 5 at about three-fourths. Microsculpture visible throughout, but distinct on the apical half only.

- Sternum: prosternum coarsely and to some extent confluently punctate; metasternum with a few punctures at sides.
- Legs: claws with a projecting tooth at middle.
- Length, 8-9 mm.

18. *Hexagonia longithorax*, Wied.

Diagnostic characters

- Colour black, shiny; buccal organs and legs darker or lighter ferruginous; antennae, metasternum, and venter brown or piceous.
- Head pentagonal, longer than wide; frontal impressions wide and shallow, bounded on each side externally by a slight ridge, reaching mid-eye level, a few fine punctures within them behind; genae half as long again as eyes, curving backwards less; the fovea behind the eye connected as in that species, with the postorbital pore; antennae extending a little beyond base of elytra.
- Prothorax moderately convex, sub-hexagonal, barely wider than head and only slightly wider than long, widest a little before middle, base truncate, sides obtusely angulate at the widest point, in front of which they curve round to neck, the front angles almost rounded away, straight behind to a sixth from base, thence sinuate and falling vertically on base, the hind angles right and sharp, a seta on each side at the lateral angle, but none visible behind; median line deep, basal foveae deep, diverging in front, but hardly extending forward beyond middle; lateral channels bounded at least at middle by an inner ridge; surface with some fine cross-striation, basal

area and lateral channels behind finely punctate.

- Elytra rather flat, twice as wide as prothorax, a little over a half longer than wide, slightly dilated behind; basal border entire, forming an obtuse angle opposite stria 4, margin faintly sinuate on each side before apex; striae deep and clearly punctate, at least on basal half, a slight umbilicate pore sometimes visible at the origin of 1 and 2, scutellary striole moderately developed; intervals moderately convex, 7 to 9 narrower than the inner intervals; dorsal pores on 3 and 5 and microsculpture.
- Legs: claws with a projecting tooth.
- Length, 8-10.5 mm.

19. *Hexagonia uninotata*

Diagnostic characters

- Colour pale ferruginous, shiny; joints 1 to 3 of antennae (rest fuscous), head, and prothorax dark ferruginous or brown, a common, oval, piceous spot on the apical half of the elytra, extending forward to middle and outwards on each side to stria 4 or stria 5.
- Head pentagonal; frontal impressions, genae hardly longer than eyes, which do not project laterally far beyond them, curving backwards nearly uniformly to neck; a moderately deep groove (viewed from above) on each side between the fovea and the post orbital pore; antennae just reaching the base of elytra.
- Prothorax convex, cordate, as wide as head, slightly wider than long, widest at a fourth from apex, base arcuate, so that its sides are oblique close to the angles, front angles rounded away, sides rounded in front, then nearly straight to a point just before base, where there is a gentle sinuation, the hind angles slightly obtuse, but sharp, and projecting a little laterally, a seta on each side at the widest point, none behind; median line deep, basal foveae short and not very deep; surface punctate along all the margins, in the foveae, along the median line, and on each side of disk in front.
- Elytra rather flat, a little more than a half wider than prothorax, more than twice as long as wide, sides nearly parallel, basal border angulate over stria 5, terminating at stria 3, and thence replaced by a slight ridge; striae,

only moderately impressed, finely punctate, 1, 2, and the short scutellary striole arising in an umbilicate pore behind the basal ridge; intervals slightly convex, 8 and 9 narrower than the rest, dorsal pores. Microsculpture of the elytra slight, hardly forming meshes, even behind.

- Sternum: prosternum densely punctate; mesosternum, sides of metasternum, and metepisterna moderately punctate.
- Leg: claws normal, without projecting tooth.
- Length, 7.75-8.25 mm.

Key to the Indian species of genus *Axonya* Andrewes

1. Prothorax cordate, moderately contracted behind and slightly constricted, one marginal seta only at apical fourth

……… championi Andr.

20. *Axonya championi*, Andr.

Diagnostic characters

- Colour dark green, the elytra often metallic green at sides, surface shiny; underside black, venter piceous; joints 1 to 4 of the antennae (rest fuscous), palpi, labrum, and tarsi ferruginous, femora and tibiae flavous.
- Head moderately convex, frontal furrows bounded externally on each side by a slight ridge, between which and the eye there is a deep sulcus, clypeal suture distinct, ending on each side in a pore, middle of front and vertex smooth, the furrows and neck moderately punctate.
- Prothorax convex, hardly wider than head and very little wider than long, about equally contracted at extremities, sides of base oblique close to the angles, the front angles distinct and not much rounded, sides finely bordered, gently and evenly rounded to basal fifth, and there rather strongly sinuate so that the rectangular hind angles project a little laterally; median line fine, not reaching extremities, front transverse impression obsolete, hind one distinct but not deep, basal foveae just indicated on each side close to the sinuation, surface moderately punctate, chiefly on the basal area and along the margins, nearly impunctate on each side of disk.
- Elytra convex, with square shoulders and nearly parallel sides, three-

fourths wider than prothorax, quite a half longer than wide, widest a little behind middle; deeply punctate striate, the outer striae not quite reaching base, 9 punctate like the rest, without setae, all deeper near base than apex, intervals moderately convex. Microsculpture isodiametric, fairly distinct on the elytra, hardly visible on the head or prothorax.

- Length, 9.5-11 mm; width, 3.6-4 mm.

Key to the Indian species of genus *Perileptus* Schaum

1. Prothorax with its sides moderately dilated and rounded behind the front angles, elytra pale at the apex, striae 6 and 7 obsolete; microsculpture present on the elytra

……… ceylanicus Andr.

2. Eyes small, genae two thirds as long as eyes, elytra fully twice as long as wide, microsculpture present on the elytra

……… microps

3. Prothorax with its base two-thirds as wide as apex, a small but distinct carina in the hind angles, elytra with a dark patch at apical third, without microsculpture

……… cameroni Jeann.

21. *Perileptus ceylanicus*, Andr.

Diagnostic characters

- Colour ferruginous, head and underside a little darker, joints 3 to 11 of the antennae, brownish, lateral margins and suture of the elytra at least, to some extent fuscous. Pubescence sparse but not very short.
- Head large, with deep curved impunctate furrows; clypeus with a slight central tubercle labrum with a more conspicuous one; eyes large, genae very short, curving round sharply to the neck; antennae, a little dilated at apex, nearly reaching middle of elytra, surface with very scanty pubescence.
- Prothorax moderately convex, cordate barely wider than head, a fourth wider than long, base produced at middle, its sides both oblique and slightly emarginate, about a sixth narrower than apex, sides rounded in front, rather sharply sinuate close to base, the hind angles sharp, a little

acute, and projecting slightly laterally, with hardly a rudiment of a carina; median line moderately deep, the surface surrounding it usually depressed, transverse impressions slight, basal foveae small, surface finely and fairly closely punctate, basal area sub-rugose.

- Elytra flat, with nearly parallel sides, slightly compressed behind shoulders a fourth wider than prothorax, nearly three-fourths longer than wide; striae finely punctate, shallow, 1 deeper behind, 2 to 5 distinct on disk, disappearing before apex, outer striae, obsolete, intervals slightly convex, 1 raised behind, dorsal pores distinct, surface finely and not very closely punctate.
- Length, 2.5-3.2 mm.

22. *Perileptus microps*

Diagnostic characters

- Colour ferruginous, lateral borders of prothorax and elytra piceous. Pubescence short and rather scanty.
- Head large, with deep curved impunctate furrows, surface sub-rugose at sides; clypeus and labrum each with a fairly conspicuous tubercle; eyes moderately prominent but rather small, the genae consequently more conspicuous than usual, convex, and about two thirds as long as eyes; antennae stout not quite reaching middle of elytra.
- Prothorax a little convex, cordate, just wider than head and also slightly wider than long, base somewhat arcuate, a fifth narrower than apex, sides gently rounded and sinuate near base, the hind angles sharp but somewhat obtuse, not projecting laterally, and without carina; median line moderately wide and deep, a small rounded impression at middle on each side of it, the other impressions slight, disk moderately punctate, base rugose-punctate along the margin.
- Elytra long and flat, with square shoulders and nearly parallel sides, a fourth wider than prothorax, quite twice as long as wide; striae 1 to 5 lightly impressed and finely punctate, 6 to 8 obsolete, 1 only reaching apex and becoming obsolete before reaching base, intervals rather flat, dorsal pores visible though inconspicuous, surface finely and sparsely punctate.
- Length, 3.6 mm.

23. *Perileptus cameroni*, Jeann.

Diagnostic characters

- Colour light ferruginous, the elytra each with a vague dark patch at apical third, apical fourth of elytra and legs flavous, the border of both prothorax and elytra darker. Pubescence pale, formed by rather long hairs, scanty on the head and prothorax, arranged on the elytra in single lines, inclined backwards down the middle of each interval.
- Head fairly large, almost impunctate, the furrows deep and sub-angulate at mid-eye level; clypeus and labrum without tubercle; eyes large and prominent, genae very short, oblique; antennae stout, moniliform, dilated towards apex, reaching basal fourth of elytra.
- Prothorax convex, cordate, about sixth wider than head and as much wider than long, base truncate, about two-thirds as wide as apex, sides strongly rounded in front, sinuate a little before base, the hind angles sharp but slightly obtuse, not projecting laterally, and with a small but evident carina at right angles to the base; median line deep, widening behind, base depressed, coarsely rugose-punctate, disk rather sparsely punctate, with punctures of unequal size.
- Elytra convex, oval, slightly compressed at middle, a fourth wider than prothorax, three-fifths longer than wide; striae lightly impressed but clearly punctate, 1 only entire and nearer the suture at extremities than at middle, the outer striae indicated mainly by irregular punctures; intervals faintly convex, dorsal pores hardly distinguishable from the punctures in stria 3. No appreciable microsculpture.
- Length, 2.45 mm.

Key to the Indian species of genus *Neoblemus* Jeannel

1. Genae only slightly convex, shorter than eyes; elytra brown red with dark apex, the puncturation on the striae distinct; protibiae with a deep external groove

   ………. championi Jeann.

   Genae very convex, longer than eyes; elytra ferruginous, the puncturation on the striae indistinct; protibiae with a shallow external groove

   ………. andrewesi Jeann.

24. *Neoblemus championi*, Jeann.

Diagnostic characters

- Colour reddish brown; metasternum, sides of head, sometimes disk of prothorax, margins, suture, and apical third of elytra piceous; legs and apical border of elytra ferruginous.
- Head wide, eyes large and prominent, genae shorter than eyes, slightly convex, contracting rapidly to the neck constriction, neck and convex area between the sulci impunctate, smooth, and shiny, the latter triangular, the apex of the triangle in front just reaching the clypeal suture, the genae and clypeus covered rather sparsely with long hairs, very long behind, directed mainly inwards, labrum with a slight tubercle at middle.
- Prothorax: cordate, slightly convex, as wide as head, a third wider than long, apex a third wider than base, sides reflexed, rounded in front and sinuate at about a fifth from base, the hind angles somewhat acute, sharp, projecting laterally, but not reflexed; median line deep and wide but contracting at extremities, basal area rather coarsely rugose-punctate.
- Elytra flat, with parallel sides, a third wider than prothorax, two-thirds longer than wide; punctate-striate, the four inner striae moderately impressed on disk but not quite reaching base, 5 visible, the outer striae, obsolete, 1 reaching apex, 2 to 4 disappearing before apex; intervals a little convex on disk only, dorsal pores on stria 3, placed not far from base, and just behind middle, surface shortly pubescent and finely punctate, the punctures smaller than those in the striae.
- Legs: protibiae with a deep external groove.
- Length, 3.8-4.2 mm.

25. *Neoblemus andrewesi*, Jeann.

Diagnostic characters

- Head large; eyes rather small but moderately prominent; genae convex, rather longer than eyes, sulci not quite deep as in *championi*, the apex of the convex area on front not quite reaching the clypeal suture, the whole surface except the sulci sparsely punctate and pubescent, but less conspicuously than in *championi*; labrum without tubercle.
- Prothorax cordate and slightly convex, a little wider than head and a third

wider than long, very similar to that of, but the lateral margins are less reflexed, the median line is rather shallower, the transverse impressions are more evident, and the basal area is less coarsely rugose-punctate.

- Elytra flat, with nearly parallel sides, a third wider than prothorax and fully three-fourths longer than wide; striation and surface as in *championi*, but the puncturation of the striae is very indistinct.
- Legs: protibiae with a shallow external groove.
- Length, 3.8-4.6 mm.

Key to the Indian species of genus *Trechus* Schellenberg

1. Colour brown or piceous, sometimes slightly iridescent
……… indicus, Putz.

26. *Trechus indicus*, Putz.

Diagnostic characters

- Colour brown or piceous, shiny, and slightly iridescent, the lateral margins of the prothorax and elytra generally a little paler than the disk; palpi, joint 1 of antennae, and legs more or less flavous. Body winged.
- Head with deep furrows, converging to mid-eye level, where they are obtusely angulate, and thence curving round on each side behind eyes, eyes fairly large and convex; genae very small; antennae reaching basal third of elytra, slightly dilated and, sub-moniliform towards apex, the joints approximately equal, except 3 and 11, which are little longer than the rest; tooth of mentum slightly sulcate, but not bifid.
- Prothorax sub-quadrate, moderately convex, about a third wider than head and a half wider than long, base truncate, a little wider than apex, produced a little backwards at middle, sides rounded from apex to base, reflexed, narrowly in front, more widely behind, the hind angles right and sharp, projecting on each side as a minute tooth; median line fairly deep, basal sulcus deep, with three pores at middle (not always well defined), the foveae, moderately deep, diverging in front.
- Elytra sub-oval, convex, nearly three fifths wider than prothorax, rather less than a half longer than wide, shoulders well marked, sides nearly parallel but widest a little behind middle; striae entire, indistinctly punctate,

1 to 4 moderately impressed, 5 and 6 rather faint, 7 just visible, recurrent striole straight, fairly long and deep, ending opposite stria 6; intervals moderately convex on disk, dorsal pores adjoining stria 3, at about a fifth and just behind a half respectively. Microsculpture of the elytra formed by extremely fine, barely visible, transverse lines; on the prothorax very wide meshes are just visible; on the head the meshes are isodiametric but very faint. The species is a very variable one both in form and colour.

- Length, 4-5 mm.

Key to the Indian species of genus *Agonotrechus* Jeannel

1. Eyes moderately prominent, labrum emarginate in front. Length 5-8 mm
………. iris

27. *Agonotrechus iris*

Diagnostic characters

- Colour of the underside brown, the upper surface piceous black and a little more iridescent; palpi and joints 1 to 3 of the antennae ferruginous; lateral margins of the prothorax (vaguely), lateral margins and suture of the elytra, rest of antennae, and legs dark ferruginous.
- Head forms a shallow groove instead of a fine line where they curve round on each side behind; the front of the labrum is emarginate instead of bisinuate; the eyes are moderately prominent; joint 3 of the antennae half longer than 2.
- Prothorax nearly similar in form, but two-fifths wider than head and a third wider than long, base about a third wider than apex; the impressions are all a little deeper but of the same form.
- Elytra a little wider, three-fifths wider than prothorax, but a little less than a half longer than wide, the striae hardly differing in depth but a little more conspicuously punctate.
- Length, 5.8 mm.

Key to the Indian species of genus *Asaphidion* Des Gozis

1. Head not longitudinally striate; elytra three fourths longer than wide; the surface nearly even, colour aeneous. Length 4 mm

………. indicum Chaud.

28. *Asaphidion indicum*, Chaud.

Diagnostic characters

- Colour of the upper surface aeneous, with traces here and there of green and blue, vaguely purplish on the basal half of the elytra, with a short inconspicuous grey pubescence underside black with faint green reflections; joints 1 to 4 of antennae, (rest brown), palpi, and legs ferruginous, apex of femora, of tibiae and of the tarsal joints often infuscate.
- Head nearly a fifth wider than prothorax; the surface strigose-punctate, neck very finely so; antennae rather slender, joint 2 very little shorter than 3.
- Prothorax convex, a sixth wider than long, base slightly produced at middle, oblique, close to the angles, distinctly narrower than apex, sides obtusely angulate, hind angles slightly obtuse, not projecting, without seta; median line very fine, sub-foveate at the point, where it joins the shallow front transverse impression, base compressed, almost constricted, a slight fovea on each side, surface closely reticulate-punctate.
- Elytra elongate-oval, a half wider than prothorax, quite three-fourths longer than wide, shoulders very square, border slightly sinuate on each side before apex; striation only vaguely defined, suture a little raised behind, surface nearly even, a little impressed between the dorsal pores, which are placed at a fourth and three-fifths respectively, apical pore indistinct, surface moderately and closely punctate, a little less closely towards apex, without any smooth areas at sides, the pubescence inconspicuous, hardly forming any distinct patches. The microsculpture, where visible between the punctures on the elytra, consists of rather faint nearly isodiametric meshes. Sterna punctate and slightly pubescent; the striation on the first ventral segment is obsolete.
- Length, 4 mm.

Key to the Indian species of genus *Bembidion* Latreille

1. Elytra pale at extreme apex only, femora dark; elytral striae visible to apex;

meshes of the microsculpture irregular, on average only a little wider than long. Length 4.5-5.5 mm

………. xanthacrum Chaud.

2. Head coarsely punctate except along median line; frontal furrows parallel but short and shallow; prothorax without carina in the hind angles; microsculpture isodiametric; colour aeneous or cupreous

………. compactum Andr.

3. Venter with some slight scattered pubescence; elytral striae entire

………. kara Andr.

29. *Bembidion xanthacrum*, Chaud.

Diagnostic characters

- Colour bronze-green above, piceous beneath, apex of venter ferruginous; palpi, joints 1 to 3 of antennae, with basal half of joint 4, base and apex of femora, tibiae, tarsi, and apex of elytra covering from a sixth to an eighth of their length, flavous; rest of femora and extreme apex of tibia and tarsal joints piceous.
- Head with short shallow furrows, a slight longitudinal engraved line at each end of the clypeal suture; eyes large and moderately prominent; antennae filiform, reaching basal fifth of elytra.
- Prothorax moderately convex sub-quadrate contracted more in front than behind, two-fifths wider than head three-fifths wider than long, base bisinuate front angles projecting forward, sides nearly straight in front and behind, rounded (sometimes sub-angulate) at about middle, sinuate quite close to base, hind angles sharply rectangular, with a very slight carina; median line slight, basal sulcus moderately deep between the short fovea, the base bordered on each side between the fovea and the angle, surface smooth, basal area somewhat uneven.
- Elytra moderately convex, oval, a sixth wider than prothorax, nearly two-thirds longer than wide, border serrate, making a sharp angle at shoulder and extending inwards to the base of stria 4; punctate-striate, the striae fine, the punctures very small, disappearing towards apex, 8 deep, joining the marginal channel behind shoulder, scutellary striole very fine, apical stria deep; intervals nearly flat, 3 with two pores adjoining stria 3, surface

smooth. Microsculpture isodiametric and coarsely engraved on the head; on the prothorax and elytra the meshes, which average about twice as wide as long, are more finely impressed, and the surface is shiny.

- Sternum: prosternal process coming to a sharp point; metasternal process unbordered.
- Length, 4.1;-5.25 mm.

30. *Bembidion compactum*, Andr.

Diagnostic characters

- Colour of the upper surface cupreous, sometimes brassy, and occasionally with purplish blotches, underside black; joints 1-2 of antennae, with the base of 3-4, palpi, and legs ferruginous, rest of antennae, penultimate joint of palpi, and knees fuscous.
- Head with shallow furrows, extending on to clypeus, which is bordered in front; eyes rather flat; antennae reaching basal fourth of elytra, surface punctate, sparsely on vertex, middle of front and neck smooth.
- Prothorax cordate, very convex, very little wider than head and barely a third wider than long, extremities truncate, sides of base slightly oblique, sides moderately rounded and sinuate close to the hind angles, which are right, though they project a little laterally, without trace of carina; median line fairly deep, confined to disk, base deeply depressed, almost constricted, foveae hardly distinguishable, the whole basal area coarsely rugose-punctate, occasionally with some punctures along front margin, surface otherwise smooth, with some vague cross-striation.
- Elytra convex, with very square shoulders, sides nearly parallel, the border rounding the shoulder and reaching a point between striae, 4 and 5, nearly twice as wide as prothorax and about a half longer than wide; stria closely and moderately punctate, all deep to apex, though 4-6 are a little fainter behind, scutellary striole very long, extending to quite a third from base, apical stria deep, forming an integral part of stria 7; intervals convex, especially at sides, 3 with two large pores at about a third and two-thirds, the surrounding area depressed near the front one, surface smooth and shiny. Microsculpture practically absent in the ♂ formed by isodiametric meshes and confined to the elytra in the ♀. Sterna coarsely punctate at

sides, metasternum with a few punctures at base and apex, metasternal process with a semi-circular border; ventral surface smooth and impunctate.

- Length, 4.25-4.75 mm.

31. *Bembidion kara*, Andr.

Diagnostic characters

- Colour black, very shiny, head and pro thorax with faint greenish reflections, elytra very dark blue, slightly iridescent; joint 1 of the antennae ferruginous, rest of antennae, palpi, and tarsi piceous.
- Head with deep, uneven, parallel furrows; eyes prominent; antennae, reaching basal fifth of elytra; surface smooth.
- Prothorax cordate, moderately convex, a little wider than head, a half wider than long, base wider than apex, sides rounded in front, and gently sinuate before base, hind angles slightly obtuse but very sharp, with only rudimentary carina; median line, hind transverse impression, and basal foveae all moderately deep, lateral border continued inwards on each side as far as the foveae, surface smooth, the basal area finely and rather vaguely rugose-punctate.
- Elytra rather flat, the shoulders square, sides parallel, three-fifths wider than prothorax and as much longer than wide, border rounding the shoulder and extending inwards to stria 5; fairly deeply punctate-striate throughout, the punctures very fine and disappearing towards apex, scutellary striole long, apical stria deep, joining 5; inner intervals flat, outer ones a little convex, 3 dorsal pores, at a fourth, a half, and three-fourths respectively, adjoining stria 3. Microsculpture formed by very fine, closely placed, transverse lines, visible only wider the microscope.
- Sternum: metasternum with a few punctures in front and behind, sparsely pilose; metasternal process bordered at sides only. Venter sparsely pilose.
- Length, 5-6-25 mm.

Key to the Indian species of genus *Tachys* Stephens

1. Elytra more than a half longer than wide, the border and the suture more or less brown; striae 1 to 3 moderately impressed, the other striae mostly

visible

………. cardoni Andr.

2. Elytra with a distinct apical striole; colour mainly flavous

………. ochrias Andr.

3. Striae 3 faint, visible only in the dorsal pores; elytra black, each with a small apical reddish spot

………. vagabundus

4. Elytra without spots. Length 2.5 mm

………. babulti Andr.

Elytra each with two large pale spots. Length 3 mm

………. championi Andr.

32. *Tachys cardoni*, Andr.

Diagnostic characters

- Colour ferruginous, the head hardly darker, border of the prothorax and border and suture of the elytra brownish.
- Head with long, fairly deep, simple furrows, diverging behind; eyes rather flat; antennae slender, filiform, joint 2 longer than 3.
- Prothorax convex, cordate, nearly a half wider than long, base with its sides very slightly oblique a little wider than apex, sides rounded and sinuate a little before the hind angles, which are right and somewhat reflexed; without any appreciable carina; basal sulcus minutely crenulate, slightly interrupted by the median line, the area behind the sulcus longitudinally striate.
- Elytra moderately flat, elongate, sides nearly parallel, not very much wider than prothorax, but more than a half longer than wide, border minutely setulose, rounded at shoulder and extending inwards to rather beyond the base of stria 4; striae 1 to 3 moderately impressed and crenulate, 4 to 7 more or less obsolete, though 4 and 5 are quite visible near base, and 7 behind, 1 entire, the rest evanescent behind, 2 deep near apex, 8 deep behind, wanting at middle, represented by large pores in front, striole long, curved, hooked in front, on the middle of the elytron, its pore near apex; front dorsal pore on the middle of interval 6 at a fourth from base, hind one in the hook of the striole. Microsculpture of the prothorax and elytra

consisting of very fine transverse lines; that of the head reticulate and very distinct, the meshes slightly transverse.

- Last ventral segment ♀ minutely setulose, the inner pores far removed from the margin.
- Length, 3-3.4 mm.

33. *Tachys ochrias*, Andr.

Diagnostic characters

- Colour pale ferruginous, head rather darker, prothorax lighter than elytra; as the elytra are translucent, some vague dark markings are often seen through them, the border and suture being generally darker.
- Head wide, with short, wide furrows, diverging a little behind; mentum with two pores; eyes small and not prominent, setulose; antennae short, moniliform joint 2 much longer than 3.
- Prothorax slightly convex, transverse, base with its side very oblique close to hind angles, sides rounded and gently sinuate before base, the angles reflexed and obtuse, without carina; median line very faint, basal foveae shallow, the sulcus deep, without any crenulations, its sides running forward to form an obtuse angle at middle.
- Elytra depressed, slightly truncate at apex, quite a third wider than prothorax, border minutely dentate and setose, forming a very wide angle at shoulder and extending inwards for some little distance beyond hind angles of prothorax; stria 1 vaguely crenulate, lightly impressed, and not reaching base, 8 traceable only by its large punctures, surface otherwise smooth, but with vague indications of punctures by means of which most of the other striae, can be traced, apical striole short but distinct, curved, on middle of elytron, the pore far back near apex; dorsal pores small but clear, on stria 3, at two fifths and three quarters. Microsculpture formed by very fine transverse lines on the elytra, obsolete on the head and prothorax. Body beneath minutely and sparsely setose, prosternum faintly depressed, metasternal process very indistinctly bordered protarsi ♂ with hardly dilated joints.
- Length, 1.8 mm.

34. *Tachys vagabundus*

Diagnostic characters

- Colour piceous; palpi, antennae, and legs; pale ferruginous; femora a little darker, elytra each with a small apical reddish spot, occasionally wanting.
- Head with short, parallel, duplicated furrows; mentum without pores: eyes not very prominent; antennae: filiform, joints 2 and 3 equal.
- Prothorax convex, cordate a half wider than head and as much wider than long, base much wider than apex, sides well rounded in front and gently sinuate before base, with a fairly wide marginal channel, hind angle right sharp and with a short but distinct carina; median line tine in front, deeper behind, where it forms more or less of a pore, separating the two parts of the basal sulcus, which is fairly deep, not crenulate, basal foveae deep, adjoining the angles.
- Elytra convex, oval, the border smooth, forming an indistinct angle at shoulder and extending inwards and a little backwards beyond the hind angles of the prothorax; two fairly deep indistinctly crenulate striae, 1 reaching apex, but when viewed from above terminating before base, though viewed sideways it can be traced to base, 2 extending beyond the dorsal pores in both directions, 3 just visible between the dorsal pores, 8 deep throughout, striole short but deep, nearly straight, on middle of elytron, the pore half way along it; dorsal pores small, on the site of stria 3, at about a third and three fifths. No microsculpture. Prosternum sulcate; metasternum with an arcuate groove in front.
- Length, 2.6 mm.

35. *Tachys babulti*, Andr.

Diagnostic characters

- Colour bronze-black, iridescent; joints 1 to 3 of antennae (rest brown), and legs ferruginous.
- Head with the frontal furrows short and not very deep, hardly duplicated; mentum without pores; eyes moderately prominent; antennae filiform, joints 2 and 3 equal.
- Prothorax convex, a little more than a third wider than long, base a trifle wider than apex, sides evenly rounded, sinuate just in front of hind angles,

which are sharp and rectangular, with a short carina: median line fine but visible, basal sulcus fairly deep, finely (crenulate, interrupted, and with a rather shallow pore at middle.

- Elytra moderately convex border smooth, extending inwards rather beyond hind angles of prothorax; two dorsal stria; finely crenulate and disappearing very gradually in front, 1 reaching apex but not quite reaching base 2 extending well beyond dorsal pores and nearly as long as 1 in front, 3 and even 4 visible but hardly impressed, 8 deep throughout, striole on middle of elytron, the pore half-way along it; dorsal pores distinct, on stria 3, at a third and three fifths. The fine transverse lines of the microsculpture are just visible on prothorax and elytra more visible on the back of the head, while on the front there is a distinct, if fine, isodiametric reticulation metasternal process with a rather shallow arcuate groove.
- Length, 2.5 mm.

36. *Tachys championi*, Andr.

Diagnostic characters

- Colour black, iridescent, without any aeneous tinge; joints 1 to 4 of antennae (rest brown), palpi, legs, and two fairly large spots on each elytron ferruginous, underside piceous red.
- Head with the inner furrows short and straight, the outer ones obsolete; mentum without pores, eyes moderately prominent; antennae short, joints 2 and 3 equal.
- Prothorax moderately convex, transverse, base a little wider than apex, sides rather gently rounded, sinuate not far from base, hind angles right, with a small carina; basal sulcus not very deep, distinctly though finely crenulate, interrupted and with a pore at middle.
- Elytra moderately convex, with a smooth border, rounded at shoulder; two finely crenulate dorsal striae, not deeply impressed or ending abruptly, 1 reaching apex but not base, 2 extending beyond dorsal pores, 3 just visible on middle of disk, 8 deep throughout, striole slightly curved, on middle of elytron, the pore half-way along it; dorsal pores small but distinct, at a third and two-thirds, on stria 3. Microsculpture hardly

Species account of ground beetles (Carabidae) from Simbalbara WLS

Nebria cameroni

Siagona pumila

Scarites inconspicuus

Scarites dubiosus

Scapterus guerini

Sparostes striatulus

Coryza maculata

Clivina westwoodi

Clivina extensicollis

Hexagonia terminata

Hexagonia longithorax

Axonya championi

Perileptus ceylanicus

Neoblemus championi

Neoblemus andrewesi

Agonotrechus iris

Plate 8

Asaphidion indicum

Bembidion xanthacrum

Bembidion compactum

Bembidion kara

Tachys cardoni

Tachys vagabundus

Tachys babulti

Tachys championi

Plate 8

appreciable on the prothorax and elytra; visible but faint on the head, the meshes isodiametric.

- Prosternum sulcate; metasternum with an arcuate groove in front; protarsi with two very slightly dilated joints in ♂.
- Length, 2.75-3.25 mm.

II. Coleoptera: Cicindelidae (Tiger beetles) (Plate 11 to 13)

Identifying characteristics for the family Cicindelidae include:

- First abdominal sternite *divided* by hind coxae (sub-order Adephaga).
- Prominent eyes such that head is *as wide as or wider* than pronotum.
- Pronotum *narrower* than elytra.
- Antennae filiform and inserted *above* base of mandibles.
- Often patterned on elytra, or blue or metallic green.
- Tarsi 5-5-5.
- Many tiger beetles are active, usually brightly coloured found in open sunny situations, often common on sandy beaches. They can run or fly rapidly and are very difficult and wary and difficult to approach. They take flight very quickly, sometimes after running a few feet, and usually alight some distance away from facing the pursuer. They are predaceous and feed on a variety of small insects, which they capture with their long sickle-like mandibles. When handled, they can sometimes administer a painful bite.
- The larvae are equally predaceous and live in vertical burrows in soil in dry paths or fields or in sandy beaches.
- Over 2,300 species worldwide, 208 species in India (Gupta 2004).

Key to the Indian species of genus *Neocollyris* Horn

1. Posterior tibiae dark

    a. Pronotum strongly dilated before the basal constriction

    ………. bonelli Guérin

    b. Pronotum cylindrical, without well developed collum

    ………. saphyrina Chaud

1*. Neocollyris bonellii*, **Guérin**

Diagnostic characters

- Head is blue green, bright greenish or bluish-green colour, more of less coppery, narrow slightly impressed between eyes; antennae are long and slender, very slightly thickened, with the four basal joints deep blue and eyes are only moderately prominent.
- Pronotum is bluish green, elongate, slender, much constricted before base, elongate conical, with the pronotal collum almost or quite merged into the posterior portion.
- Elytra is bluish, long, narrow, parallel-sided, with the shoulders oblique, distinctly, closely, and regularly punctured, the punctures becoming finer at the apex which is dentate and somewhat excised near the suture.
- Legs with coxae blue-green with their apices black. Femora and trochanters are brick red coloured.
- In males, head is more ovate than in the female, the antennae longer, and the pronotum longer and more slender in front.
- Length, 8.8-13 mm.

2*. Neocollyris saphyrina*, **Chaudoir**

Diagnostic characters

- It is of the same sub-genus as *N. bonellii* in overall form but differs in having five intermediate teeth of the labrum strong and blunt.
- Head is bluish, a little longer, with the sides less rounded behind the eyes.
- Pronotum is short, bluish, elongate, slender, constricted before base as in *N. bonellii*; antennae variable in colour, terminal joints indistinctly dark at the apex.
- Elytra are more elongate, with the shoulders more obsolete, and the whole upper surface more finely and closely punctured.
- Legs with coxae blue-green and their apices are black, with black trochanters and femora brick red coloured.
- Length, 13.5-17 mm.

Key to the Indian species of sub-genus *Spilodia* Rivalier

1. Pronotum covered with whitish setae only along lateral margins, fore and

mid-trochanters each with a sub-apical seta.

a. Elytra somewhat velvety, impunctate; genae moderately setose, aedeagus with flagellum coiled only two times

……… striolata Illiger

2. Proepisterna and metepisterna densely setose, setae covering most of the surface

……… multiguttata Dejean

3. Genae glabrous, elytral markings with humeral band short, not extended near to middle band which extends up to one fourth from apex; aedeagus very broad in middle, female with apical emargination of eighth sternite broad

……… parvimaculata Fowler

3. *Lophyra (Spilodia) striolata*, Illiger

Diagnostic characters

- Head is coppery, with greenish reflection, blue and green behind eyes laterally, slightly raised in middle between eyes; antennae with four basal segments metallic rest blackish and dull.
- Pronotum is with a more or less distinct coppery reflections, with the sides bright green and coppery, and with two short blue lines between the eyes, about as long as broad, with the sides more or less rounded with distinct short and scanty setae at the sides.
- Elytra with sides sub-parallel, velvety black, with a basal spot, two juxta-sutural spots, a discal spot joined to a sub-marginal spot by a narrow line, and a sub-apical, usually interrupted lunule [extending up to middle band].
- Legs and underside metallic, coppery green and cyaneous.
- Length, 10-15 mm.

4. *Lophyra (Spilodia) multiguttata*, Dejean

Diagnostic characters

- Head coppery and greenish, bluish laterally behind eyes, with two dark blue and green stripes between eyes in front, head less widened and flat between eyes; surface of head deeply striated longitudinally on occipital declivity, finely so in front, finely rugose at other areas, glabrous.

- Antennae with four basal segments metallic greenish, rest dark, scape with one stout pre-apical seta and general decumbent white setae. Genae sparsely setose. Eyes prominent.
- Pronotum coppery, sometimes with greenish reflection, blue and green laterally, blue along impressions; pronotum quadrate with sides slightly rounded, slightly narrowed in front, with impressions moderately marked, central lineless marked; surface of pronotum finely rugose, moderately densely covered with white decumbent setae laterally and along anterior margin with few setae on both sides of central line.
- Elytra elongate with sides sub-parallel, with surface closely and shallowly punctate, apical margin with finer micro serrulations, apex evenly and jointly rounded in male and separately rounded in female, sutural spine minute; elytra dark, dull blue-green with whitish testaceous markings, each with a basal spot, a humeral lunule which extends up to one fourth from base medially on disc, with middle spot joined narrowly to a sub-sutural spot at three-fourth from base, apical lunule fragmented into two spots, two elongate sub-sutural spots on basal half.
- Abdominal sternites dark blue, greenish laterally; densely setose laterally with last visible segment glabrous in male. Male genitalia with aedeagus narrow and curved near base, widened up to apical one-fourth, then abruptly narrowed to form a long apical portion apex broad and rounded, ventral side convex from behind base to three-fourth from base, side dorsal rounded; parameres extending beyond middle of aedeagus endophallus with central plate almost without tooth portion two groups of large pointed tubercles covering most of the endophallus near apex of flagellum. Female genitalia with apical margin of eighth sternite moderately deeply emarginate forming a V-shape, each emargination with two minute apical setae; coxites long and narrow with few setae near apex on inner margin; styli short, blunt, slightly curved; paraproct and proctigers jointly rounded at apex, proctigers gradually curved on apical half and evenly broad throughout.
- Length, 12-12.4 mm; width, 3.3-3.8 mm

5*. Lophyra (Spilodia) parvimaculata*, **Fowler**

Diagnostic characters

- Head coppery, with two broad blue-green stripes extended front and approximating in middle between eyes, blue-green in laterally behind eyes and along posterior margin, slightly raised in middle between eyes; deep and longitudinal striations on occipital declivity, surface of head with moderately finely striated in front and in middle between eyes; with transverse fine wavy striations behind eyes, almost smooth at some places, glabrous. Labrum testaceous with margins dark in male, dark testaceous to blackish in female, moderately long, strongly and broadly carinate in middle, with three minute teeth on its anterior margin, its surface with six sub-marginal setae.
- Antennae with four basal segments metallic greenish and violaceous rest pitchy, scape with one pre-apical seta, fourth antennal segment in male with a penicillum of dark brownish clubbed bristles. Genae blue-green, glabrous. Eyes prominent, moderately bulging.
- Pronotum coppery with greenish reflection blue and green laterally and, along impressions and central line quadrate, slightly rounded at sides, narrowed near base moderately constricted before apex, with basal impression moderately marked, anterior impression and central line less marked; pronotal surface almost smooth, only very finely strigose covered with white setae along lateral and anterior margins with few setae on disc. Thoracic sterna and pleura metallic blue-green with proepisterna violaceous, mesepisterna and metepisterna golden-green and blue, with setae white and decumbent, prosternum setose on posterior lateral corners, proepisterna and proepimera sparsely setose near inner-margins, mesosternum glabrous, mesepisterna sparsely setose on inner half near anterior and posterior margins, metasternum (moderately densely setose laterally, metepisterna sparsely setose on anterior-half and near posterior margin.
- Legs with trochanters glabrous and non-metallic pitchy, femora metallic coppery and green with apices violaceous tibiae and tarsi bluish-green.
- Elytra slightly rounded at sides, evenly and shallowly punctate its apical margin with very fine micro serrulations, apex conjointly rounded which is

more so in male than in female, sutural spine minute; elytra dark-greenish with coppery reflection, with punctures blue, markings white, each elytron-on with an elongate basal spot, two small sub-sutural spots on basal half, a complete humeral lunule extending up to one fourth from base, middle band extending behind obliquely into a narrow hooked line, apical lunule fragmented into two spots. Abdominal sternites greenish to deep blue, more or less densely setose later-ally except apical segment and with fine setae in middle.

- Male genitalia with aedeagus narrow at base, gradually widened and curved up to basal one-fourth, of broad for most apical portion, ventral narrowed posteriorly to form a short broadly rounded side slightly convex behind middle, the part dorsal side much rounded; parameres extending up to two-third from base; endophallus with central plate well developed with large its tooth portion strongly sclerotized and forming near tooth of broad and curved spine like structure, tubercles slightly large central plate. Female genitalia with apical margin of eighth sternite moderately deeply emargination with two apical setae; setae inner margin, coxites moderately notched and with few long and on paraproct and proctigers gradually curved before apex.
- Length, 13.0 mm, breadth, 4.4 mm.

Key to the Indian species of sub-genus *Chaetodera* Acciavatti and Pearson

1. Pronotum sparsely setose, with few lateral setae invading the disc. Male genitalia with flagellum longer than half of aedeagus coiled anti-clockwise forming a small coil at its base and a slightly longer coil behind it.

   ………. vigintiguttata Acciavatti and Pearson

6*. Cicindela (Chaetodera) vigintiguttata*, Acciavatti and Pearson

Diagnostic characters

- Head blackish with greenish and coppery reflection, green and bluish in front, bright coppery along eyes, sometimes with two blue-green stripes between eyes in front, slightly raised in middle between eyes; surface of head very finely strigose between eyes, in front and laterally behind eyes, rugulose in middle behind eyes, with a tuft of white decumbent setae above antennal insertion; labrum testaceous with margins blackish in male, dark testaceous to blackish in female, with one long median tooth and two minute teeth on its anterior margin, its surface with six to eight sub-marginal.

- Antennae with four basal segments metallic greenish cyaneous, fifth joint fuscous, rest blackish, scape with two stout pre-apical setae, fourth antennal segment with a penicillum of stiff bristles in male. Genae blue and green covered with thick ventrally directed decumbent setae. Eyes prominent. Pronotum dark coppery with greenish reflection, bright green and blue laterally and along basal impression, sub-quadrate, with sides sub-parallel gradually narrowed near base and abruptly so near apex, with basal impressions moderately marked, anterior impression and central line less marked; pronotal surface very finely strigose along central line, finely rugulose at other places, covered with sparse appressed white setae laterally, with few such setae on disc. Thoracic sterna and pleura greenish and bluish, episterna greenish and purple, with setae white and appressed, with prosternum glabrous, proepisterna and proepimera densely setose on lower half mesosternum setose laterally and near coxal cavities, mesepisterna setose on lower one-fourth, mesepimera entirely setose metasternum densely setose laterally, metepisterna densely setose and with a large glabrous patch along inner margin. Legs mostly purple with trochanters metallic black and femora except apices of anterior and hind pairs green with coppery reflection.
- Elytra with sides sub-parallel, with surface somewhat velvety, very shallowly and sparsely punctate, almost smooth before apex; with apical margin moderately microserrulate, apex conjointly rounded which is more so in male than in female. Sutural spine minute; blackish with greenish and blue reflection, markings whitish, each elytron with an elongate and slightly arcuate basal spot, three sub-sutural spots a complete humeral lunule which extends up to one-fourth from base longitudinally elongate middle band not touching a discoidal spot behind it apical lunule which is fragmented into two spots.
- Abdominal sternites blue and green with apical segment dark blue,

densely covered with thick decumbent setae laterally except the apical segment in male genitalia with aedeagus narrow and slightly curved on basal one-third, straight and broad up to one-fifth from apex, narrowed to form a hooked and roundly pointed apex; parameres extending slightly beyond basal half of aedeagus; endophallus with arciform piece very strongly arcuate, central plate moderately developed, tubercles small. Female genitalia with apical margin of eighth sternite moderately deeply emarginate forming a V-shape with its base rounded, each emargination with five to six stout apical setae; coxites with few long setae on apical half of inner margin; styli pointed and strongly curved; proctigers strongly bent before apex densely setose on apical one-third, proctigers with few setae on disc in apical half.

- Length, 14-15 mm; breadth, 5-5.2 mm.

Key to the Indian species of genus *Jansenia* Chaudoir

1. Episterna more or less glabrous; metasternum covered with short setae and abdominal sternites glabrous; elytra with margins continuously bright blue green

……… chloropleura Chaudoir

2. Elytra less convex and much less narrowed towards base; only one row of small green spots near the suture

……… crassipalpis Horn

7. *Jansenia chloropleura*, Chaudoir

Diagnostic characters

- Head is predominantly coppery, with greenish reflection in front, green laterally behind the eyes, rather long, somewhat excavate and strongly striate between the eyes, which are moderately prominent; antennae with the first four basal segments black with greenish reflection, rest black.
- Pronotum is bright coppery, green and blue laterally, strongly rounded at base, constricted near apex and base.
- Elytra are dull coppery red or olivaceous with brilliant blue or green margins and suture, and with two white spots on each, just touching the marginal colour, one at middle and other at apex, surface with small moderately deep punctures.

- Legs are black, with coppery and greenish reflection, trochanters are red, and underside is brilliant green or deep blue with very little pubescence.
- Length, 10-12 mm.

8. ***Jansenia crassipalpis*, Horn**

Diagnostic characters

- Head is predominantly green and violaceous with vertical striations, greenish reflection in front, and metallic green laterally and behind the eyes; eyes are prominent with metallic blue tinge; antennae with the first four basal segments with metallic greenish blue reflection, rest maroon red.
- Pronotum is bright green and metallic blue laterally, strongly rounded at base, constricted near apex and base with very little setae.
- Elytra are with brilliant blue margins and suture; maculations include two yellow spots on shoulder, two minute red spots near the margin in the middle, and three big, conspicuous yellow spots at the margin on each elytron, the surface being uniformly pitted with moderately deep punctures.
- Legs are black, with blue-green reflections, trochanters are red, and underside is brilliant blue with very little pubescence.
- Length, 10-12 mm.

Key to the Indian species of genus *Calomera* Chaudoir

1. Head sparsely setose between the eyes; elytra always without white humeral spot and pre-apical marginal line

   ………. chloris Hope

2. Humeral lunule hooked at its apex; lateral margins of elytra not expanded laterally; fourth antennal segment with a penicillum of clubbed setae

   ………. plumigera macrograptina Acciavatti and Pearson

   Humeral lunule not hooked at its apex; lateral margins of elytra expanded laterally; fourth antennal segment without a penicillum of clubbed setae

   ………. angulata Fabricius

9*. Calomera chloris*, **Hope**

Diagnostic characters

- Head is greenish with coppery and bluish reflection, broad slightly raised in middle between eyes, surface is finely striated; antennae with four basal segments green with coppery reflection, rest black.
- Pronotum green, with the sides and depressions blue or violaceous, slightly transverse.
- Elytra green to bluish green with blue punctures, much broader than pronotum, dull, granulose, at the margin about the middle there are two white spots joined by a thin line, before the apex a more or less comma-shaped spot.
- Legs metallic, underside green and violaceous, with the whole of the sides of the abdomen, the episterna and the genae thickly clothed with long white coarse pubescence.
- Length, 11.5-12 mm.

10*. Calomera plumigera macrograptina*, Acciavatti and Pearson

Diagnostic characters

- Head is dark greenish and coppery, antennae black with four basal joints with purple reflection.
- Pronotum is contracted before the base with greenish central line and green punctures.
- Elytra are much broader than pronotum dark brown or olive green with elaborate or white testaceous markings. White colour extends from the shoulders to the apex, with an interruption before the apical lunate patch; there is a transverse extension towards suture, a large inverted V-or S-shaped patch at middle extending backwards.
- Legs are greenish and coppery with reddish trochanters.
- Length, 12.5-16 mm.

11*. Calomera angulata*, Fabricius

Diagnostic characters

- Head dull coppery, brilliant bright and greenish, broad and flat between eyes, glabrous, very finely striated longitudinally between eyes.

Pubescence coarser and thicker, hairs in front of the white labrum are also thicker, antennae black with four basal joints with blue or green reflection.

- Pronotum with colour similar to that of head, slightly rounded near apex, narrowed towards base, with impressions strongly marked, central line slightly marked. The margins of the elytra in the female are sometimes irregular and sinuate.
- Elytra with colour similar to head and pronotum, with greenish punctures and white markings, slightly widened in middle. White colour extends from the shoulders to the apex, with an interruption before the apical lunate patch; there is a transverse extension towards suture, a large inverted V- or S-shaped patch at middle extending backwards.
- Legs are greenish sometimes with coppery reflection.
- Length, 10.5-14 mm.

Key to the Indian species of genus *Calochroa* Hope

1. Each elytron with less than four yellowish spots or lines; fore and mid trochanters without sub-apical setae; female genitalia with 8th sternite bearing two to three stout setae on apex of each projection. Abdomen with apical segments reddish-orange

………. bicolor haemorrhoidalis Fabricius

2. Each elytron with more than four yellowish spots or lines much larger and rounder, covering a greater part of the elytra

………. flavomaculata Hope

12*. Calochroa bicolor*, Fabricius

Diagnostic characters

- Head is coppery and dark green, flat between eyes, front parts green, finely and rugosely sculptured; broad between the eyes; antennae metallic black with four basal segments greenish.
- Pronotum as long as head without the labrum with colour and sculpture similar to that of head, sides convex and narrow base.
- Elytra dark greenish, cyaneous or bluish with very fine sculpture, almost smooth and with two large yellow spots.
- Underside of the parts violaceous or partly green, abdomen dark, with the

apex and the side margins reddish.

- Legs metallic, episterna of metasterna bare with a tuft of white hairs at inner posterior corner.
- Length, 15-17 mm.

13*. Calochroa flavomaculata*, Hope

Diagnostic characters

- Moderate sized, dark velvety species, head and pronotum with very obscure metallic reflections, blue or green at the sides.
- Pronotum quadrangular, with the impressions and central line distinct, and with a bright metallic callosity at each end of the basal one.
- Elytra with the sides somewhat rounded, velvety with the sides and suture narrowly bright green or blue with three white or yellowish spots on each of about the same size, arranged in a line.
- Femora are metallic green or violet, tibiae and tarsi more or less pitchy; underside bright green or violaceous, sides of abdomen with scanty pubescence.
- Length, 13.5-16 mm.

Key to the Indian species of genus *Cosmodela* Rivalier

1. Pronotum covered with white setae along the entire lateral margin; metepisterna almost entirely covered with sparse white setae; each elytron with a median discoidal spot rarely joined narrowly to a lateral spot; eighth sternite in female with five stout setae on apex of each process
   ………. intermedia Chaudoir

14*. Cosmodela intermedia*, Chaudoir

Diagnostic characters

- Head greenish, coppery in middle, with two purple blue stripes in front of eyes, slightly raised in middle between eyes, glabrous; antennae with four basal segments greenish black and deep blue.
- Pronotum reddish coppery, with margins and impressions green and blue, with sides slightly rounded, narrowed towards base, with well marked impressions. Central line is moderately marked, rugose.

- Elytra much broader than the pronotum, with the sides being slightly rounded shoulders sub-rectangular, greenish and coppery. Each elytron has a white spot at the shoulder, and four others on each elytron, three in a longitudinal row near the margin (marginal spots), and a small one (humeral spot) just behind the middle one and near the suture.
- Underside shining green and deep blue, legs blue and black and trochanters are dark brownish-grey, femora metallic, tibiae and tarsi dark; genae with few white hairs.
- Length, 14-15 mm.

Key to the Indian species of sub-genus *Monelica* Rivalier

1. Pronotum with sculpture moderately rugose, its surface laterally covered with moderately dense setae

……… fastidiosa Dejean

15*. Cicindela (Monelica) fastidiosa*, Dejean

Diagnostic characters

- Head green and coppery slightly raised or entirely green slightly raised in middle between eyes; its surface glabrous, with moderately deep longitudinal striations on occipital declivity and fine striations in front, moderately rugose in middle and behind eyes. Labrum moderately fusco-testaceous with anterior margin dark, convex, with one or three teeth on anterior margin, middle tooth being prominent with four or five sub-marginal setae.
- Antennae with four basal segments greenish-black, sometimes partially or entirely fuscous; scape with one pre-apical seta. Genae glabrous strongly bulging. Pronotum coppery and green or entirely green sub-quadrate with sides slightly rounded, slightly narrowed at base with impressions well marked and central line slightly marked; pronotal surface moderately rugose, laterally covered with white setae. Thoracic sterna and pleura greenish and coppery or pitchy; prosternum covered with long white setae on outer-posterior corners, proepisterna and proepimera sparsely setose entirely, mesosternum setose laterally and along coxal cavities, mesepisterna setose on inner half along posterior margin, mesepimera

sparsely setose entirely, metasternum moderately densely setose laterally and along anterior margin, metepisterna less densely setose entirely.

- Legs reddish testaceous or partially or almost entirely greenish with trochanters reddish.
- Elytra slightly widened behind middle, with shoulders sub-rectangular, elytral surface less closely and shallowly punctate with few large deep punctures in middle near base; each elytron coppery-green or greenish with whitish markings which consist of a complete and often broad humeral lunule almost meeting a discoidal spot, a slightly sinuate middle band originating from abroad marginal line which almost meets humeral lunule in front and apical lunule behind, a small spot towards suture on disc behind middle band and a broadly complete lunule with a long narrow anterior extension; apical margin of elytra finely microserrulate, apex slightly separately rounded, sutural spine moderately prominent.
- Abdominal sternites greenish or fuscous laterally setose, sometimes almost entirely setose. Male genitalia with aedeagus slightly curved near base gradually widened up to middle then almost evenly broad up to just before apex where it abruptly narrows to a broad apex; parameres extending up to middle of aedeagus; endophallus with standard plates moderately developed with an additional small plate towards left side of arciform piece, tubercles fine. Female genitalia with apical margin of eighth sternite shallowly and broadly emarginate, each emargination with five to seven apical setae; styli pointed; paraproct and proctigers jointly rounded at apex.
- Length, 10-11 mm; breadth, 3.4-4.2 mm.

Key to the Indian species of genus *Myriochile* Motschulsky

1. Elytron without a humeral lunule

……… undulata Dejean

2. Pronotum sub-parallel; hind trochanters non-metallic testaceous

……… melencholica Fabricius

16. ***Myriochile undulata*****, Dejean**

Diagnostic characters

- Head is small, dull coppery with the apex and baso-lateral portions being bluish green and coppery, feebly striated between the eyes and with no setae; antennae with the first segment metallic rest are dull brown coloured.
- Pronotum is more or less with parallel sides and lateral margins with setae the lateral sides of apex are bluish green while rest of the pronotum is dull coppery coloured.
- Elytra are uniformly pitted expanded towards the base, the antero-lateral margins being bluish green while the rest of the elytra are dull coppery coloured. The markings include a crecentric-shaped patch running towards base, two prominent circular white spots near the base and the baso-lateral margins have the dull white marking running some way towards apex along the margins.
- Legs are with greenish trochanters, metallic, setose while rest of the segments is brownish, tarsi brown ending in two claws.
- Length, 10-11 mm.

17. ***Myriochile melencholica*****, Fabricius**

Diagnostic characters

- Head is green and coppery, slightly raised between eyes, its surface is glabrous; antennae with four basal segments greenish black.
- Pronotum is coppery and green, sub–quadrate with sides slightly rounded, and narrowed at base.
- Elytra are slightly widened behind middle, with shoulders sub-rectangular, surface with few large deep punctures in middle near base. Margin of elytra broad and unevenly whitish testaceous; at the shoulders there is a crescent, produced behind into a sharp point, which almost joins a spot on the disc. A narrow band starts from the centre of margin and is strongly hooked ceases at the middle of the disc. Below the apex of this and near the suture is a white spot, the apical margin is white and produced at its upper end.
- Legs are reddish-testaceous with reddish trochanters.

- Length, 10 mm.

Key to the Indian species of sub-genus *Eugrapha* Rivalier

1. Elytron with apex of humeral lunule hooked, middle band with its apical portion extended towards apex along suture

……… venosa Kollar

2. Elytron with humeral lunule joining a discal spot, anterior end of apical lunule dilated on disc

……… grammophora Chaudoir

18. *Cylindera (Eugrapha) venosa*, Kollar

Diagnostic characters

- Head greenish and coppery, broad and slightly raised between eyes, with a small depression on each side of raised area, its surface glabrous, very finely striated between eyes and in front.
- Antennae with four basal segments greenish, rest black. Its scape is with one stout pre-apical seta.
- Pronotum greenish and coppery, transverse with sides straight and parallel, its surface are with transverse striations along central line and almost smooth at other places, laterally covered with long white setae.
- Elytra slightly rounded at sides with shoulders slightly rounded, surface shallowly punctate with few basal punctures setigerous. Each elytron green and coppery with white maculation, which comprise of a complete white marginal line extending from shoulders to apex formed by fusion of a complete humeral and apical lunules and middle band.
- Abdominal sternites green, densely setose with glabrous areas in middle. Legs green with anterior and hind trochanters partially reddish.
- Length, 8-9 mm.

19. *Cylindera (Eugrapha) grammophora*, Chaudoir

Diagnostic characters

- Head is blue, green, coppery and black, flat between the eyes, surface with broad and deep striations; antennae with four basal segments greenish, rest black.

- Pronotum coppery, greenish laterally, with sides straight and parallel surface is rugose covered with few white setae laterally.
- Elytra is dull, dark usually with more or less distinct greenish reflections at base, with sides sub-parallel, shoulders sub-rectangular, surface shallowly punctuate. Margins are mostly white testaceous, being interrupted before the basal and apical markings the white markings consist of a large crescent-shaped spot at the shoulders, a central inverted V-shaped marking springing from the marginal patch, with the inner lines produced and dilated towards the suture.
- Legs metallic trochanters red, underside, head, and genae, thickly set with tomentose pubescence.
- Length, 8-8.5 mm.

Key to the Indian species of sub-genus *Ifasina* Jeannel

1. Elytron with apex of humeral lunule not hooked at the apex, apical lunule incomplete

……… erudita Wiedemann

2. Elytron with apical lunule not touching the discal spot, not dilated near the suture

……… bigemina Klug

3. Elytron with a distinct middle band; aedeagus distinctly curved before apex on ventral side

……… subtilesignata Mandl

Elytron without a distinct middle band; narrowly joined to a discal spot; aedeagus not curved before apex

……… spinolai Gestro

4. Elytron with a black longitudinal velvety patch, macular spots much reduced

……… viduata Fabricius

20*. Cylindera (Ifasina) erudita*, Wiedmann

Diagnostic characters

- Head coppery and golden in middle, green along eyes, and laterally behind them, with two purple stripes slightly raised in middle between eyes, glabrous with deep striations on occipital declivity. Labrum testaceous with anterior margin pitchy, short with a prominent acute median tooth on its with eight to eleven sub-marginal setae.

- Antennae with four basal segments greenish-black rest pitchy. Genae blue-green, Eyes prominent, strongly bulging laterally and moderately so dorsally. Pronotum coppery with impressions and lateral margins, green transverse with sides slightly rounded, narrowed at moderately marked and central line slightly marked, surface rugulose, densely covered laterally numerous thick short white setae. Thoracic sterna and, pleura green with episterna purple setae thick and white, prosternum glabrous, proepisterna densely setose on lover two third, proepimera densely setose, mesosternum glabrous, mesepisterna densely setose on lower half along posterior mesepimera densely setose, metasternum densely setose laterally, metepisterna more or less densely setose. Legs green and coppery with trochanters-reddish.
- Elytra with sides slightly rounded, shoulders sub-rectangular surface almost impunctate with few minute punctures on basal one-fourth few of these being setigerous, apical margin finely microserrulate, apex much separately rounded in both sexes, sutural spine acute and prominent; elytra blackish with green and coppery reflection, maculation whitish, each elytron with a well marked and complete humeral lunule at an acute angle and at touching margin, with apical lunule fragmented into a broad apical spot and a moderately large round sub-apical and sub-marginal spot.
- Abdominal sternites bluish, densely setose laterally with apical joint in both sexes without white setae. Male genitalia with aedeagus slightly curved near base, gradually widened up to middle and gradually narrowed to a broadly pointed apex; parameres extending up to middle of aedeagus; flagellum forming one-and-a-half coils anticlockwise; endophallus with tubercles fine stiffening rib almost semi-circular, tooth portion of central plate broad and sub-parallel sided, arciform piece well developed. Female genitalia with apical margin of eighth sternite shallowly and broadly emarginate forming a V-shape, each emargination rounded at apex and with five stout setae; coxites slightly notched and with few long setae before apex, styli less curved and blunt; proctigers broadest at apex, its

outer margin slightly sinuate, paraproct oval.

- Length, 7-8 mm, breadth, 2.6-3 mm.

21. *Cylindera (Ifasina) bigemina*, Klug

Diagnostic characters

- Head is coppery, with green reflection and its surface is striated between eyes; antennae are black, four basal segments have greenish reflection. Genae and clypeus glabrous.
- Pronotum is coppery, slightly narrowed towards base, with straight sides. Female coupling sulci a broad shallow groove.
- Elytra with sides sub-parallel, shoulders sub-rectangular, extreme margins greenish-metallic dull, uniformly and thickly punctured. Each elytron has a whitish yellow spot at the shoulder, two on the disc and a sinuate middle band (acutely bent at middle), as well as an apical lunule.
- Legs are metallic, trochanters black; underside deep blue or greenish, coppery in front, with much thicker pubescence.
- Length, 9-10 mm.

22. *Cylindera (Ifasina) subtilesignata*, Mandl

Diagnostic characters

- Head green, blue, coppery and golden, finely striated longitudinally between eyes, and finely rugose at other places, glabrous.
- Antennae with four basal segments greenish-black, rest pitchy; scape with one pre-apical seta.
- Pronotum coppery with margins green, sometimes entirely greenish, sub-quadrate, slightly narrowed towards base. Its surface is finely rugose (having wrinkles), covered with few white setae laterally.
- Elytra slightly widened behind basal one-fourth with shoulders sub-rectangular. Each elytron is coppery with a green strip extending marginally from shoulders to basal one-fourth and then sub-marginally up to basal three-fourth, suture and base green; markings whitish and comprise of a humeral spot, a discoidal spot and a small sub-marginal spot.
- Abdominal sternite dark blue green, six basal segments in ♂ five in ♀.

- Legs blue, green, and coppery, with trochanters reddish.
- Length, 7-8 mm.

23. *Cylindera (Ifasina) spinolai*, Gestro

Diagnostic characters

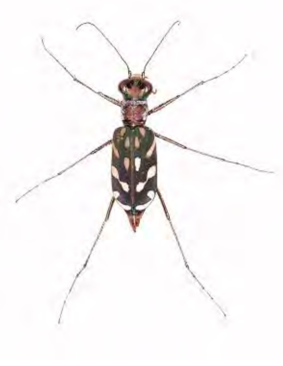
- Head is small, black, striated between the eyes, glabrous (without setae); antennae with four basal segments metallic with red-green lustre, rest segments dull black coloured.
- Pronotum is small, with bluish margins, rugose, coppery, and transverse striations along median line.
- Elytra surface is uniformly pitted; brown coloured, shoulders are bluish green, coppery metallic. Each elytron with two conspicuous whitish yellow spots near the posterior half on the margin, and two minute yellowish spots roughly in the centre on either side of the elytra.
- Legs with trochanters are red-green metallic while rest segments are black dull, tarsi green ending in two claws.
- Length, 7-8 mm.

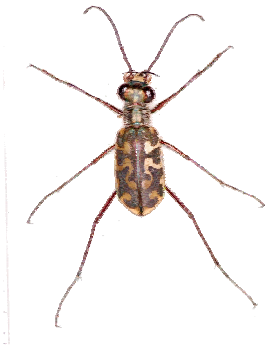
24*. Cylindera (Ifasina) viduata*, Fabricius

Diagnostic characters

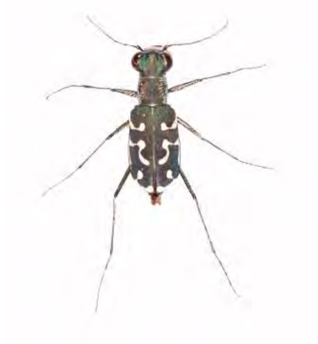
- Head is short, striated vertically between the eyes, coppery green; antennae with four basal segments with greenish red lusture, rest are dull black.
- Pronotum is short, elongated, coppery green, transversely striated, the apical sides are bluish green, feebly setose.
- Elytra with shoulders are flat, elytra is uniformly densely pitted. Each elytron with three whitish spots in lower half, one elongated at margin in the middle, one round spot near 2/3rd portion of body along mid-elytral suture, one at the lower end is crecentric-like.
- Legs are with trochanters dull greenish coloured and tarsi are dull black.
- Length, 7-8 mm.

Species account of tiger beetles (Cicindelidae) from Simbalbara WLS

 *Neocollyris bonellii*	 *Neocollyris saphyrina*
 *Lophyra striolata*	 *Lophyra multiguttata*
 *Cicindela vigintiguttata*	 *Jansenia chloropleura*
 *Jansenia crassipalpis*	 *Calomera chloris*



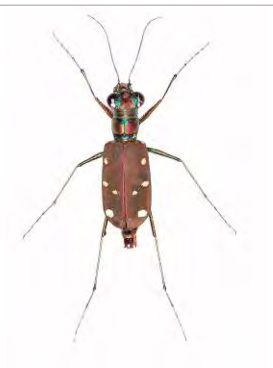
Calomera plumigera



Calomera angulata

Calochroa bicolor

Calochroa flavomaculata



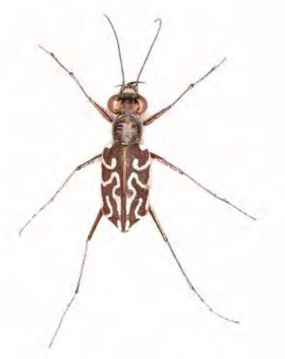
Cosmodela intermedia

Cicindela fastidiosa

Myriochile undulata

Myriochile melencholica

Plate 11

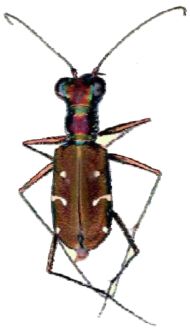


Cylindera venosa

Cylindera grammophora

Cylindera (Ifasina) erudita

Cylindera bigemina



Cylindera subtilesignata

Cylindera (Ifasina) spinolai

Cylindera viduata

Heptodonta pulchella

Plate 11

Key to the Indian species of genus *Heptodonta* Hope

1. Pronotum not globular, broadest near apex; elytron immaculate

……… pulchella Hope

25*. Heptodonta pulchella*, Hope

Diagnostic characters

- Head is large, brown coloured, striated between the eyes, without setae, lateral margins are metallic green and bluish; antennae are long, filiform pedicel is metallic coppery while the segments are dull brown coloured. Labrum with seven teeth in front.
- Pronotum is medium, dull red coloured, with rounded sides and without setae, margins are metallic green and bluish with some coppery tinge.
- Elytra are uniformly pitted, dull red brown coloured with mid lateral margins metallic green and bluish. It has no markings or any spots.
- Legs are with trochanters thickly setose brown coloured while rest of the segments are also red brown to brown coloured, tarsi ending in two claws.
- Length, 15-17 mm.

III. Coleoptera: Scarabaeidae (Dung beetles) (Plate 14 to 18)

Identifying characteristics for the family Scarabaeidae include:

- Robust beetles varying greatly in shape; size ranging from 2 to 62 mm.
- Distinctive *lamellate antennae*; club generally 3 to 4 segments (maximum 7) and capable of being *closed tightly*.
- Tarsi 5-5-5.
- The scarabs vary considerably in habits. Many are dung feeders or feed on decomposing plant material, carrion, and the like. Some live in the nests or burrows of vertebrates or in the nests or burrows of vertebrates or in the nests of ants or termites. A few feed on fungi. Many feed on plant material such as grasses, foliage, fruits, and flowers, and some of these are serious pests of lawns, golf greens, or various agricultural crops.
- Larvae of this family are the type for those termed scarabaeiform. Larvae of this type are sluggish, cylindrical, and C-shaped, with a well-developed head and thoracic legs. The larvae of many species feed on

roots, sap, and decaying wood and in many species are the damaging ('white grub') stage.

- This large, diverse family has more than 20,000 species described world wide; 1,200 in India (Gupta 2004).

Key to the Indian species of genus *Scarabaeus* Linnaeus

1. Pronotum unevenly punctured; head bearing two tubercles

……… sacer Linnaeus

2. Upper surface entirely dull

……… devotus Redt.

1. *Scarabaeus sacer*, Linnaeus

Diagnostic characters

- Black and sub-opaque, with the legs and lower surface shining, the lateral margins of the prothorax, the legs, and lower surface clothed with reddish hair. Broadly oval and slightly convex in shape.
- Head is densely and rugosely punctured in front and tuberculate behind, the forehead bearing a pair of tubercles placed transversely between the eyes and not far apart. The anterior edge of the clypeus is armed with four strong teeth separated by rounded notches.
- Pronotum is unevenly punctured, the punctures being absent along the middle line and near the base, and changing gradually into granules at the sides. The lateral margins are strongly rounded and finely and closely denticulate, the front angles are sharply toothed, the hind angles entirely rounded, and the basal margin closely and finely tuberculate and obtusely angulate in the middle. There is no visible scutellum.
- Elytra are very finely striate and extremely finely and sparsely punctured. The pygidium is opaque at the base, slightly shining at the apex, and very minutely and sparsely punctured.
- Pro-and meta-sternum are clothed with hair, and the abdomen is very smooth except at the sides. The front tibia bears four strong external teeth and two slight teeth, separated by a rounded excision near the middle of the inner edge. The outer edge is denticulate between and above the external teeth. The tarsi are inserted at a distance from the extremities of

the middle and hind tibiae. In ♂ the front tibia is more closely fringed at its inner and outer edges, especially at the basal part of the outer edge, the middle tibia is more dilated in the basal part than that of the female, and tapers a little to the extremity, and the hind tibia has a short but very close internal fringe.

- Length, 23-37 mm; breadth, 14-22 mm.

2*. Scarabaeus devotus*, Redtenbacher

Diagnostic characters

- Black or very deep blue-black or indigo-black, opaque, with the lower surface, legs, and sutural margins of the elytra shining and with not very long fringes of nearly black hair. Flat, not very broad, rather parallel sided. The clypeus and head are densely and confluently pitted, the clypeal margin armed with four strong teeth.
- Pronotum is very strongly transverse, finely and closely but unevenly granular, the posterior part of the median line and an irregular patch on each side being smooth. The sides are very strongly rounded, crenulate in front, the front angles obtuse, the hind angles entirely obsolete, and the base margined and not tuberculate. The scutellum is visible but minute.
- Elytra are lightly striate, and the intervals are feebly and sparsely, punctured. The pygidium is opaque and finely punctured. The lower surface is very smooth, the sides of the metasternum very thinly hairy. The front femur has a feeble tooth beyond the middle of its anterior edge, and the front tibia bears three strong outer teeth and a feeble basal one. The middle and hind tibiae have each two feeble teeth at the outer edge, and the tarsi are short, without long fringes.
- In ♂ the fringe on the upper surface of the hind tibia is dense in its middle part and in ♀ the fringe on the upper part of the hind tibia is evenly spaced and not dense.
- Length, 18-25 mm; breadth, 10.5-16 mm.

Key to the Indian species of genus *Gymnopleurus* Illiger

1. Pronotum without two basal impressions

……… ruficornis Walker

2. Upper surface without hairy clothing

………. cyaneus Fabr.

Upper surface clothed with fine hairs

………. miliaris Fabr.

3. Elytra with longitudinal shining patches only

………. maculosus Macl.

4. Pronotum rather coarsely and indistinctly punctured

………. opacus Redt.

3. *Gymnopleurus ruficornis*, Walker

Diagnostic characters

- Sooty black above and a little more shining beneath or very dark coppery red, with the front part of the head, the legs and underside black or almost black. Very broadly oval, slightly convex, with long and slender legs, the front tibia armed with three teeth occupying rather more than one-third of the outer edge, the remainder coarsely serrate. The front femur is not sharply carinate, but narrowly flattened along its anterior edge, and bears a rather sharp tooth a little beyond the middle; the middle tibia with three strong external teeth towards the end, and the hind tibia strongly serrate externally.
- The head is finely and closely granular, the clypeus acutely notched in the middle and bearing four rounded lobes.
- The pronotum and elytra are minutely and densely granular, the sides of the former are rounded, the front angles moderately prominent and the hind angles obtuse.
- The elytra are lightly and inconspicuously striate, the lateral margins strongly excised, exposing the metasternal epimera. The sides of the abdomen are sharply carinate from the base, and the pygidium is densely granular and opaque. The front tibia is slender and strongly curved, with a double lobe at its extremity, projecting inwards and downwards. The terminal spur is flat, broad, and bifid at the end.
- The front tibia is very broad, with very strong teeth, and the terminal spur is acute.
- Length, 14-19 mm; breadth, 9-12.5 mm.

4. *Gymnopleurus cyaneus*, Fabricius

Diagnostic characters

- Bright, shining, metallic green, blue or violet, with the lower surface rather darker, the antennae dark, and the body above and beneath almost devoid of hairs or setae. Broadly oval and not very convex, with slender legs, the front tibia armed with three strong teeth, occupying rather less than half the outer edge, the remainder of the edge rather strongly serrate, the front edge of the front femur a little flattened or hollowed, with a tooth placed at two-thirds of its length, from the base; the middle tibia scarcely, and the hind tibia distinctly, serrate.
- The head is slightly rugose and asperately punctured in front, smooth and deeply punctured behind, the clypeus having four blunt teeth, and the ocular lobes slightly prominent.
- The pronotum is very short and convex, smooth, unevenly and very strongly but fairly sparsely punctured, hollowed and very slightly rugose in the front angles. The sides are strongly rounded, the front angles acutely produced, the hind angles almost obsolete, the base finely margined, with a short longitudinal groove extending a very short distance forward from its middle.
- The elytra show at the base the beginnings of deep sulci which, shortly behind the base, resolve themselves into series of very large and partly confluent pits, the second interval from the suture very broad and showing very large transverse depressions. The lateral margins are very deeply excised.
- The sides of the abdomen are not sharply carinate at the base; the pygidium has a longitudinal median carina and is a little hollowed on each side and rather rugosely punctured.
- The spur of the front tibia is flat, truncate at the end, and rather strongly bent downwards. The spur of the front tibia is slender and acute.
- Length, 8-12 mm; breadth, 5-8 mm.

5. *Gymnopleurus miliaris*, Fabricius

Diagnostic characters

- Blue-black, dark green or coppery, with the lower surface black or nearly black, and the upper surface closely clothed with minute grey setae, bearing a few shining denuded patches, viz. a central spot upon the prothorax, a ring of five spots surrounding it, an outer one on each side and the lateral pit on each side near the last, the basal and apical parts of the sutural interval upon each elytron, two spots adjoining the basal margin of each, one near the middle of the suture on each side, an outer one close to each of the last, and one upon the apical callus. Moderately broad, not very convex, with slender legs, the front tibia armed with three strong teeth occupying half the outer edge and finely serrate in the upper half, and the middle and hind tibiae rather coarsely serrate externally.

- The front femur has two sharp carinae along its anterior edge, and is slightly hollowed between them, with a minute tooth placed at two thirds of its length, from the base.
- The head is densely granulated, and the clypeus has four blunt lobes at its front edge.
- The pronotum and elytra are also densely granulate, except upon the shining spots enumerated, and the lateral margins of the former are strongly and evenly rounded, the front angles acutely produced, the hind angles bluntly prominent, and the base gently rounded and marked on each side of the middle with a minute impression.
- The elytra are finely striate with the lateral margins deeply excised behind the shoulders exposing the metasternal epimera and the sides of the abdomen are rounded at the base.
- The pygidium is granular and setose at the base and smooth and shining at the apex. In ♂ the front tibia is a little longer and less broad than that of the female with shorter exterior teeth and its terminal spur is very blunt. In ♀ the terminal spur of the front tibia is strongly curved and very sharp at the end.
- Length, 7.5-11.5 mm; breadth, 5-8 mm.

6*. Gymnopleurus maculosus*, Macl.

Diagnostic characters

- Bluish or greenish black, occasionally coppery, with a clothing of recumbent greyish setae, rather scanty upon the lower surface and legs and fairly close upon the upper surface, but with numerous small, denuded, shining patches, viz. a short transverse pit, partially divided in the middle, near each lateral margin of the pronotum, a small median spot, two at a short distance from it on each side, another just behind, and two contiguous to the basal margin, a juxta-sutural row of similar spots upon each elytron, and two or three other rather ill-defined rows upon each. The shape is oval and moderately convex and the legs are fairly slender.

- The front tibia has three strong teeth occupying not quite half the outer edge, the remainder of which is serrate, and the front femur is rather broadly flattened at the front edge, with a minute tooth placed at two-thirds of its length, from the base; the middle tibia has three or four teeth; and the hind tibia is closely serrate along the outer edge.
- The head is closely granular and setose, the clypeus is produced into four blunt lobes, and the ocular lobes are very bluntly prominent. The pronotum is convex, with a slight longitudinal median groove behind; the sides are straight in front and strongly rounded behind, with the front angles acutely produced and the hind angles very obtuse.
- The elytra are faintly striate, and their lateral margins are deeply excised, exposing the metathoracic epimera.
- The sides of the abdomen are sharply carinate to the base, and the pygidium is minutely and not very closely granular and thinly clothed with setae. The front tibia in ♂ is rather long, slightly bent before the middle, and exhibits an indentation of the inner edge just before the extremity, sometimes large, semi-circular, and conspicuous. The terminal spur is truncate.
- Length, 13-15 mm; breadth, 7.5-9 mm.

7. *Gymnopleurus opacus*, Redtenbacher

Diagnostic characters

- Black, with a slight greenish or bluish tinge on the upper surface, the lower surface moderately shining and the upper surface entirely rough and opaque. Broadly oval and not very convex, the legs slender, the front tibia bearing three strong teeth upon the distal end and the remainder of the outer edge armed with about six or eight not very fine serrations, the front femur bearing a tooth at the middle of its front edge, which is a little flattened and not sharply carinate, the outer edge of the middle tibia rather feebly, and that of the hind tibia strongly, serrate.

- The head is closely granular and armed in front with four blunt teeth. The pronotum is coriaceous, with minute irregular granules traceable in the anterior part and shallow confluent punctures in the posterior part. It is convex, with the lateral margins strongly rounded, the front angles acute, the hind angles very obtuse, and the base has a minute punctiform impression on each side of the middle.
- The elytra are closely and finely granulate, and bear fine minutely punctured striae. The lateral margins are strongly excised, the sides of the abdomen form straight sharp carinae extending to the base, and the pygidium is finely coriaceous.
- The front tibiae in ♂ are sinuous and rather abruptly incurved at the end; their spurs are truncate but not short, and the hind tibiae are strongly curved at the end.
- Length, 13-16 mm; breadth, 9-11 mm.

Key to the Indian species of genus *Sisyphus* Latreille

1. Pronotum with very shallow punctures

………. neglectus Gory

8. *Sisyphus neglectus*, Gory

Diagnostic characters

- Black and opaque, except the legs and metasternum, which are shining, and fairly closely clothed above with minute brown, erect, hooked setae. Oval, highly convex, with very long and slender posterior legs, the front tibia armed with three sharp teeth occupying rather less than half its outer edge, the upper half finely serrate, the four posterior femora very slender at the base, the basal half of the hind femur forming a long footstalk, the hind trochanter bearing a sharp tooth in the middle of its posterior edge.
- The head and pronotum are moderately closely punctured, the latter with rather a deep posterior median groove. The front margin of the clypeus has two fairly widely separated teeth, divided by a curvilinear excision, and

the outer teeth are blunt and feeble.

- The pronotum is a little wider than it is long, with the front angles acute, the lateral margins strongly but not acutely angulate before the middle, and the posterior lateral flattened area very sharply defined.
- The elytra are not longer than their conjoint width, and have well marked punctured striae and flat intervals. The metasternum is coarsely punctured and has a slight rounded depression posteriorly, and the mesosternum is rugosely punctured.
- The hind femur has a minute sharp tooth just beyond the middle of its posterior edge, directed backward towards the base. The hind femur has very feeble angulations at its posterior margin, but is not toothed.
- Length, 5.5-7 mm; breadth, 3.5-4 mm.

Key to the Indian species of genus *Heliocopris* Burm.

1. Pronotum not entirely granulate; ♂ head two-or four-horned

……… gigas Linnaeus

9. *Heliocopris gigas*, Linnaeus

Diagnostic characters

- Black, with the lower surface, and sometimes the elytra deep reddish black, and clothed with reddish hair upon the sides of the head, the sides and anterior part of the pronotum, the sides of the metasternum, the legs, and mouth-organs. Broad and very convex, with the upper surface closely rugose and not shining.
- The head is broad and transversely strigose, the clypeus hollowed and its margin showing two slight prominences on each side.
- The pronotum is short and broad, with a steep anterior declivity bearing outstanding reddish hairs, the posterior part prominent in the middle. The surface is coarsely and irregularly rugose, with a smooth area on each side in the male.
- The elytra are rather more evenly and less closely rugose, with a narrow sutural border to each, smooth and finely, not closely, and punctured, sloping strongly from the suture to each side, and the sutural region strongly rounded from base to apex.

- The pygidium is smooth and shining, with very sparse, fine, scattered punctures. The metasternal shield is smooth in the middle, bears long erect hairs in front and at the sides, and has, just before the base, a transverse impression containing scattered hairs. The sides of the metasternum are densely clothed with hair. The front tibia is armed with three strong teeth. The outer margins of the clypeus in ♂, at the point of junction with the ocular lobes, are produced upwards as a pair of long, slightly curved, nearly parallel horns, between which the clypeus is deeply hollowed.
- Length, 30-50 mm; breadth, 18-29 mm.

Key to the Indian species of genus *Catharsius* Hope

1. Head very transverse; pronotum of male with two tubercles ………. pithecius Fabricius

10*. Catharsius pithecius*, Fabricius

Diagnostic characters

- Black and shining, with the pronotum partly or entirely opaque, the antennae, mouth organs, and hairy clothing of the legs and lower surface reddish. Shortly oval and very convex.
- The head is nearly semi-circular in shape, with the clypeus very feebly excised in the middle of the front margin and closely strigose. The ocular lobes are closely granular.
- The sides of the pronotum are strongly and uniformly rounded, the front angles are generally distinct and the hind angles entirely obliterated, and the base is gently rounded and finely margined.
- The elytra are finely but distinctly striate, with scarcely perceptible punctures in the striae, the intervals shining, except near the base, where they are opaque and very minutely punctured.
- The pygidium is finely and not very closely punctured. The metasternal shield is acutely angular in front, very smooth and shining, with a median longitudinal groove, and the sides of the metasternum are closely and rugosely punctured and hairy. The head in ♂ is lightly sculptured and shining, and bears a nearly straight slender horn, arising just in front of the

eyes, and inclined very slightly backwards. The pronotum bears a slight, sharp, conical protuberance on each side of the median line and midway between the front and hind margins. The surface is gently hollowed between the two points, flattened, smooth and shining in front of them, and closely covered with minute granules upon the posterior part, usually with a round, smooth, shining patch behind each lateral protuberance. The two smooth patches may become enlarged and united or, especially in poorly developed specimens, may be very small or entirely absent. The head in ♀ is more deeply sculptured and less shining, and bears a slightly acuminate transverse elevation just in front of the eyes. The pronotum has a median longitudinal furrow in its basal part, and is closely covered with minute granules, sometimes absent from a smooth basal area on each side of the median furrow.

- Length, 15-23 mm; breadth, 10-13.5 mm.

Key to the Indian species of genus *Copris* Illiger

1. Inner front angle of the prothorax rounded
……… brahminus Hope
2. Elytra not distinctly punctured
……… sacontala Redt.
Elytra closely punctured
……… sabinus Gill.
3. Front angles of prothorax very blunt
……… indicus Gill.
4. Front angles of prothorax distinct
……… sarpedon Har.
5. Clypeal margin with two processes
……… excisus Wat.
6. Pronotum very distinctly punctured, the front margin prominent in the middle
……… punjabensis Gill.
7. Elytral intervals very closely punctured
……… surdus

11. *Copris brahminus*, Hope

Diagnostic characters

- Black, not very shining, with the antennae and mouth organs reddish, and the lower surface and legs clothed with reddish hair. Oval and not very convex.
- The head is rugose in front and granular behind, short and very broad, the clypeus deeply notched in the middle and bluntly bilobed, the ocular lobes produced into very long, curved, and sharp-pointed processes. There is a blunt tubercle in the middle of the forehead.
- The pronotum is moderately and rather evenly convex, covered with fine and close granule; except in the middle of the basal part, which bears a few fine punctures and a faint longitudinal groove. The lateral margin is sharply bidentate anteriorly but the internal angle is rounded. The hind angles are very obtuse and the base is well rounded.
- The elytra are fairly strongly striate, the intervals slightly convex and lightly coriaceous.
- The pygidium hears fine scattered granules at the sides. The metasternum is smooth, with lightly rugose sides and deep posterior excavation. The middle and hind tibiae are very gently curved and not very broad at the extremity, and the hind femur bears a minute posterior tooth not far from the base. The hind tibia bears a long and very close fringe of reddish-golden hairs along its entire length.
- Length, 28-30 mm; breadth, 17-18 mm.

12. *Copris sacontala*, Redt.

Diagnostic characters

- Black, not shining, with the antennae, mouth organs, and hairy clothing of the legs and lower surface red. Broadly oval and very convex.
- The head is rather short and broad, rugose, except between the eyes, and very feebly notched in the middle of the front margin.
- The pronotum is entirely rugose, coarsely in front and more finely and closely behind, with a feeble longitudinal groove in the posterior part. The sides are strongly rounded the front angles truncate and the hind angles entirely obsolete.

- The elytra are very finely and obsoletely striate some of the striae with traces of minute punctures. The intervals are flat and finely alutaceous.
- The pygidium is fairly closely covered with rather ill-defined punctures. The metasternal shield is rather smooth in front, with a deep transverse impression, and closely and rugosely punctured behind, and the sides of the metasternum are densely punctate, rugose, and clothed with hair.
- The front tibia is broad and bears three external teeth and the middle and hind tibiae, are digitate at the extremity. The head in ♂ bears a curved and tapering, rather sharp pointed horn, quadrangular and rugose in its basal part. The pronotum has a nearly vertical anterior declivity, the upper edge of which bears two blunt prominences placed close together, and there is also a sharp lateral tooth on each side, separated by a slight hollow from the dorsal prominence. The head in ♀ bears a transverse carina, sharp at the summit, broad at the base, and rather oblique in direction, the summit obtusely angular and the outer angles sharp.
- Length, 21-27 mm; breadth, 13-16 mm.

13*. Copris sabinus*, Gill.

Diagnostic characters

- Black, closely punctured, not shining above, with the antennae, mouth organs, and scanty hairs upon the legs and the sides of the body beneath red. Broadly oval and very convex.
- The head is semi-circular, with the front margin scarcely at all indented in the middle, the surface granular, but the granules obsolete in the middle.
- The pronotum is densely and rugosely punctured, except in the posterior dorsal part, where the punctures are close but separate, and in the lateral excavations of the male, which are entirely smooth. There is a strong median groove in the posterior part, the lateral margins are strongly rounded, the front angles broadly rounded, and the hind angles entirely obsolete.
- The elytra are deeply striate, the intervals slightly convex and closely punctured. The pygidium is closely punctured. The front angles of the prothorax are hollowed, smooth and shining beneath. The metasternal shield is almost smooth, with a few feeble punctures at its sides and a pit

in front, and the sides are strongly punctured.

- The front tibia is broad and bears three external teeth, and all the femora are finely and moderately closely punctured. The head in ♂ bears a slender erect horn. The front of the pronotum is almost vertical in the middle, the dorsal hump is narrow and bilobed, and there is a sharp lateral process on each side, separated from the dorsal hump by a deep smooth excavation. The head in ♀ bears a short transverse carina and the pronotum is strongly convex, without carina, and entirely opaque and closely sculptured.
- Length, 17-20 mm; breadth, 10-11 mm.

14*. Copris indicus*, Gill.

Diagnostic characters

- Black, with the anterior part strongly and densely punctured and the elytra very shining, sometimes with a faint opalescent lustre, the antennae, the mouth-organs, and the bristles upon the legs red. Broadly oval and highly convex.
- The head is semi-circular in shape, with the front margin feebly bilobed in the middle. The surface is closely punctured, rugosely in front, less closely between the eyes.
- The pronotum is strongly and densely punctured, the sides are nearly straight in front, strongly rounded behind, the front angles are broadly truncate and the hind angles very obtuse.
- The elytra are very strongly sulcate, the sulci closely and not very finely punctured, the intervals convex and finely and sparingly punctured. The pygidium is not very strongly or very closely punctured. The metasternal shield is rather vaguely punctured in front and nearly smooth behind, with a median groove, and the sides of the metasternum are strongly but not very closely punctured.
- The front angles of the prothorax are not hollowed beneath. The front tibia is broad and armed with four blunt external teeth, and the terminal spur has the tip bent almost at a right angle. The femora are punctured beneath, the front ones rather more strongly than the rest. The head in ♂ bears a short erect horn in the middle, flattened from front to back, slightly

dilate and feebly bicuspid at the extremity. The front of the pronotum is vertical in the middle and the front edge of the dorsal prominence is nearly straight. There is also a sharp lateral tubercle on each side of the pronotum. The head in ♀ bears a slight transverse elevation in the middle. There is a rudimentary transverse elevation parallel to the front margin of the pronotum.

- Length, 12.5-13.5 mm; breadth, 7.5-9 mm.

15*. Copris sarpedon*, Har.

Diagnostic characters

- Black and very shining, with the antennae, the mouth organs, and scanty bristles upon the legs red. Oval and highly convex.
- The head is semi-circular, strongly and moderately closely punctured, with the front margin reflexed and feebly notched in the middle.
- The pronotum is very strongly but unevenly punctured, with a deep median longitudinal groove, on each side of which the punctures are fine and sparse. The lateral margins are strongly rounded, the front angles broadly truncate, and the hind angles obsolete.
- The elytra are very deeply striate, the striae closely punctured, the intervals convex and minutely but not very sparsely punctured.
- The pygidium is evenly and very strongly punctured. The metasternal shield is smooth, with a deep pit and a very few fine punctures in front and a longitudinal groove behind. The sides of the metasternum are fairly strongly but not closely punctured and without hair.
- The front tibia is broad and armed with four teeth, and the extremity of the terminal spur is bent almost at a right angle. All the femora are moderately closely punctured.
- The head in ♂ bears a slender horn, smooth in front and rugose behind, with a minute posterior tooth on each side at a short distance from the base. The pronotum is steep in front, and has a quadrate dorsal prominence, the front edge of which bears four equidistant points, the two middle ones more deeply separated from each other than from the outer ones. There is also a long, sharp, compressed lateral process on each side of the pronotum, separated by a deep, strongly punctured excavation

from the dorsal hump. In small individuals the lateral process may be reduced to a slight blunt prominence. The head in ♀ bears a short transverse carina with rather sharp angles. The pronotum bears a transverse, feebly sinuate carina, parallel to and a little behind the front margin.

- Length, 12-15 mm; breadth, 7-10 mm.

16. *Copris excisus*, Wat.

Diagnostic characters

- Black and moderately shining, with the head and lower surface very smooth and glossy, the antennae, mouth-organs, and the hairy clothing of the legs reddish. Elongate oval and not very convex.
- The head is very smooth and shining in front, moderately punctured behind, with a median tubercle and a transverse excavation between the eyes.
- The pronotum is evenly and fairly closely punctured, the punctures fine in front but becoming stronger towards the base, which has a row of large, annular, oval impressions. There is a broad marginal membrane in the anterior emargination. The lateral margins are gently rounded, the front angles slightly, and the hind angles very obtuse.
- The elytra are rather deeply striate, with fine and fairly close punctures in the striae, the intervals slightly convex and finely but not closely punctured.
- The pygidium is strongly and fairly closely punctured. The metasternal shield is very smooth, with a few scattered punctures in front, and the sides of the metasternum are sparingly and fairly strongly punctured. The femora are well punctured and the front tibia is armed with four sharp teeth.
- The head in ♂ bears a minute conical tubercle in the middle, and the clypeus is deeply incised on each side, forming a pair of short but rather slender lateral processes, directed outward and curving slightly upward. The front margin of the head is almost straight. The clypeus is bluntly bidentate in front. The median tubercle is stronger than in the male and the posterior excavation is deeper.

- Length, 11-12 mm; breadth, 6-7 mm.

17. *Copris punjabensis*, Gillet

Diagnostic characters

- Entirely black and opaque above, with the antennae, mouth organs, and bristles upon the legs red moderately elongate and depressed.
- The head is rather finely and closely punctured, with the clypeus a little smoother and shining in front and its anterior margin strongly reflexed and produced in the middle into a rounded tongue-like lobe. There is a rather deep depression between the eyes.
- The pronotum is finely and very deeply punctured, without a distinct median groove, the lateral margins are evenly and gently rounded, the front angles broadly rounded and the hind angles obsolete.
- The elytra are deeply sulcate, with the intervals convex and finely but not closely punctured.
- The pygidium is strongly and closely punctured. The metasternal shield is rather finely and evenly punctured in front and smooth behind, with a median groove and a row of punctures close to the hind margin, and the sides of the metasternum are evenly and rather more strongly punctured.
- The front tibia is broad and armed with four teeth, and the front femur and the outer part of the middle and hind femora are rather closely punctured. The head in ♂ bears in the middle a slight longitudinal elevation, of a rather triangular shape, with the pointed end behind. The head has a feeble rounded elevation in the middle.
- Length, 12-13 mm; breadth, 6.5-7 mm.

18. *Copris surdus*

Diagnostic characters

- Black, opaque above, with the head, lower surface, and legs shining, the antennae, mouth organs, and scanty bristles upon the legs reddish. Elongate oval, not very convex. The clypeus is bidentate in front, smooth in the middle, lightly punctured at the sides, the ocular lobes are strongly punctured, and there is a deep transverse depression at the back of the head and a short horn or conical elevation immediately in front of it.

- The pronotum is finely and closely punctured, with a broad marginal membrane in the anterior emargination and a very feeble posterior longitudinal groove. The front angles are truncate and the hind angles very obtuse.
- The elytra are finely striate, the intervals almost flat and finely and very densely punctured.
- The pygidium is strongly and closely punctured. The mesosternum is finely and densely punctured, the metasternal shield is smooth, with a few, scattered punctures in front and behind, and the sides of the metasternum are strongly punctured.
- The marginal teeth of the clypeus in ♂ are strong, sharp, and triangular, and reflexed at right angles to the clypeus. The cephalic horn is short but very slender and blunt at the tip. The pronotum is a little more convex than that of the female, and its front margin is sharply angular in the middle. The marginal teeth of the clypeus in ♀ are blunt, and the head bears a slight conical elevation in the middle.
- Length, 12-14 mm; breadth, 6.5-7.5 mm.

Key to the Indian species of genus *Caccobius* Thoms.

1. Clypeus strongly bilobed

……… tortricornis

2. Metasternum not punctured in the middle; ♂ with a cephalic horn

……… unicornis Fabricius

3. Clypeus entire

……… pantherinus

19*. Caccobius tortricornis*

Diagnostic characters

- Black, shining, with a small deep red spot upon each shoulder and a red marginal patch at the extremity of each elytron. The antennae and legs are also reddish.
- The head and the anterior part of the pronotum are sometimes slightly metallic. The upper surface is fairly sparsely clothed with minute greyish setae. Broadly oval, compact and convex. The head is broad behind and

bluntly angular in front of the eyes, the clypeus sharply bidentate, with its sides straight and convergent.

- The pronotum is moderately strongly but not very closely punctured. The front angles are fairly sharp, the sides nearly straight in front, feebly curved behind, and the base is gently rounded.
- The elytra are finely striate, the intervals flat and minutely and sparsely aciculate-punctate. The pygidium is fairly strongly but not very closely punctured. The metasternum bears a few large punctures at the sides and in the middle.
- The head in ♂ is shining and very minutely punctured, the clypeus very sparingly, the forehead rather more numerously, the head and clypeus indistinctly separated. The posterior margin is produced backwards as a flat plate, of which the angles are produced into short, sharp horns, curving forward and then backward, and having a short, blunt process between them. The pronotum is broadly vertical in front, and the upper margin of the declivity is sharp and not produced in the middle. The teeth of the front tibia are short. The clypeus and forehead in ♀ are separated by a strong curved carina, the clypeus rugose and very strongly bidentate, the forehead rugosely punctured. The pronotum is uniformly convex. The teeth of the front tibia are long and sharp.
- Length, 4.5-5.5 mm; breadth, 3-3.5 mm.

20*. Caccobius unicornis*, Fabr.

Diagnostic characters

- Black or pitchy, usually with the clypeus, elytra, and legs dark red. The antennae and mouth organs are yellow, and the upper and lower surfaces are clothed with minute pale setae. Minute, very broadly oval and compact, and moderately convex.
- The head is rather short and broad, with the clypeus slightly bilobed in front and rounded at the sides. The pronotum is evenly and moderately strongly punctured. The front angles are very blunt and not produced, the lateral margins are rounded in front feebly sinuate behind, and the base is rounded.
- The elytra are finely striate, the 7th stria is strongly curved, and the

intervals are flat and minutely and sparingly punctured.

- The pygidium is finely and not closely punctured. The metasternal shield is almost smooth in the middle, but bears a few large punctures in front, behind, and at the sides, and the sides of the metasternum are coarsely pitted.
- The legs are short, and the hind tibia is broad at the extremity. The head in ♂ is shining, with only a few scattered punctures, and bears a short, erect horn with a depression behind it. The head in ♀ bears intermixed large and small punctures, the clypeus is separated by a rounded carina from the forehead, and there is a short, straight, posterior carina.
- Length, 3-3.5 mm; breadth, 2-2.5 mm.

21. *Caccobius pantherinus*

Diagnostic characters

- Shining dark coppery, the elytra yellow, each with the sutural interval, the outer margin, and six spots, one before and one behind the middle, upon the 3rd, 5th, and 7th intervals, black.
- The innermost anterior spot is sometimes united with the black sutural margin, and it is probable that the six spots sometimes form two transverse bands. The pygidium is coppery at the base and yellow at the apex and the tarsi, antennae and mouth organs are red. Oval and moderately convex, without hair or setae upon the upper surface.
- The head is fairly closely and finely punctured, strongly rounded at the sides, with the clypeus a little produced.
- The pronotum is rather evenly, not very strongly or very closely, punctured. The front angles are rather sharp and the sides are feebly rounded in front, nearly straight behind, the hind angles obsolete, and the base strongly rounded.
- The elytra are finely striate, the intervals are flat and distinctly, not very finely, punctured.
- The pygidium is not very finely nor very closely punctured. The metasternal shield is strongly punctured in front and very finely and sparsely behind, and the sides of the metasternum bear large annular punctures. The clypeus in ♂ is produced into a narrow reflexed process,

the clypeo-frontal carina is almost obsolete, and the posterior part of the head is produced backwards as a broad triangular lamina, the apex of which forms a short, upwardly curved horn. The anterior part of the pronotum is broadly hollowed beneath the cephalic process. The clypeus in ♀ is very slightly produced in front and separated by a slight curved carina from the forehead, and there is a straight posterior carina between the eyes.

- Length, 5.5-7.5 mm; breadth, 3.5-4.5 mm.

Key to the Indian species of genus *Onthophagus* Latreille

1. Eyes large separated by distinctly less than three times their length. Vertex without horn or ridge

   ………. hystrix Bouc.

2. Pronotum moderately closely punctured

   ………. ochreatus d’Orb.

3. Pronotum not grooved, vertex without a median tubercle

   ………. pacificus Lansb.

4. Elytral suture shining

   ………. tarandus F.

   Elytral suture not shining

   ………. dynastoides

5. Pronotum opaque

   ………. griseosetosus

6. Not entirely black; elytra strongly granular

   ………. necrophagus

7. Pronotum long sides nearly straight; elytra feebly striate

   ………. pactolus F.

8. Elytra not very short

   ………. variegatus F.

9. Pronotum closely asperately punctured

   ………. troglodyta Wied.

10. ♂ cephalic horns reclined; ♀, pronotum with two short carinae in front

    ………. orientalis Har.

11. Clypeus feebly bilobed

………. sternalis

12. Elytra opaque

………. exquisitus

13. Elytra shining

………. arboreus

14. Front angles of pronotum not very acute

………. ramosus Wied.

15. Pronotum granular, with very few punctures

………. amplexus Sharp

16. Elytra is extremely smooth above

………. atropolitus d'Orb.

17. Clypeus not bilobed

………. furcillifer Bates

18. Upper surface uniformly coloured

………. circulifer

19. Elytral striae replaced by large contiguous circles

………. amicus Gill.

20. Large, elytra not very glossy

………. dama F.

21. Elytra dark

………. hamaticeps

22. Elytra with a narrow transverse black band

………. fasciatus Bouc.

23. Dark thoracic patch narrow in front

………. expansicornis Bates

24. Elytra very lightly striate; ♀, tubercles of the pronotum separated

………. luridipennis Boh.

25. Pronotum with a bituberculate anterior hump

………. beesoni

26. Pronotum without an oblique basal impression on each side, with two widely separated tubercles in ♂

………. mopsus F.

27. Elytra dark, with the shoulder red; ♂ with the head produced in front and

behind

………. vaulogeri Bouc.

22. *Onthophagus hystrix*, Bouc.

Diagnostic characters

- Reddish-chocolate, rather shining, with the antennae yellow, and fairly closely clothed above and beneath with rather long erect pale hairs. Broadly oval, not very convex.
- The head is rather large, but not very dilated laterally before the eyes, which are large, as seen from above, and separated by less than three times the length of each. The clypeus is coarsely and rugosely punctured, feebly emarginate in front, separated by a fine curved carina from the forehead, which is sparingly punctured. There is a pair of minute transversely placed tubercles between the eyes.
- The pronotum is closely and moderately finely punctured, a little less closely in the middle. The front angles are acutely produced the sides straight in front, nearly straight behind, the base rounded.
- The elytra are finely striate, the intervals flat and minutely asperately punctured. The pygidium is strongly and sometimes rugosely punctured. The metasternum is finely punctured except along the middle line, a little more strongly at the sides.
- The front tibia is armed with three strong teeth and extremely finely serrate above them and the middle and hind tarsi are rather slender. The two sexes are alike.
- Length, 3-5.5 mm; breadth, 2-3.5 mm.

23. *Onthophagus ochreatus*, d'Orb.

Diagnostic characters

- Rusty-red, with the head, except the clypeus, black. The upper surface, except the head, not very shining, clothed with very minute and fairly close yellow setae. Broadly oval, compact, and not very convex.
- The head is large with large eyes, the transverse diameter of which is about a quarter of that of the space between them. The sides of the head are gently rounded, the clypeus is a little produced, rather roughly but

sparsely granulate, the margin feebly excised in front. There is a curved carina separating the clypeus from the finely punctured forehead.

- The pronotum is finely and moderately closely punctured, the front angles are sharp, the sides nearly straight in front and feebly sinuate behind, and the base rounded.
- The elytra are finely striate, the 7th stria gently curved, the intervals almost flat, finely and fairly closely punctured.
- The pygidium is finely and rather sparingly punctured, sub-opaque at the base and shining at the apex. The metasternum bears small scattered punctures in the middle and at the sides. The head in ♂ bears between the eyes a pair of short, stout, parallel horns, pointed at the end and inclined obliquely backward. The horns are often reduced to short, blunt tubercles. The clypeus is very feebly emarginate in front. In ♀ there is a carina between the eyes, more or less interrupted in the middle.
- Length, 5.5 mm; breadth, 3.5 mm.

24. *Onthophagus pacificus*, Lansb.

Diagnostic characters

- Black, very smooth and shining, with the head, legs, antennae and parts of the body beneath red, the pronotum frequently, and the metasternum and pygidium sometimes, suffused with a metallic lustre. Oval, compact, and convex.
- The head is broad, the clypeus short, with its margin rounded, separated by a strong, curved carina from the well-punctured forehead, which is separated from the vertex by a similar but straight carina.
- The pronotum is moderately punctured at the sides, very minutely in the middle. The front angle is almost rectangular, the lateral margin nearly straight in front and feebly sinuate behind, the hind angle very obtuse and the base rounded.
- The elytra are deeply striate, with ill-defined puncture in the striae, the intervals rounded and minutely and irregularly punctured.
- The pygidium is very strongly punctured. The metasternal shield is very smooth in the middle, and the sides of the metasternum bear large but not numerous punctures. The middle and hind tibiae are very broad at the

extremity, not narrower than the length of the metatarsus. The clypeus is closely punctured in ♂. The clypeus is transversely rugose in ♀.

- Length, 6-7.5 mm; breadth, 4-5 mm.

25. *Onthophagus tarandus*, Fabricius

Diagnostic characters

- Coppery or dark metallic green, with the elytra, except a dark sutural band narrowing behind, the femora, and antennae bright yellow, the head and body beneath brown.
- Oval, with the pronotum and elytra opaque, densely rugulose, and clothed with fine, rather close, recumbent yellow hairs, the pygidium and abdomen with long erect hairs. The clypeus is short and broad, transversely rugose, with the front margin very feebly excised; the ocular lobes are roundly prominent; the forehead is shining and bears a few punctures, and is enclosed between two curved carinae, the posterior one stronger than the anterior. The vertex is very smooth and shining, and produced outward on each side into a sharp pointed process, curving a little upward.
- The pronotum is very finely and closely granular, with its anterior border smooth and shining. There is a deep round excavation in this on each side, and the intervening space is produced forward as a horizontal process, bifid in front. At the outer edge of each excavation is a sharp forward process. The front angles are very bluntly rounded and the base scarcely angulated.
- The elytra are feebly striate, with the intervals finely and densely punctured.
- The pygidium is densely and more strongly punctured, without carina near the base. The metasternum is very smooth in the middle and rather strongly punctured at the sides. The two sexes are almost alike, but the clypeus of the male is slightly shining, and that of the female more closely rugose and opaque. The median thoracic process of the male is divided anteriorly into two sharper and more divergent lobes.
- Length, 6.1-9 mm; breadth, 4-5 mm.

26. *Onthophagus dynastoides*

Diagnostic characters

- Black or greenish-black, shining beneath and opaque above, with the elytra (except the sutural and epipleural margins), antennae, and mouth-organs rust-red. The entire surface is clothed with yellow hair, which is long and erect and not very close upon the head, pygidium, and lower surface and very fine, dense, and recumbent upon the pronotum and elytra. Oval, rather elongate, moderately convex.
- The head is not broad, its sides are rounded in front of the eyes, which are not very small, and the clypeus is evenly rounded, its margin strongly reflexed.
- The pronotum is very minutely, densely, and confluently punctured. The front angles are very blunt, the sides obtusely angulate before the middle of the front part and lightly sinuate behind, and the base strongly rounded. The elytra are very finely striate, with the intervals flat.
- The pygidiums are minutely and densely granulate. The metasternum bears moderately fine punctures which are scattered and scanty on the shield and a little closer at the sides. The clypeus in ♂ is rather scantily asperately punctured and divided from the forehead by a curved carina, immediately behind which arises a rather broad transversely flattened horn, erect at the base, curving backwards, and strongly forked at the end. The pronotum is vertical and a little hollowed in front, and the upper edge of the declivity is produced obliquely forward and upward in the middle as a short blunt process, a little hollowed above.
- Length, 11 mm; breadth, 6 mm.

27. *Onthophagus griseosetosus*

Diagnostic characters

- Brownish-black, very opaque above, sometimes with a very slight coppery lustre upon the head and pronotum, the lower surface greenish-black, the antennae and mouth-organs reddish, the pygidium and lower surface clothed with short greyish hairs, and the upper surface evenly and moderately closely clothed with grey setae. Oval, fairly long, deeply waisted, and convex.

- The head is rather narrow, the eyes moderately large, the ocular lobes not dilated, feebly rounded externally, the clypeus a little produced, divided by a slight rounded carina from the forehead, with its front margin strongly reflexed and rounded.
- The pronotum is closely covered with fine oval granules. The front angles are produced and moderately sharp, the lateral margins nearly straight in front, feebly sinuate behind, and the bases strongly rounded and obtusely angulate in the middle.
- The elytra are finely striate, the intervals flat, with numerous fine setigerous punctures.
- The pygidium is rather finely, not closely, punctured. The metasternal shield is strongly punctured at the sides, smooth in the middle, and the sides of the metasternum are finely punctured. The clypeus and forehead in ♂ are fairly strongly and closely punctured, and the head is produced between the eyes into a short horn, oblique and triangular at the base, and sharply pointed at the tip. The front margin of the pronotum is rather smooth and a little hollowed. The spur of the front tibia is short and blunt. The head is densely rugose in ♀ and bears a slight median tubercle between the eyes. The spur of the front tibia is long, acutely pointed, and abruptly bent at a right angle.
- Length, 10.5-12.5 mm; breadth, 6-7 mm.

28*. Onthophagus necrophagus*

Diagnostic characters

- Metallic green, not shining above (except sometimes upon the posterior part of the head and the anterior part of the pronotum, which may be coppery), with the elytra blue or bluish green, and the antennae, mouth organs, and tarsi red. The upper surface is clothed with fine pale setae. Elongate oval, deeply waisted, and highly convex.
- The head is fairly broad, closely transversely rugulose in front and rugosely punctured behind, the clypeus; produced to a rather sharp, but short, point, separated by a very feeble carina from the forehead, the sides of the head very strongly rounded in front of the eyes, and the posterior margin strongly produced or tuberculate in the middle.

- The pronotum is densely covered with oval granules, which change to a round shape near the base on each side. The front angles are very bluntly produced, the sides are nearly straight in front and feebly sinuate behind, and the base is very obtusely angular in the middle.
- The elytra are shallowly striate, the intervals flat and moderately closely and not very finely granular.
- The pygidium is rather strongly and closely punctured. The metasternal shield is bluntly angulate anteriorly, very feebly and sparsely punctured in the middle and a little more strongly at the sides, and the sides of the metasternum are fairly strongly punctured. The legs are short and stout. The hind margin of the head in ♂ bears a short erect horn in the middle, the pronotum is hollowed behind the horn, and the spur of the front tibia is short and clubbed. The hind margin of the head in ♀ bears a blunt tubercle in the middle, the pronotum is not hollowed, and the spur of the front tibia is long and slender.
- Length, 6-8 mm; breadth, 4-5 mm.

29*. Onthophagus pactolus*, F.

Diagnostic characters

- Rich deep metallic green, with the sides of the prothorax, and sometimes part of the head, reddish-golden, the elytra reddish orange, with the suture green and the antennae pale yellow.
- The head, legs, and lower surface are clothed with moderately long yellow hair, and the pronotum and elytra with minute yellow setae. Rather narrowly oval, convex, with the elytra, except the sutural margins, and in a less degree the middle of the pronotum, opaque. The clypeal margin is entire and feebly reflexed.
- The head, pronotum, and elytra are densely punctured or granular, the elytra very minutely and evenly, the pronotum smooth and shining at the middle of the front margin, sparingly granular in the front angles, and punctured, not very densely, upon the basal lobe.
- The pronotum is long, with the sides nearly straight, the front angles produced, and the base strongly lobed and flattened in the middle, with a slight apical depression.

- The elytra are feebly striate, with the juxtasutural interval carinate, the two carinae meeting at the apex and diverging anteriorly.
- The pygidium is densely punctured and closely hairy at the base, moderately punctured and shining at the apex. The metasternum and femora are other strongly punctured. The tibiae are short and stout. The clypeus is semi-circular, and the vertex bears a slender horn, erect at the base and curving backward a little at the tip, with a minute oblique tooth on each side near the middle.
- The pronotum bears a slight tubercle on each side above the retuse anterior part which is produced backwards a little between them. The spur of the front tibia is nearly straight. The clypeus is a little produced but not pointed; there is a strongly arcuate frontal carina and a short straight one upon the vertex, inclined a little backwards and bearing a small erect tubercle at each end, and a rather longer process between them. The smooth surface in the middle of the front of the pronotum is small and limited above by a short transverse carina on each side. The spur of the front tibia is bent inwards towards the end.
- Length, 11-16 mm; breadth, 7-10 mm.

30*. Onthophagus variegatus*, F.

Diagnostic characters

- Sub-opaque, with the head and lower surface shining. Deep yellow or rusty brown, with the head and lower surface dark and suffused with metallic lustre and the pronotum and elytra mottled with black markings and more or less metallic. The elytral striae are generally dark, and two well-defined transverse rows of small and sometimes partly confluent dark spots are generally traceable. The antennae mouth organs, femora, and pygidium are yellow, and the upper surface bears a fairly close clothing of very short pale setae. Oval and highly convex.
- The head is rather narrow, with the clypeus a little produced and notched in the middle and the ocular lobes gently rounded externally.
- The pronotum bears rather evenly and not very closely distributed fine granules. The front angles are acutely produced, the lateral margins are gently sinuate in front and behind, and the base is strongly rounded.

- The elytra are rather strongly striate, the striae closely punctured, and the intervals slightly convex and very sparsely and minutely punctured.
- The pygidium is fairly strongly and closely punctured. The metasternum bears scattered punctures, those at the sides a little closer than those in the middle. The head in ♂ is very smooth and shining, with fine scattered punctures. The clypeus is shallowly excised in front, and the posterior part of the head bears a pair of straight parallel horns, produced obliquely backwards, not very far apart, and united by a basal lamina. The front margin of the pronotum is steep, smooth, and shining. The clypeus in ♀ is acutely notched and bidentate, rather rugosely punctured, separated by a strongly rounded carina from the finely punctured forehead, and there is a strong, straight, posterior carina.
- Length, 4-5 mm; breadth, 2.5-3 mm.

31*. Onthophagus troglodyta*, Wied.

Diagnostic characters

- Black, with the elytra pale yellow, the suture and a zig-zag transverse band crossing the middle but not quite reaching the outer margin, usually with a branch reaching the front margin at the middle, black. The antennal club is dark, with the footstalk, mouth-organs and tarsi red, and the upper surface is fairy closely clothed with short pale setae. Very short, convex, and globular.
- The head is short but not very broad, the ocular lobes not very prominent laterally, the clypeus a little emarginate in front.
- The pronotum is strongly and fairly closely, but not densely, punctured, with minute interspersed granules. The front angles are produced and acute, the lateral margins feebly sinuate in front and behind, and the base strongly rounded.
- The elytra are rather deeply striate, the striae closely punctured, the 7th stria nearly straight and parallel to the 6th, and the intervals slightly convex and minutely and sparsely granular, the granules generally forming two series.
- The pygidium is coarsely pitted. The metasternal shield is sparsely punctured, and the sides of the metasternum are shallowly and fairly

closely punctured. The head is shining, the clypeus very feebly emarginate, coarsely punctured, the forehead finely and sparsely punctured, and the vertex is produced backwards and upwards as a flat, not very broad plate, the angles of which are drawn into a pair of short, curving, and rather divergent horn. The front tibia is a little elongate, with four short external teeth. The clypeus is coarsely rugose, distinctly emarginate, and divided by a curved carina from the forehead, which is strongly punctured. The front tibia is short and its teeth are long.

- Length, 4-4.5 mm; breadth, 3 mm.

32. *Onthophagus orientalis*, Har.

Diagnostic characters

- Black and shining, with the pronotum slightly coppery, greenish or bluish, the clypeus and legs more or less red, and the antennae, yellow. The greater part of the body above and beneath is clothed, not very closely, except upon the pygidium, with short yellowish hair. Oval and very convex. The head is not broad and the clypeal margin is strongly rounded.
- The pronotum is very convex, very strongly and deeply and rather closely punctured, except near the front margin, the punctures becoming asperate in front. There is a deep median longitudinal groove at the base. The front angles are blunt, the lateral margins feebly curved in front, strongly bisinuate behind, the hind angles distinct but obtuse, and the base finely margined and very obtusely angulate in the middle.
- The elytra are finely striate the intervals a little rounded and irregularly, deeply, and not very finely punctured. The sutural region is rather deeply depressed, especially near the base.
- The pygidium is strongly and closely punctured and clothed with moderately long recumbent hair. The metasternal shield is strongly but not closely punctured, with a smooth median line, and the sides of the metasternum are densely punctured.
- The clypeus in ♂ is shining, with a few punctures in the posterior part and very lightly strigose transversely in the anterior part. The forehead is divided from the clypeus by a fine, feebly elevated carina, and is very shining, with a very few punctures. The hinder margin of the head is

produced backward, forming a pair of upward curving, nearly parallel horns behind the eyes, united at the base by a lamina, which is a little elevated in the middle, forming a rectangular process. The pronotum is a little hollowed behind each horn, leaving a slight rounded prominence between. The clypeus in ♀ is closely transversely strigose and not shining, except behind. It is separated by a very strongly elevated, nearly straight carina from the smooth forehead, and there is a similar parallel carina between the eyes. The anterior margin of the pronotum is nearly vertical, and the upper edge of the declivity forms a short but strongly marked straight carina on each side of the middle.

- Length, 7.5-13 mm; breadth, 4-7 mm.

33*. Onthophagus sternalis*

Diagnostic characters

- Black, smooth and shining, with the antennae and mouth parts reddish yellow. Oval, deeply waisted, and highly convex.
- The head is short but minutely bilobed at the front margin, the eyes not very small above, the sides of the head bluntly angular in front of the eyes, the clypeus separated from the forehead by a rather strong, nearly straight carina, and the posterior margin elevated into a similar carina.
- The pronotum is highly convex, finely and evenly punctured, more coarsely and rather rugosely near the front angles, and with an oblique depression on each side near the hind angles, containing moderately large granules. There is a well-marked median longitudinal groove upon the posterior half of the pronotum. The front angles are blunt, the sides almost straight in front, sinuate behind, and the base very obtusely angular in the middle.
- The elytra are finely striate, the intervals flat, and minutely, numerously punctured.
- The pygidium is fairly strongly and closely punctured. The metasternum is vertical in front and strongly compressed laterally, forming a blunt process. It is finely and not closely punctured in the middle, and more strongly and closely at the sides. The front tibiae are short and stout. The clypeus in ♂ is strongly and closely punctured. The clypeus in ♀ is transversely

rugulose.

- Length, 7-10 mm; breadth, 4.5-6 mm.

34. *Onthophagus exquisitus*

Diagnostic characters

- Black, opaque above, with the head and pronotum fiery coppery red, sometimes with golden or greenish reflections, and the antennae and mouth organs bright yellow. Elongate oval, rather deeply waisted, extremely convex.
- The head is short and broad, rather flat, but a little hollowed between the eyes, with the posterior margin a little thickened, the sides bluntly angular, the clypeus broadly rounded. The surface is closely granular, becoming transversely rugulose upon the clypeus.
- The pronotum has a well marked posterior median groove, and is finely, evenly, and rather asperately punctured on each side of the middle and granular at the sides and in the middle behind. The granules are oval, rather large and close in the inner lateral part, finer and less close elsewhere. The front angles are blunt, the sides gently rounded in front and sinuate behind, and the base obtusely pointed in the middle.
- The elytra are finely striate, with the intervals flat and minutely granular.
- The pygidium is finely and closely punctured. The metasternum is pointed and vertical in front, the shield is evenly and not very finely punctured, and the sides are finely and closely punctured.
- Length, 5-6 mm; breadth, 3 mm.

35. *Onthophagus arboreus*

Diagnostic characters

- Deep metallic green or coppery, with the elytra black, the tibiae and tarsi dark red, and the antennae bright orange. The upper surface bears only very minute, scanty and inconspicuous pale setae. Elongate oval, deeply waisted, and highly convex.
- The head is short and broad and very flat, the sides bluntly angulate before the eyes, the clypeus transversely rugose, with its front margin uniformly rounded and the forehead punctured and a little hollowed.

- The pronotum has a rather strong longitudinal median impression on its posterior half and is finely but sparingly punctured in the middle, but the punctures become indistinct, and are replaced by granules of varying shape and size at the sides. The front angles are very blunt, the sides are feebly rounded in front, slightly sinuate behind, and the base is very bluntly angulate in the middle.
- The elytra are finely striate, with the intervals slightly convex, not very shining, and finely and sparingly asperate-punctate.
- The pygidium is shining and rather evenly, not closely or very finely, punctured. The metasternum is produced into a blunt process anteriorly, and is finely and very sparsely punctured in the middle and coarsely and shallowly at the sides. The two sexes are almost alike.
- Length, 4.5 mm; breadth, 3 mm.

36*. Onthophagus ramosus*, Wied.

Diagnostic characters

- Opaque, black or very dark blue black or indigo black above, with the lower surface shining black. Broadly oval, compact, moderately convex almost without hair or setae above or beneath.
- The head is almost semi-circular in outline, with the entire surface transversely rugose, the front margin reflexed, the clypeus separated from the forehead by a slight rounded carina, and the vertex bearing a pair of backwardly inclined horns united by a straight carina between the eyes, which has a slight sharp point in the middle.
- The pronotum is moderately closely punctured, the punctures rather coarse and confluent at the sides and finest and least close near the middle of the base. There is a slight flattening or feeble depression at the middle of the anterior part. The front angles are bluntly produced, the sides nearly straight, the margin distinct all round, and the base gently rounded and not angulate in the middle.
- The elytra are finely striate, the striae, finely punctured, the intervals flat and extremely finely and sparsely punctured except at the sides, where the punctures are larger and more numerous.
- The pygidium is opaque and rather finely punctured. The lower surface is

very smooth and shining, with the metasternum closely punctured in front, the meso-metasternal suture straight the middle and hind femora with a few setigerous punctures near the end. In ♂ the horns are long and compressed laterally, diverge strongly at the base, curve outward, and again approach one another at the tips, and each bears a strong tooth near the middle of the anterior edge. The female resembles in all respects the males of low development except in the unemarginate last ventral sternite.

- Length, 8-11.5 mm; breadth, 5.5-6.5 mm.

37*. Onthophagus amplexus*, Sharp

Diagnostic characters

- Deep metallic green, dark blue or bluish black, very smooth and shining beneath, closely sculptured and not very shining above, with scanty and inconspicuous greyish hairs at the sides. Oval and compact in shape.
- The head is semi-circular and entirely rugosely granular, with a clothing of short recumbent hairs, and bears a strong anterior carina and a pair of posterior horns, directed backward and united at the base.
- The pronotum is long, rugosely granular, completely margined, with the front angles bluntly produced and the base strongly rounded, obtusely angular in the middle, but not lobed. It is excavated in front and the dorsal part is produced forward.
- The elytra are rather indefinitely striate; with the intervals slightly convex and closely and deeply punctured.
- The pygidium is opaque and moderately punctured. The front angles of the prothorax are hairy beneath, the sides of the metasternal shield and those of the metasternum are strongly but scantily punctured, and there is a closely punctured patch in the middle of the hind margin. The middle and hind femora bear only scattered punctures.
- The clypeal carina in ♂ is short, and the vertex bears a pair of long slender horns, strongly curved outward, united by a continuous carina and enclosing part of a circle. The connecting carina is sharply toothed in the middle. The anterior part of the pronotum is deeply hollowed and very smooth and shining in the cavity, and the posterior margin of the cavity is

produced obliquely forward in the middle forming It strongly compressed knife-like horn, with its tip rounded and, at the greatest development, a very little thickened. The clypeal carina in ♀ is longer and more strongly elevated, and the posterior carina is produced straight backward at each end, forming a pair of rather short parallel horns. The anterior part of the pronotum is more narrowly and shallowly excavated, but fairly deeply on each side, and the posterior margin of the excavation is produced forward as a sharp edged rounded lobe.

- Length, 12-15 mm; breadth, 8-9 mm.

38*. Onthophagus atropolitus*, d'Orb.

Diagnostic characters

- Smooth, shining black, the elytra a little less shining than the head and pronotum, and the latter with a small opaque area in the middle of the base; the legs and lower surface pitchy red, the antennae light red and thinly clothed with light hairs at the sides beneath. Rather narrowly oval in shape.
- The head is sub-circular, with the clypeus transversely rugose, its margin reflexed and entire, the forehead separated by a strong rounded carina.
- The pronotum is feebly punctured (almost unpunctured in the male), completely and finely margined, the front angles blunt, the sides nearly straight, and the base very obtusely angulate in the middle.
- The elytra are finely striate and the intervals are flat and not distinctly punctured.
- The pygidium is shining and thinly, but fairly strongly, punctured, and the sides of the metasternum are similarly punctured. The basal joint of the antennae has a minutely serrate carina in front. The forehead in ♂ is smooth and shining, and pair of short erect and parallel horns arises between the eyes. The anterior part of the pronotum is vertical, and its upper edge forms a sharp carina. In small males the horns are replaced by a strongly elevated carina a little produced at each extremity. The forehead in ♀ is feebly rugose and the vertex bears a straight carina. The pronotum is very finely punctured in front and has a very narrow vertical anterior margin.

- Length, 8-12.5 mm; breadth, 4.5-7 mm.

39. *Onthophagus furcillifer*, Bates

Diagnostic characters

- Black, not very shining, with the head and pronotum, or at least the front and sides of the latter, obscurely coppery, the antennae and mouth organs yellow and the body clothed above and beneath with pale setae, those of the upper surface extremely minute. Oval and very convex.
- The head is short but not very broad, the ocular lobes are strongly rounded, the clypeus rounded but very feebly emarginate in the middle, and separated by a strongly rounded carina from the sparingly punctured forehead.
- The pronotum is closely covered with large annular punctures, the centre of each forming an elevated granule. The front margin is vertical and rather smooth in the middle, and at its upper edge there are four nearly equidistant tubercles, the two inner ones more or less united together. The front angles are blunt the lateral margins gently rounded in front and sinuate behind, the base very obtusely angulate in the middle.
- The elytra are fairly strongly striate, the dorsal intervals flat and bearing minute scattered granules.
- The pygidium bears close shallow punctures, the metasternal shield is strongly but sparingly punctured, and the sides of the metasternum are less strongly but more closely punctured. The clypeus in ♂ is shining and bears a few large deep punctures, and between the eyes a vertical lamina rises that dilates and bifurcates slightly at its summit. The vertical front margin of the pronotum is broad and the four marginal tubercles are large and project freely. The clypeus in ♀ is rugose, and there is a straight posterior carina between the eyes. The vertical front margin of the pronotum is narrow, the two inner tubercles are united and the two outer ones feeble.
- Length, 5.5-6 mm; breadth, 3-5 mm.

40*. Onthophagus circulifer*

Diagnostic characters

- Dull black, with the head, the anterior margin of the pronotum, and the lower surface dark coppery and shining, the antennae and mouth organs yellow, and clothed above with minute erect grey setae. Oval, very compact and convex.
- The head is fairly broad, coarsely and sparingly punctured, with the ocular lobes strongly rounded externally.
- The pronotum is very convex and evenly and closely punctured, with large annular punctures, except at the front margin, which is vertical; smooth, and shining, its upper edge usually bearing four very feeble prominences, the two middle ones sometimes fused together. The front angles are blunt, the lateral margins nearly straight in front, gently sinuate behind, and the base strongly rounded.
- The elytra are shallowly striate, the intervals flat, with minute and not very numerous granules.
- The pygidium bears large annular punctures. The metasternal shield bears large scattered punctures and a median groove, and the sides of the metasternum are similarly but a little more closely punctured. The clypeus in ♂ is slightly produced and bilobed in front, and the posterior part of the head is produced into a pair of short parallel horns inclined backwards, not far apart and united at the base by a carina which bears a sharp tooth in the middle. The clypeus in ♀ is very short, rounded and entire in front, divided from the forehead by a short strongly curved carina, and there is a straight posterior carina between the eyes.
- Length, 5.5-6 mm; breadth, 3-3.5 mm.

41*. Onthophagus amicus*, Gill.

Diagnostic characters

- Black and moderately shining, with the head coppery and the front of the pronotum sometimes slightly metallic, each elytron with a red spot upon the shoulder and another at the outer part of the posterior margin, the antennal foot-stalk, tarsi, and mouth-organs red, and the upper surface, except the head, fairly thinly clothed with short, stiff, grey setae. Broadly oval, compact and convex.

- The head is smooth and shining, not very broad, with a few scattered punctures, the sides strongly rounded and the clypeus bilobed.
- The pronotum bears large, close, umbilicate punctures. The front angles are sharply produced, the sides feebly bisinuate in front and nearly straight behind, and the base is strongly rounded.
- The elytral striae consist of chains of large, contiguous, annular punctures and the intervals are flat and bear conspicuous but not very numerous or regular granules.
- The pygidium bears large not very numerous punctures. The metasternal shield bears a few large scattered punctures, and the sides of the metasternum have fairly close annular punctures. The front angles of the pronotum are a little hollowed beneath. The lobes of the clypeus in ♂ are bluntly rounded and the head bears between the eyes an erect quadrate lamina gently emarginate at its upper edge. The front margin of the pronotum is nearly vertical in the middle. The clypeus in ♀ is sharply notched in front and the two lobes are acute. It is separated from the forehead by a rounded carina, and there is a straight carina between the eyes. The pronotum has a slight double prominence immediately behind the front margin.
- Length, 4-4.5 mm; breadth, 2.5 mm.

42*. Onthophagus dama*, Fabricius

Diagnostic characters

- Dark greenish-or bluish-black or coppery, with the lower surface, head, and pronotum shining, and the elytra not very shining. Oval, compact, not very convex, entirely without hair or setae, above. The clypeus is semi-circularly rounded, with the margin a little more strongly raised in the middle than at the sides.
- The pronotum is finely and sparsely punctured, with the front angles blunt, the sides nearly straight, and the base gently rounded.
- The elytra bear distinctly punctured striae with the intervals almost flat and extremely finely and sparsely punctured, except at the sides, where the punctures are rather larger and more numerous.

- The pygidium is opaque and moderately punctured, the front and sides of the metasternum are strongly punctured. The clypeus in ♂ is feebly punctured, bordered behind by a feeble carina or with none, and the vertex bears a pair of horns, arising close to the eyes, inclined slightly backward, curving outward, and approaching one another at the tips, each having an external tooth beyond the middle. The horns are often very short, without tooth and not curved, and sometimes they are merely slight prominences. The clypeus in ♀ is strongly transversely rugose, separated from the forehead by a strong curved carina, and sometimes with another parallel carina close to and in front of the last. Upon the middle of the vertex there is an erect, flattened and truncate tubercle. The pronotum is a little more strongly punctured in front than that of the male, and bears two slight tubercles just behind the front margin, not very close together.
- Length, 8.5-11 mm; breadth, 5-7 mm.

43. *Onthophagus hamaticeps*

Diagnostic characters

- Black and very shining, with the head and pronotum dark coppery and the elytra red at the shoulders and posterior margins. The legs, antennae, and mouth-organs are also red. Oval, compact, and convex, entirely devoid of hair or setae above.
- The head is short and broad, sub-angulate on each side in front of the eyes.
- The pronotum is fairly finely and not very closely punctured, the front angles are rounded, the sides are gently curved in front and behind, and the base is strongly rounded.
- The elytra are finely striate, with indistinct and remote punctures in the striae, the 7th stria strongly curved; the intervals flat and very minutely and sparsely punctured.
- The pygidium is sparsely but rather strongly punctured. The metasternal shield is strongly punctured in front, very finely and sparsely behind, and the sides of the metasternum are coarsely but not closely punctured. The front angles of the prothorax are very slightly hollowed beneath. The clypeus in ♂ is finely and sparsely punctured, with its front margin a little

excised in the middle. The posterior part of the head bears an elevated crescent, the two ends of which are produced obliquely forward and upward as short, stout, parallel horns and very smooth.

- Length, 3 mm; breadth, 2 mm.

44*. Onthophagus fasciatus*, Bouc.

Diagnostic characters

- Bright yellow, with the head, the middle of the pronotum as far usually as the front and sometimes the hind margin (but leaving always pale lateral margins and sometimes a narrow pale median posterior line), the sutural margins of the elytra and an irregular transverse band touching the suture behind the middle, and the lateral margin before the middle (but leaving the epipleurae pale), the greater part of the lower surface and the tibiae, black; the pronotum strongly, and other parts feebly or not at all suffused with a metallic green lustre. The antennae, mouth-organs, and the greater, part of the legs are yellow. The upper surface, with the exception of the head, is not very shining, and the upper and lower surface and the pygidium are very thinly clothed with yellow setae. Oval, deeply waisted, and very convex.
- The head is not very broad, the ocular lobes are gently rounded externally, and the clypeus is a little produced.
- The pronotum is fairly closely but not very finely punctured, the front angles are rather sharply produced the lateral margins almost straight in front and sinuate behind, the hind angles very obtuse, and the base rounded.
- The elytra are rather deeply striate, the dorsal intervals feebly convex and finely but fairly numerously punctured.
- The pygidium is rather strongly punctured, the metasternal shield very sparsely and minutely, and the sides of the metasternum not very strongly or closely. The clypeus is feebly punctured in the middle and more strongly and closely at the sides, produced to a point, which is gently reflexed and divided by a slight curved carina from the sparsely punctured forehead. The posterior margin of the head is produced backward and gently curved upward, the median part forming a curved tongue-like

process and the sides a pair of nearly parallel horns, broad at the base and tapering to the tips. The pronotum is almost vertical and finely and sparsely punctured in front.

- The clypeus in ♂ is transversely rugose, the sides are convergent, and the front margin is strongly reflexed and nearly straight in the middle, the forehead is fairly strongly punctured and separated from the clypeus by a strong, nearly straight carina, and there is a second strong carina upon the vertex. The pronotum bears a well-marked transverse carina in the middle just behind the front margin.
- Length, 5-6.5 mm; breadth, 3-4 mm.

45. *Onthophagus expansicornis*, Bates

Diagnostic characters

- Bright orange-red, moderately shining, with the head, a median patch upon the pronotum, usually dilating from front to hind margin, but sometimes occupying the whole pronotum except the lateral margins or the front angles, the sutural margins of the elytra, expanding in the middle into an oval patch, the lower surface, tibiae, and tarsi dark, more or less suffused with a coppery or metallic greenish lustre. The antennae and mouth-organs are yellow, and the upper surface is thinly clothed with minute yellowish setae. Broadly oval and convex.
- The head is not broad, the clypeus is a little produced, and the ocular lobes are not strongly rounded externally.
- The pronotum is rather closely and not very finely punctured, except in the middle of the front margin. The front angles are fairly sharp, the lateral margins almost straight in front, gently sinuate behind, and the base is rounded.
- The elytra are finely striate, the intervals flat, fairly closely and not very minutely punctured.
- The pygidium is rather strongly punctured. The metasternal shield is finely and very sparsely punctured, and the sides of the metasternum a little more strongly and closely. The head in ♂ is shining and rather scantily punctured, the clypeus with nearly straight sides, pointed and gently recurved in front, and not separated from the forehead, and the posterior

part of the head is produced backward on each side as a pair of horns strongly curved outward, not united, but broadly and rather abruptly dilated inwardly at the base of each. The pronotum is broadly and shallowly hollowed and smooth in the middle of the anterior part. The clypeus is rugosely punctured, feebly rounded, but a little narrowed in front, separated by a short, nearly straight carina from the strongly punctured forehead, and there is a strong, straight, posterior carina. The front margin of the pronotum is narrow, but rather steep in the middle, with a short, straight, upper marginal carina.

- Length, 6-7.5 mm; breadth, 4-4.5 mm.

46*. Onthophagus luridipennis*, Boh.

Diagnostic characters

- Brownish-yellow, with the head, the pronotum except the margins and a median longitudinal line at the base, the elytral striae and punctures and parts of the lower surface, dark, the head and pronotum suffused with metallic lustre. The dark colour may extend over the whole of the pronotum, except the front angles, and the elytra may be more or less dark except at the base and sutural margin. The upper surface is not very shining, and is scantily clothed with minute pale setae. Broadly oval and convex.
- The head is closely punctured and not very broad. The pronotum is closely and evenly, not very finely, punctured. The front angles are fairly sharp, the sides gently rounded in front and feebly sinuate behind, the base rounded and very bluntly angulate in the middle.
- The elytra are finely striate, the intervals flat and finely and fairly closely punctured.
- The pygidium is rather strongly punctured. The metasternum is very finely punctured in the middle and rather strongly at the sides. The head in ♂ is flat, without carinae, a little produced, pointed and reflexed in front. The head behind the eyes is produced backward into a pair of flat, widely separated and divergent horns, strongly curved and fitting closely against the pronotum. The pronotum is extremely convex, with its anterior part rather smooth, flat, and sloping. The clypeus in ♀ is finely rugose, slightly

narrowed but rounded in front, and separated by a straight, rather strong carina from the punctured and hollowed forehead. There is another straight carina between the eyes. The pronotum bears two blunt tubercles closely contiguous immediately behind the front margin.

- Length, 5-7 mm; breadth, 3-4 mm.

47*. Onthophagus beesoni*

Diagnostic characters

- Testaceous yellow, with the head, a large median patch upon the pronotum, usually reaching the front and hind margins but leaving a small pale spot in the middle of the latter, an irregular transverse band crossing the middle of the elytra and sometimes broken into several irregular patches, the tibiae, tarsi, and usually the middle, of the sternum, and the abdominal sutures, dark coppery. Oval, very convex, rather shining, with a thin and inconspicuous clothing of pale setae upon the upper surface.
- The head is fairly strongly and evenly punctured, not very wide, the ocular lobes not strongly dilated.
- The pronotum is very convex, rather strongly and closely punctured. The front angles are fairly sharp, the lateral margins are gently rounded in front, gently sinuate behind, the hind angles are distinct but obtuse, and the base is rounded, with an obtuse angle in the middle.
- The elytra are finely striate and the dorsal intervals are flat and finely and rather numerously punctured.
- The pygidium is moderately punctured, the metasternal shield finely and unevenly, and the sides of the metasternum strongly but not closely. The head in ♂ is flat, without carinae, the front margin of the clypeus is nearly straight, strongly reflexed, and produced into a short rounded process in the middle. There is a pair of slight tubercles placed rather far apart between the eyes. The anterior part of the pronotum is broadly elevated in the middle and produced into a slight tubercle on each side. The surface between the elevation and the front angle may be a little hollowed and smooth. The front legs are elongate, the tibia very long and slender, with its external teeth short, and far apart, and the terminal spine long, stout, and abruptly bent at the end. The clypeus in ♀ is feebly rounded in front,

nearly straight at the sides, and separated by a strong, nearly straight carina from the forehead, and there is a short, straight posterior carina between the eyes. The front tibia is broad and strongly curved.

- Length, 7-8.5 mm; breadth, 4 mm.

48. *Onthophagus mopsus*, F.

Diagnostic characters

- Bronze or blackish brown, with a slight metallic green lustre, but not very shining, clothed fairly closely above with very minute greyish setae. Oval, compact, not very convex.
- The head is rather broad, with the clypeus rugosely punctured, its front margin evenly rounded and strongly reflexed. The pronotum is finely and closely punctured, scarcely impressed at the base on each side. The front angles are fairly sharp, the sides nearly straight in front and feebly sinuate behind, and the base gently rounded.
- The elytra are finely striate, with the intervals flat, the dorsal intervals minutely granulate, and the lateral ones fairly closely punctured.
- The pygidium is moderately strongly punctured, and the metasternum is sparsely punctured in the middle and a little more closely at the sides. The clypeus in ♂ is divided from the forehead by a curved carina, and between the eyes arise a very short, erect, conical horn or tubercle. The smooth anterior margin of the pronotum is vertical, and there is a short straight carina in the middle of its upper edge. This is occasionally divided into two slightly oblique carinae. The clypeus in ♀ is divided from the forehead by a curved carina, and there is a straight carina between the eyes. The smooth anterior margin of the pronotum is vertical, and there is a short straight carina in the middle of its upper edge.
- Length, 6-8 mm; breadth, 4-5 mm.

49. *Onthophagus vaulogeri*, Bouc.

Diagnostic characters

- Black and shining, with the head and pronotum deep blue or green and each elytron decorated with an orange patch at the base, usually extending from the outer margin almost to the suture, and sometimes also a smaller patch near the apical margin. The antennae, mouth organs, and tarsi are reddish, and the upper surface is fairly closely clothed with very minute greyish setae. Oval, compact and convex.

- The head is very smooth, shining and sparsely punctured. The sides are rounded and the clypeus is a little produced.
- The pronotum is rather finely, closely and evenly punctured. The front angles are a little produced, the sides straight in front and feebly sinuate behind, and the base is strongly rounded.
- The elytra are finely striate, the intervals flat and finely and fairly closely punctured.
- The pygidium is moderately finely and closely punctured, and the metasternum bears fairly fine and extremely scanty punctures upon the shield and at the sides. The clypeus in ♂ is produced to a blunt point in front and strongly reflexed, the sides of the head are a little dilated and reflexed, and the posterior part is produced backward as a triangular plate, the apex of which curves upward as a short pointed horn. The front margin of the pronotum is smooth and shining and has a slight depression behind the cephalic process. The front tibiae are elongate and curved. The clypeus is emarginate in front and separated by a curved carina from the forehead, and there is a straight carina between the eyes.
- Length, 4-6 mm; breadth, 2.5-3.5 mm.

Key to the Indian species of genus *Rhomborrhina* Hope

1. Elytra extremely glossy, without puncturation

………. glaberrima Westw.

50*. Rhomborrhina glaberrima*

Diagnostic characters

- Deep green, greenish-purple or purplish-black. Moderately convex and elongate in shape, and very smooth and glossy. The clypeus is flat, finely and closely punctured, rather narrow, parallel-sided, and as long as it is broad, measured from the point of insertion of the antennae.
- The pronotum is triangular, with the sides nearly straight and the upper surface quite smooth and unpunctured, except for a few fine punctures at

the sides.

- The elytra are also quite smooth, except for an incomplete series of punctures upon each, adjoining the suture, and the posterior margins, which are rugose and thinly clothed with yellow hairs.
- The pygidium is rugose and rather thickly clothed with similar hairs. The sternal process is slender, curved and pointed. The metasternum is smooth; deeply channeled in the middle and clothed with yellow hairs at the sides, and the abdomen is entirely smooth. The club of the antennae in ♂ is very long, the middle and hind tibiae are thickly fringed with yellow hair at the inner edge, and the abdomen is arched beneath and slightly channeled in front.
- Length, 23-26 mm; breadth, 10.5-12 mm.

Key to the Indian species of genus *Heterorrhina* Westw.

1. Elytra distinctly costate

……… mutabilis Hope

2. Body rather long and depressed; pygidium granulose

……… nigritarsis Hope

51*. Heterorrhina mutabilis*, Hope

Diagnostic characters

- The two sexes of this species are remarkably different in form and colour, and possess little in common except a closely punctured upper surface, costate elytra, short clypeus and very short sternal process.
- The male is shining green, blue-green, fiery-red, or purple above and beneath. The body is short, compact and moderately depressed. The clypeus is much shorter than it is broad, quadrate, finely rugosely punctured, with the front margin straight, strongly reflexed and not toothed or notched, and the forehead without a distinct carina. The pronotum is strongly punctured all over, moderately narrowed in front and sinuated at the sides beyond the middle. The scutellum is sparingly punctured. The elytra are coarsely and closely punctured in rows which enclose two costae upon the disc of each, only the punctures towards the sides and apices being irregular. The pygidium is rugose. The sternal process is

narrow, but very short and blunt. The metasternum is thinly punctured at the sides and broadly furrowed at the middle, and the abdomen is barely punctured and neither channeled or arched beneath. The front tibiae are unarmed, and the middle and hind tibiae moderately fringed.

- The female is black, or brownish black, scarcely shining, elongate, nearly parallel-sided, and more convex than the male. The puncturation is similar, but that of the elytra shallower and less distinct. The head is more coarsely rugose, with a posterior carina terminating abruptly in front but scarcely produced. The front margin is a little produced upwards till the middle, the process generally ending in two teeth. The prothorax is almost semi-circular in shape. All the tarsi those of the hind legs, are very short, the front tibia are broad and bidentate, and the hind tibiae are very scantily fringed at the inner edge.
- Length, 19-21 mm; breadth, 9-10 mm.

52*. Heterorrhina nigritarsis*, Hope

Diagnostic characters

- Grass-green, golden-green, fiery red, purple or indigo, often with the elytra (except along the suture), the femora and tibiae lighter in colour than the rest of the body. The shape is moderately elongated, the female more oval and compact than the male.
- The head is rather short, rugosely punctured, with a smooth median carina (which is sharply elevated and free in front in the female only). The clypeus is rather broader than it is long with the margins curvilinear and strongly reflexed and the front edge broadly elevated in the middle.
- The prothorax is rather short, narrowed in front in the male, and approximately semi-circular in the female, with the sides situated beyond the middle and the disc rather strongly punctured all over.
- The scutellum bears a few punctures and the elytra are rather coarsely punctured, with two costae indicated upon the disc of each and the external margins rugose posteriorly.
- The pygidium is rugosely granular and hairy and bears a broad shallow impression on each side. The metasternum is coarsely punctured and clothed with yellow hair except in the middle, and the abdomen is very

smooth. The sternal process is not very long and tapers to a point.

- The two sexes differ considerably in appearance. The male is more elongate, more shining, and frequently of a brighter colour than the female, and in addition to the different from of the head, prothorax and front tibiae, the legs and the club of the antennae are more slender. The abdomen is not channeled beneath.
- Length, 20-23 mm; breadth, 10-11 mm.

Key to the Indian species of genus *Cetonia* Fabr.

1. Pronotum decorated with two white lines

……… bensoni Westw.

2. Pronotum without white lines

……… rutilans Jans.

53*. Cetonia bensoni*, Westw.

Diagnostic characters

- Bright coppery or golden-green, with the pronotum, scutellum and elytra deep green and opaque, and the head, legs and lower surface shining; decorated with whitish markings, consisting of an oblique line on each side of the pronotum, not reaching the front or hind margin and sometimes interrupted; a broken transverse line upon each elytron adjoining the outer margin considerably behind the middle, another behind the last, adjoining the inner margin, a spot near the apical angle and a few others scattered irregularly; a small spot near each lateral angle of the pygidium, and an inconspicuous line of spots along each side of the abdomen beneath.
- The body is depressed, broader than the other species of this genus, and not perceptibly narrowed towards the extremity. The surface, except in worn specimens, is clothed above and below with yellow hairs or setae, short upon the upper surface and absent from the middle of the pronotum, metasternum and abdomen.
- The head is strongly punctured and deeply notched at the front margin. The pronotum is very coarsely punctured and its sides gently curved. The scutellum is long and unpunctured.
- The elytra have each two well-marked costae; they are strongly punctured

between and out and lateral side these, and rugose at the sides and apices. The sides are strongly sinuated behind the shoulders and do not converge towards the extremities, which are broad, with the sutural angles slightly spinose.

- The pygidium is finely granulated, the metasternum rugose at the sides, and the abdomen strongly punctured except in the middle. The two terminal teeth of the front tibia are very sharp and slender.
- Length, 19-21 mm; breadth, 10-12 mm.

54*. Cetonia rutilans*, Jans.

Diagnostic characters

- Coppery-red, with the pronotum, scutellum and elytra opaque green, and the head, legs and lower surface shining and clothed with yellow hairs; decorated with a pair of minute white spots placed transversely at the middle of the pronotum, a transverse white line adjoining the outer margin of each elytron considerably behind the middle and another posterior to it adjoining the inner margin, with sometimes a few inconspicuous scattered spots anteriorly, and a minute spot near each lateral angle of the pygidium. The lower surface is immaculate. Moderately depressed in shape and not much narrowed behind. The clypeus is strongly punctured, broadly, emarginate in front and not narrowed.
- The pronotum is strongly but sparingly punctured, with the sides strongly margined, contracted in front and rather feebly angulated in the middle. The scutellum is long and narrow.
- The elytra are strongly punctured, distinctly bicostate on the disc, and rugosely punctured at the sides and apex. The sides are strongly sinuated behind the shoulders and the apical angles are slightly spinose.
- The pygidium is very finely granulated and hairy, the metasternum corrugated and hairy, except along the middle line; and each segment of, the abdomen (except the last) has a transverse line of punctures along the middle, very strong and confluent laterally. The abdomen is slightly hollowed in the ♂, and the inner spur of the hind tibia is very blunt in the ♀.
- Length, 17-21 mm; breadth, 9-10 mm.

Key to the Indian species of genus *Protaetia* Burmeister

1. Legs green or blue

……… pretiosa Nonf.

55. *Protaetia pretiosa*, Nonf.

Diagnostic characters

- Entirely deep golden-green or blue-green, with the tarsi generally deep blue; very smooth and shining and without markings or clothing, except some pale yellow hairs upon the legs and a few very minute setae upon the sides of the metasternum. It is a broad, robust and moderately convex species.
- The head is relatively small, scantily punctured, with the clypeus rather quadrate, the front margin strongly reflexed and very feebly notched. The prothorax is strongly punctured at the sides and scantily or not at all in the middle; narrow in front and strongly and rapidly dilated towards the base, the sides being little curved and the hind angles moderately distinct. The basal margin is not strongly excised before the scutellum, and the latter is rather short and triangular, without punctures except at the base.
- The elytra are minutely and scantily punctured in rows, with rather stronger scattered punctures near the apex.
- The pygidium is decorated with transverse striations, the sides of the metasternum are very coarsely strigose, and the abdomen is almost smooth beneath. The sternal process is short and broad, but slightly prominent, the front tibia has three very short teeth and the hind tibia has a fringe of short yellow hairs and is rather digitate at the end. The apical angles of the elytra in ♂ are sharply produced and the pygidium is lightly strigose. The puncturation is stronger in ♀ than in the ♂, and the pygidium and last ventral segment are closely strigose.
- Length, 22-27 mm; breadth, 12.5-15 mm.

Key to the Indian species of genus *Oxycetonia* Burmeister

1. Pygidium transversely strigose

……… albopunctata F.

56. *Oxycetonia albopunctata*

Diagnostic characters

- Black and shining, with the pronotum, scutellum, and elytra brick-red and opaque, the circumference of each elytron (interrupted in front) and a large discoidal spot, and a narrow lateral patch upon each side of the pronotum, black. There are also white markings, consisting of a narrow line at each lateral margin of the prothorax, a minute spot at the apex of the scutellum, one on each mesosternal epimeron, four at the outer margin of each elytron (the fourth in the apical angle), and a short transverse bar, more or less interrupted, crossing the suture before the middle, four spots placed transversely upon the pygidium, and a single or double series on each side of the body beneath. The head is long, finely and closely punctured, and bluntly bidentate in front.
- The pronotum is rather evenly and not closely punctured, with the sides gently curved, the hind angles completely rounded off, and the base abruptly emarginate.
- The scutellum is bluntly pointed, and the elytra are decorated with rows of rather coarse punctures.
- The pygidium is finely transversely strigose, the metasternum rugose at the sides, and the abdomen scantily punctured. The spurs of the hind tibia in ♂ are sharper than in the ♀.
- Length, 14-16 mm; breadth, 7-8 mm.

Key to the Indian species of genus *Agerstrata* Latreille

1. Pygidium very short, broad and transversely carinated, surface strigose ………. orichalcea L.

57. *Agerstrata orichalcea*, L.

Diagnostic characters

- Metallic blue, green, purplish or black, with the coxae, femora, mesosternal epimera, pygidium and sides of the sternum and abdomen orange-red, and sometimes an inconspicuous narrow patch of the same colour at the lateral edge of the prothorax. The body is very long and narrow and rather flat. The clypeus is narrow and rather straight-sided, lightly punctured, but rather more strongly in front.

- The pronotum is very finely coriaceous, with minute punctures which are most distinct at the sides. The lateral margins are finely raised, the posterior angles-well marked but rounded, and the basal lobe rather pointed but not long.
- The elytra are very long, smooth, scarcely perceptibly punctured, except at the sides, and rather rugose at the extremity. The outer margins are rather feebly sinuated behind the shoulders; the inner margins (at least at the posterior half) are strongly raised, and the apical margins a little excised beside the apical angle, which is produced.
- The lower surface of the body is very smooth, but the sides of the metasternum are very finely and densely punctured. The club of the antennae is longer than the footstalk in both sexes and considerably longer in the male, although varying greatly. In the latter sex the sides of the pronotum are more divergent behind, the last abdominal segment is deeply emarginate in the middle and the ventral part of the pygidium correspondingly lobed.
- Length, 36-46 mm; breadth, 15-22 mm.

Key to the Indian species of genus *Xylotrupes* Hope

1. Pygidium moderately strongly and closely punctured, rugose at the sides ………. gideon L.

58*. Xylotrupes gideon*, L.

Diagnostic characters

- Chestnut red or brown with the head, pronotum and legs generally darker, the sternum and hind coxae clothed with a fine pubescence. The pronotum in ♂ has a dull satiny gloss, except at the anterior sloping part and the front part of the horn, and is very finely and sparingly punctured. The scutellum is short and broad, and has a fine irregular puncturation.
- The elytra have a very fine and close, but irregular and coriaceous, puncturation.
- The pygidium is moderately strongly and closely punctured, becoming rugose at the sides, and its ventral portion is smooth and shining. The

abdomen is shining beneath in the middle and irregularly rugose at the sides. The head is armed with a horn projecting obliquely forward and upward and nearly straight, but terminating in two diverging points which curve backwards. The basal part of the horn is laterally compressed and almost carinate above, ending in a strong compressed tooth, beyond which the born becomes depressed.

- The pronotum is drawn out into a cone directed obliquely forward and produced at the apex into a gently curved horn bifid at the extremity, with the points directed a little downwards. The sides of the horn are carinate on the basal part of the lower surface. In fully developed specimens the thoracic horn reaches beyond the cephalic horn and, measured from the tip to the base of the thorax, considerably exceeds the elytra in length. The inner edge of the front tibia is gently bisinuate and the outer edge armed with three very sharp slender teeth, of which the two uppermost are rather distant. ♀ is generally rather darker in colour and the upper surface is much more rugose.
- The head is very rugose, the pronotum coarsely punctured, the punctures coalescing at the front and sides, the scutellum thinly, and the elytra closely and irregularly, punctured. The pygidium is finely rugose and the abdomen irregularly punctured beneath.
- Length, 25-50 mm; breadth, 13-28 mm.

Key to the Indian species of genus *Episcapha* Lacord.

1. Upper surface devoid of hair

………. indica Crotch

59. *Episcapha indica*, Crotch

Diagnostic characters

- Black and shining, each elytron decorated with two pale yellow patches, the first placed at the basal margin and occupying the humeral angle, but with a small, completely or incompletely enclosed, black humeral spot and a deep circular emargination at the inner margin and three sharp tooth-like processes at the hind margin, the second patch placed beyond the middle, transverse and a little arched, with four sharp tooth-like processes anteriorly and three or four posteriorly. Rather narrowly elongate, moderately convex, smooth, and shining above, with a very fine clothing of dark pubescence beneath.

- The antennae are moderately slender, the third joint a little shorter than the fourth and the club as long as the preceding six joints together.
- The head is fairly strongly punctured, the clypeus rather more strongly; the eyes are large and prominent and separated by an interval barely equal to twice their radius.
- The pronotum is fairly strongly punctured, a little more finely and closely at the sides than in the middle, the lateral margins are evenly curved, strongly elevated, the front angles acutely produced, the hind angles bluntly quadrate and the base trisinuate. The scutellum is strongly transverse and very bluntly angulated behind.
- The elytra are very finely punctured, without distinct longitudinal lines, and a little wider at the shoulders than the pronotum at the base. The prosternum is strongly and closely punctured, the mesosternum longitudinally channeled on each side and the metasternum and abdomen beneath finely punctured.
- Length, 13-16.5 mm; breadth, 5-6.5 mm.

Key to the Indian species of genus *Megalodacne* Crotch

1. Antennae very short, club rather long

……… brachycera

2. Body sparsely punctured beneath; humeral angle black

……… consimilis

60*. Megalodacne brachycera*

Diagnostic characters

- Black, with each elytron decorated with two broad orange bands, the anterior one placed a little beyond the base, which it almost touches at the shoulder and again a little within it, and extending from the outer margin to near the suture, the posterior band a little before the apex, extending from the suture to near the outer margin, with its front edge toothed and its hind edge arched. Rather long and narrow, a little depressed; smooth and moderately shining.

- The head and pronotum are strongly and closely punctured, a little less so in the middle of the latter, the eyes very prominent but not very large, and divided by a space about three times as wide as their radius.
- The pronotum is about one and a half times as wide as it is long, with the sides nearly straight and parallel, the front angles fairly sharp, the hind angles minutely blunted and containing a rather well-developed angle-pore, the base finely margined at the sides and lobed in the middle. The scutellum is short and broad, and the elytra are everywhere finely but, distinctly punctured, with not very well-defined lines of larger punctures.
- The prosternum is very strongly punctured, except in the middle, the metasternum is strongly punctured at the sides and finely in the middle and the abdomen is finely and closely punctured.
- The antennae are short and stout, the 3rd joint only very little longer than the 2nd or 4th, joints 4 to 7 about as long as they are wide, 8 transverse and the last three rather large strongly transverse but not closely united, together almost as long as the preceding six.
- Length, 7-8.5 mm; breadth, 3 mm.

61*. Megalodacne consimilis*

Diagnostic characters

- Black and shining, each elytron decorated with two irregular transverse orange bars, the first placed behind the shoulder, almost reaching the outer margin, but more distant from the inner, and sending a short branch to the base, the second placed just before the extremity, reaching almost from side to side and a little produced forward in the middle. The abdomen beneath, the tarsi and the base of the antennae are dark red. Oblong oval, moderately convex.
- The head and pronotum are evenly and rather strongly punctured, the eyes prominent and divided by about three times their radius, the pronotum strongly transverse. The lateral margins of the pronotum are very fine, rounded in front, straight and parallel behind, the front angles are rather sharp, the hind angles blunt, and the base is finely margined except in the middle. The scutellum is very short and broad.

- The elytra are moderately convex and bear lines of fine, not very close, punctures, with the intervals extremely minutely and scantily punctured. The prosternum is finely and scantily punctured in the middle and coarsely at the sides. The mesosternum is very sparingly punctured, with a few of the punctures large at the sides, and the abdomen is finely and not closely punctured.
- Joints 2 to 8 of the antennae are a little elongate, the 3rd one and a half times as long as those adjoining, and the last three form a very loosely articulated club, the 9th not strongly transverse.
- Length, 5 mm; breadth, 2 mm.

62. *Anomala* sp.

Diagnostic characters

- Form extremely variable, sometimes short and globose, sometimes very long and narrow, with stout, moderate or very long and slender legs. The surface may be extremely smooth and shining, or strongly sculptured and opaque, and sometimes entirely clothed with hair. The membranous external fringe of the elytra is always distinct and in some species considerably developed. The clypeus is transverse, rounded or straight in front, rarely at all excised and never produced or rostriform. The eyes are prominent and sometimes very large.
- The prothorax is transverse, generally slightly lobed and never excised in front of the scutellum, and with or without a complete marginal stria at the base. The prosternum is not, or only very little, elevated behind the front coxae; in a few species (e.g. *A. anopunctata* and *A. enigma*) it forms a small acute vertical process, but is not bent forward between the front coxae as in the genus *Mimela*.
- The mesosternum is most commonly not produced between the middle coxae, but occasionally forms a process of varying shape, sometimes very short and rounded (*A. ebena*), sometimes slender and sharply pointed.
- The legs are very variable in development; the front tibia is armed with one, two, or three teeth and bears a single spur at the base of the tarsus; the middle and hind tibiae may be long or short, but are generally spinose externally, and each bears two terminal spurs; the tarsi are generally

moderately long, the claws always entire upon the hind feet, the longer one of the front feet, or of the front and middle feet, cleft, or all entire.

- The labrum is bilobed, not prominent, and horizontal in position and not presenting a face at right angles to the clypeus. The mandible is short and rounded, concealed when in repose, produced into several teeth at the tip, and bears a large, strongly-ridged, molar surface at the base. The maxilla is short and strong, generally bearing five sharp and nearly equal teeth, one of them terminal, the others in pairs behind, and all parallel. The palpi are 4-jointed, the last joint long. The mentum is approximately quadrate, feebly bilobed in front, with short, 3-jointed palpi. The apical tooth of the front tibia is usually shorter and sharper in the male than in the female, and the inner front claw more or less dilated.
- The club of the antennae is sometimes very long in the male, and the eyes may also be enlarged.
- Sexual differences are also found in different species in the coloration, sculpture of the elytra or pygidium, the hairy clothing of the latter, the form of the clypeus, margins of the elytra, spurs of the hind tibia, and other features.

63*. Adoretus* sp.

Diagnostic characters

- Variable in form, but generally elongate and rather depressed. Clothed above and beneath with short hairs, setae or scales, which may be dense, scattered or aggregated into numerous small patches, and sometimes interspersed with a few longer erect hairs.
- Head very variable in size, sometimes very broad, with large and prominent eyes.
- Clypeus large or small, generally more or less semi-circular, occasionally slightly emarginate in the middle. Labrum vertical and produced in the middle as a long incurved rostrum, truncated at the end, where it meets the mentum, and finely serrated on each side. Mandibles short and stout, separated by the rostrum, each having a large basal molar and a broad rounded external ramus. Maxilla short and stout, with a strongly chitinised lobe provided with about four very strong short teeth set obliquely; the

palpi rather long.

- Mentum short and broad, deeply emarginate at the middle of the anterior edge and deeply constricted at the sides for the insertion of the palpi.
- Antennae normally 10-jointed, in a few species 9-jointed. Pronotum short and scutellum small. Prosternum sometimes forming a well elevated vertical process behind the front coxae.
- Elytra closely, not serially punctured, with more or less visible narrow sutural, lateral and three discoidal costae; apical angles generally rounded off. The uniformity in the sculpture of the elytra is a rather characteristic feature. In certain species there is a peculiar smooth opaque lateral border (epipleura), due to the enlargement of the usually narrow reflexed part of the elytron, which in most species is only conspicuous near the shoulder. When dilated in this way the epipleura has always a very different texture from the remainder of the surface, from which it is separated by a very sharp carina.
- The pygidium is generally clothed with erect hairs, which are short at the base and become gradually longer towards the most prominent part, sometimes forming a distinct tuft. The sides of the abdomen are generally evenly rounded, but in a certain number of the species there is a special modification which appears to have the object of securing an extra close contact between the outer edges of the elytra and the body beneath.
- A sharp continuous ledge runs along each side on the line corresponding with the lateral margin of the elytron, and the posterior edge of the penultimate dorsal segment is similarly elevated. But this posterior ledge does not follow the line of the margin of the segment to the side, where it meets the lateral margin at an angle, but cutting across the angle curves forward to meet the lateral carina. In the small triangle so cut off on each side of the propygidium lies the last spiracle, which thus has the appearance of lying outside the segment to which it belongs. In a few species (e. g. *Adoretus hicaudatus*, *vitticauda* and *nephriticus*) the spiracle is not outside the short connecting ridge, but stands actually in it.
- If the presence or absence of this abdominal ridge is not easily visible, it may be readily made so by slightly raising at its extremity the elytron through which the specimen is not pinned. This peculiar structure, which is

Species account of dung beetles (Scarabaeidae) from Simbalbara WLS

Scarabaeus sacer

Scarabaeus devotus

Gymnopleurus ruficornis

Gymnopleurus cyaneus

Gymnopleurus maculosus

Sisyphus neglectus

Heliocopris gigas

Catharsius pithecius

Plate 14

Copris brahminus

Copris sacontala

Copris sabinus

Copris indicus

Copris sarpedon

Copris excisus

Copris punjabensis

Copris surdus

Plate 15

Onthophagus hystrix

Onthophagus ochreatus

Onthophagus pacificus

Onthophagus dynastoides

Onthophagus necrophagus

Onthophagus pactolus

Onthophagus variegatus

Onthophagus orientalis

Plate 16

Onthophagus furcillifer

Onthophagus amicus

Onthophagus expansicornis

Onthophagus mopsus

Rhomborrhina glaberrima

Cetonia bensoni

Protaetia pretiosa

Oxycetonia albopunctata

Xylotrupes gideon

Episcapha indica

Megalodacne consimilis

Anomala sp.

Anomala sp.

Anomala sp.

Adoretus sp.

Adoretus sp.

Plate 18

found in all those species just mentioned as having smooth opaque epipleurae to the elytra, as well as in certain others, is evidently of some importance in relation to the habits of the species. It may be useful for insects which habitually conceal themselves underground to possess a special means of excluding earthy particles from the cavity containing the wings and most of the spiracles.

IV. Coleoptera: Staphylinidae (Rove beetles) (Plate 19)

Identifying characteristics for the family Staphylinidae include:

- First abdominal sternite *entire*, not divided by hind coxae (sub-order Polyphaga).
- Adults elongate-slender, 0.7-25 mm.
- Elytra short, leaving 3 to 6 abdominal segments exposed.
- Tarsi usually 5-5-5, but 4-5-5, 5-4-4, et al.
- These beetles occur in variety of habits, but are probably most often seen about decaying materials, particularly dung or carrion. They also occur under stones and other objects on the ground, along the shores of streams, in fungi and leaf litter, and in the nests of birds, mammals, ants, and termites; some species are predaceous on insects.
- The larvae usually occur in the same places and feed on the same thing as the adults. A few are parasites of other insects.
- Over 46,000 species described worldwide with more than 3,000 species in India (Gupta 2004).

1. *Micropeplus* sp.

Diagnostic characters

- Small, oblong-ovate species, the whole upper surface strongly costate. Gular sutures united in front, widely divergent behind, gular plate foveate on either side; below the eyes deeply sulcate for reception of the antennae, which are 9-jointed, the 1st joint narrow at the base, much dilated apically and lightly curved, 9th large, clavate.
- Labrum corneous, transverse, narrowed in front, the anterior margin truncate. Mentum corneous, transverse, narrowed in front, anterior border truncate, the sides strongly notched. Tongue short broad, membranous,

truncate in front with two long cilia. Labial palpi very short, stout, 3-jointed, the 1st and 2nd joints transverse, 3rd scarcely longer than broad, truncate at apex. Inner lobe of maxilla narrow, the apex with three strong, short, curved teeth, inner margin finely, and sparingly ciliate; outer lobe broader and a little longer than the inner, the apex truncate and densely ciliate.

- Maxillary palpi 4-jointed, the 1st joint very small 2nd very narrow at the base and from thence strongly dilated, 3rd transverse, narrower than the apex of the preceding, 4th about two and a half times longer than broad, apex narrower and obliquely truncate.
- Mandibles short and broad, the apex bifid, the inner border with a ciliated membrane. Prosternum moderately well developed, keeled in the middle and with three deep transverse impressions on either side, prosternal process narrow, parallel sided, sulcate, extending to the posterior margins of the coxae; epimera not reaching the prosternal process, the coxal cavities widely open behind; between the prosternum, epipleura, and epimera with a deep oval depression for the reception of the antennae.
- Mesosternum with three large, impressions on either side; mesosternal process broad, impressed, apex truncate, extending fully half the length of the coxae. Metasternum large, its process broad and meeting the mesosternal process, posteriorly emarginate, the posterior coxae rather widely separated. Abdomen with the 1st ventral segment with a central and three lateral grooves on either side separated by sharp ridges, the 2nd to 4th transversely impressed at the base, the dorsal surface margined laterally and strongly sulcate. Prothorax narrowed in front, deeply fossulate, the chitin thin and translucent over the antennal cavity. Scutellum small, visible.
- Elytra costate winged. Anterior and middle coxae small, the posterior transversely conical; anterior and middle trochanters small, the posterior elongate.
- Tibiae finely spinulose. Tarsi 3 jointed; the first two joints very short, the 3rd much longer than the two preceding together.

Key to the Indian species of genus *Holosus*

1. Elytra obsoletely sparingly punctured

……… brevipennis Fauv.

2. *Holosus brevipennis*, Fauv.

Diagnostic characters

- Elongate, sub-parallel, black, shining; the posterior margins of the abdominal segments narrowly and obscurely ferruginous. Thorax deeply foveate at the posterior angles, transversely impressed before the base, in the middle with fine longitudinal sulcus. Abdominal striae transverse on the first three segments and united across the middle.
- Antennae ferruginous, legs reddish-testaceous. Length 3.2 to 3.5 mm.
- Head without impressions, finely and moderately closely punctured and with a fine ground-sculpture. Antennae with the 2nd joint slightly longer than broad, about half as long as the 3rd, 4th and 5th as long as broad, 6th slightly, 7th to 10th more strongly transverse.
- Thorax transverse, the sides straight and slightly retracted for the posterior third, in front very gently rounded and widened to the rounded anterior angles, widest about the middle, posterior angles rectangular, with a deep, broad, nearly impunctate fossa, before the middle of the base slightly transversely impressed, the impression not connected with the lateral fossae, puncturation a little less fine than on the head, the ground-sculpture similar.
- Elytra a little longer, transverse and broader than the thorax, more finely and less distinctly punctured than the thorax and without ground sculpture. Abdomen scarcely narrowed behind with transverse striae (5 or 6) united across the middle on the first three segments, oblique and gradually less distinct on the posterior segments, 5th (visible) segment more distinctly punctured than the others, finely coriaceous.

Key to the Indian species of genus *Lisipinus*

1. Closely and strongly punctured species

……… beesoni Cam.

2. Small, 2.2 mm; lighter and more finely punctured species

………. iyeri Bernh.

3*. Lisipinus beesoni*, Cam.

Diagnostic characters

- Shining, brown, indistinctly coriaceous, the head and abdomen darker, the posterior margins of the abdominal segments ferruginous.
- Thorax transverse, the sides retracted but scarcely sinuate for the posterior fourth, rounded in front, laterally with moderately deep longitudinal punctured impression extending to about the middle, the disc scarcely impressed on either side.
- Antennae ferruginous, legs reddish testaceous. Length 3 mm. Head shining, blackish, bi-impressed in front, finely and moderately closely punctured. Antennae with 3rd joint a little longer than 2nd, 4th a little longer than broad, 5th and 6th as long as broad, 7th to 10th transverse (less so in ♂ than in ♀).
- Thorax transverse (4:3), with narrow, median, impunctate line, puncturation moderately fine, less fine and closer than that of the head.
- Elytra a little longer (4:3), and slightly broader than the thorax, about as long as broad, similarly punctured to the thorax and with three larger setiferous punctures on the disc.
- Abdomen distinctly coriaceous, less shining than the fore-parts, with a few fine punctures.

4*. Lisipinus iyeri*, Bernh.

Diagnostic characters

- Sub-depressed, coriaceous, moderately shining; head and abdomen black or blackish, the posterior margins of the, segments reddish.
- Thorax and elytra lighter or, darker chestnut brown, the former with median and lateral impressions extending beyond the middle, extremely finely and very sparingly punctured.
- Antennae and legs testaceous. Length 2.2 mm. Very similar to *L. subopacus* Kr., the thoracic impressions and ground sculpture very similar, but rather more depressed, the head and thorax not iridescent, the thorax and elytra less,reddish, the antennae distinctly shorter and the elytra

longer.

- Head very finely and sparingly punctured the front bi-impressed. Antennae with 2nd and 3rd joints sub-equal, 4th and 5th as long as broad, 6th to 10th transverse, gradually increasing in breadth.
- Thorax transverse (3:2), with impressions and sculpture as above indicated.
- Elytra longer (31/2:2) and a little broader than the thorax, longer than broad, exceedingly finely and sparingly punctured. Abdomen extremely finely and very sparingly punctured.

Key to the Indian species of genus *Pseudolispinoides*

1. Elytra little broader and longer than thorax, lightly longer than broad, each with two striae

………. bistriatus Bernh.

5*. Pseudolispinoides bistriatus*

Diagnostic characters

- Black, moderately shining, coriaceous, the elytra pitchy, the posterior margins of the abdominal segments narrowly rufescent. Antennae and legs reddish testaceous. Length 2 to 2.5 mm.
- Head narrower than the thorax, the eyes rather large but not prominent, in front bi-impressed, moderately finely and rather closely punctured. Antennae rather short, the 3rd joint a little longer than the 2nd, 4th to 6th slightly, 7th to 10th more strongly transverse, the penultimate about twice as broad as long.
- Thorax transverse, the sides a little rounded and widened in front, narrowed and almost straight for the posterior third, with an adjacent large deep fossa, middle of the disc occasionally with a very fine impressed line, moderately finely and moderately closely punctured and with a fine wavy ground sculpture.
- Elytra a little broader and longer than the thorax, lightly longer than broad, each with two striae, a sutural and humeral which reaches almost to the posterior margin, puncturation rather fine and more sparing than on the thorax.

- Abdomen a little narrowed behind, the sides of the segments obliquely striate scarcely punctured, finely coriaceous. Found under the bark of decaying trees.

Key to the Indian species of genus *Thinodromus*

1. Head and thorax finely, sparingly punctured

……… lunatus Motsch.

6*. Trogophloeus (Thinodromus) lunatus*

Diagnostic characters

- Shining, black, the elytra dark reddish-brown, darker towards the postero-external angles.
- Antennae, black, the first two joints reddish-testaceous. Legs reddish-testaceous, the tibiae, a little infuscate. Length 3 mm.
- Head broad, narrower than the thorax, without impressions; eyes very large, prominent, temples very short, very finely and sparingly punctured.
- Antennae, with the 3rd joint longer than the 2nd, 4th to 8th longer than broad, gradually decreasing in length, 9th and 10th as long as broad.
- Thorax transverse (5:3), the sides strongly rounded in front and strongly narrowed behind, the posterior angles obtuse, before the base with a deep crecentric impression and with a fine, rather obsolete, sparing puncturation, at the sides with numerous long hairs.
- Elytra a good deal broader and longer than the thorax (5:3), closely, rather finely and distinctly punctured, and with a long pubescence, especially at the sides. Abdomen a little narrowed behind, finely, rather closely, and obsoletely punctured, with a long greyish pubescence.

7*. Pinophilus* sp.

Diagnostic characters

- Usually large or rather large elongate sub-parallel species. Head exserted, constricted behind the eyes, the neck thick; gular sutures distinct in front converging and evanescent behind.
- Antennae 11-jointed, the penultimate joints slender and more or less clavate or short and obconical. Labrum very short, broad, rounded in front

without teeth or emargination.

- Mandibles falciform, each with a strong tooth about the middle, the apex of which is truncate and emarginate. Inner lobe of the maxilla narrow, pointed, its inner margin with long, coarse, close cilia; outer lobe short and broad, the truncate apical margin more finely and shortly ciliate than the inner, but with a larger and coarser brush of cilia at the outer angle. Maxillary palpi 4-jointed, the 1st joint very small, 2nd elongate, dilated towards the apex, the 3rd shorter, the 4th elongate, securiform, the whole outer surface flattened, the inner margin gently curved. Sub-mental plate obtriangular.
- Mentum short, broad, narrower in front. Tongue membranous, divided by a deep triangular emargination into two lobes, densely ciliate towards the sides. Paraglossae well developed, not extending beyond the tongue, densely and strongly ciliate. Labial palpi short, the 1st joint short and broad, the 2nd longer, oval, the 3rd narrower and a little shorter than the 2nd, oval, before the apex with a constriction.
- Prosternum keeled, its process laterally compressed; trochanter visible. Epimera large, triangular, separated by a raised line from the pronotum. Anterior coxae contiguous. Mesosternum constricted in front to form a neck, its process short, keeled, extending but a short distance between the coxae, these contiguous. Episternum large, forming part of the outer margin of the coxal cavity; epimeron small, sub-triangular. Metasternum triangularly emarginate behind in the middle, on either side rather strongly and broadly emarginate before the posterior coxae, the process not meeting that of the mesosternum.
- Abdomen bordered above, the 1st ventral segment strongly keeled in the middle.
- Elytra truncate. Scutellum visible. Anterior coxae elongate, exserted, femora stout; tibiae, ciliate, emarginate externally before the apex; first four tarsal joints very strongly dilated and patellate, the 5th elongate, claws simple.
- Middle coxae, elongate, contiguous, prominent; tibiae, more or less emarginate externally before the apex, ciliate; tarsi with the first four joints short, the 4th with a broad lobe below projecting below the 5th joint.

- Posterior coxae conical, prominent, the tibiae as in the preceding pair, tarsi with the 1st joint rather long, 2nd to 4th short, the latter with a broad lobe below. Claws simple.
- They are found throughout the warmer regions, usually in damp vegetable debris, trunks of decaying trees, etc.

8*. Paedurus* sp.

Diagnostic characters

- Usually large or moderate-sized species, usually bicolorous, black or blue and red, occasionally entirely black or blue or even reddish. Elongate, moderately convex, the head exserted, constricted behind, forming a thick neck. Gular sutures distinct, converging behind to the constriction of the neck.
- Antennae 11-jointed, filiform, inserted below the antero-external angle of the front before the eye. Labrum short, transverse, in the middle of the anterior border with small acute emargination mandibles falciform, each with a bicuspid tooth at the middle. Lobes of the maxilla short, the inner densely ciliated internally, the outer densely ciliated along the apical border maxillary palpi 4-jointed, moderately long, the 1st joint small, and elongate, slightly thickened apically, 3rd longer obconical, 4th small, almost as broad as the apex of the 3rd and obtuse.
- Mentum transverse, trapezoidal. Tongue broad, membranous, ciliate, in the middle with a small triangular emargination, the lobes rounded; paraglossae well developed, densely ciliated and extending a little beyond the tongue. Labial palpi short, 3-jointed, the 1st joint scarcely longer than broad, 2nd longer, narrower, cylindrical 3rd much narrower and much shorter than the preceding.
- Prosternum not keeled, hourglass-shaped, widened behind the coxal cavities, broadly rounded behind. Epimera large fused with the epipleura, narrowly separated from the prosternum behind mesosternum with a very short acute process, the coxae contiguous. Metasternum without anterior process, emarginate on either side behind, feebly emarginate in the middle between the posterior coxae.
- Abdomen bordered above, the 1st ventral segment with or without a

median keel, the apex with two stout spines. Scutellum visible.

- Elytra of normal length or reduced in the apterous forms.
- Legs rather long, the anterior coxae elongate, prominent; the middle oval, contiguous; the posterior conical, narrowly separated. Femora elongate. Tibiae setose. Tarsi 5-jointed, claws simple; the anterior with the first four joints separately dilated, sub-cordate, densely ciliate below; middle with the 1st joint about as long as the two following together, the 2nd longer than the 3rd, 4th bilobed, 5th rather long; posterior similar to the preceding, but with the joints proportionately longer.
- Terrestrial species found in various situations. A few are responsible for dermatitis in man. Universally distributed.

9. *Cryptobium* sp.

Diagnostic characters

- More or less elongate, cylindrical species, with oval, oblong, or sub-triangular head and narrow more or less cylindrical thorax. Readily distinguished from all the Indian-Paederinae except *Cephalochaetus* by the flagellate antennae the 1st joint being long and forming a scape; presence of spines on the intermediate tibiae, etc. Labrum short, transverse, narrowly excised in the middle nearly to the base.
- Mandibles slender, curved, pointed, each usually with a rather large, pointed tooth in the middle and a bicuspid behind. Maxillary lobes densely ciliate. Maxillary palpi with the 1st joint very small, 2nd elongate, curved, slightly thickened towards the apex, 3rd of equal length and similarly thickened, 4th small, conical. Labium transverse, trapezoidal. Tongue broad, membranous, divided nearly to the base by a sub-triangular excision into two rounded lobes. Paraglossae ciliate and extending beyond the tongue. Labial palpi 3 jointed, the 1st joint small, 2nd elongate and a little thicker, 3rd narrower and shorter. Gular sutures usually separated throughout and parallel.
- Sides of head before the eyes with a groove for the reception of the 1st joint of the geniculate antennae. Neck stout. Prosternum keeled, its process short but acute.
- Pronotal epipleura rather narrow, separated from the epimera by a fine

raised line, these not covering the stigma. Mesosternum short, keeled, its process short and sharp, produced but little between the coxae these narrowly separated. Metasternum rather short, its process very short.

- Abdomen keeled at the base below, the sides margined above.
- Elytral epipleura with or without a fine keel. Legs rather slender; the coxae elongate; femora not thickened; tibiae setose, the middle with a few spines; tarsi 5-jointed, the anterior simple; the 1st joint in all longer than the 2nd, 3rd and 4th decreasing in length; claws slender.
- The species are distributed throughout the world, and are found on the banks of rivers, marshes, etc.

Key to the Indian species of genus *Cryptobium*

1. Head scarcely widened behind, more finely punctured, elytra more broadly reddish-yellow behind

……… capitale Cam.

2. Larger (11 mm). Head distinctly widened behind; anterior coxae dark

……… bernhaueri Cam.

10*. Cryptobium capitale*, Cam.

Diagnostic characters

- Pitchy-black, scarcely shining, the posterior margin of the elytra, the posterior margin of 5th and whole of 6th abdominal segments reddish testaceous; antennae, palpi, and mandibles ferruginous; legs pale yellow, the knees and tarsi infuscate. Length 11.4 mm.
- Less shining, the head more finely punctured and the sides more parallel, the thorax narrower, more finely and closely punctured, the elytra more finely punctured with the posterior fifth testaceous, and the male characters.
- Head large, longer and broader than the thorax, oblong-ovate, only slightly widened behind the eyes, the posterior angles broadly rounded, the extreme front and antennal tuberosities shining and impunctate the rest of the surface densely, moderately coarsely, rugulosely punctured, more finely but equally densely behind the eyes.
- Antennae long and slender, the 3rd joint twice as long as 2nd, all the rest

elongate, the 10th half as long as 9th, as long as 11th, mandibles bidentate, the posterior tooth of the left bifid at apex.

- Thorax pitchy, narrowed and feebly sinuate behind, rather more shining than the head, with a narrow, smooth, impunctate median line posteriorly not extending beyond the middle and a small area on either side of the base shining and impunctate, the rest of the surface densely and more coarsely punctured than the head, more rugulose at the sides.
- Elytra distinctly longer and broader than the thorax, much longer than broad, the reflexed sides keeled, coarsely, rugosely punctured, the size of the punctures about the same as those of the thorax. Abdomen rather shining, sometimes pitchy, finely and closely punctured, rather more sparingly behind.
- ♂ 2nd and 3rd ventral segments each with a crecentric impression in the middle, open forwards and furnished with longer and more erect hairs than on the rest of the surface; 6th triangularly impressed behind, moderately deeply and triangularly excised, the apex rounded.

11*. Cryptobium bernhaueri*, Cam.

Diagnostic characters

- Black, shining, the elytra shining red with the basal third black. Head in both sexes strongly dilated behind; antennae, palpi, and mandibles ferruginous; femora yellow, tibiae and tarsi brown. Length 10 mm. Elytra black, the posterior border narrowly red.
- Head in both sexes broader than the thorax, much dilated behind the eyes (especially in male), a little longer than broad, posterior angles broadly rounded, front depressed between the antennal tuberosities, somewhat uneven at the sides, finely and moderately closely punctured medially, the post-ocular area closely and moderately coarsely punctured, the disc with a double puncturation of larger and smaller punctures rather closely placed, but becoming finer and more sparing towards the front, setose.
- Antennae with 4th to 10th joints all longer than broad, gradually decreasing in length, the 11th shorter than 10th; mandibles bidentate.
- Thorax narrowed behind, with broad median impunctate space throughout, externally with a narrower impunctate area not reaching the anterior

border and separated from the median space by a row of closely-set moderately large punctures, the rest of the surface except the posterior border rather coarsely and closely punctured.

- Elytra a little longer and broader than the thorax, closely, rather coarsely sub-rugulosely punctured the reflexed sides carinate.
- Abdomen moderately finely, rather closely punctured, more finely and sparingly behind. ♂ 5th ventral segment broadly and very feebly emarginate; 6th narrowly and deeply excised, the apex of the excision rounded, the sides bevelled.

12. *Pachycorynus* sp., Motsch.

Diagnostic characters

- Depressed elongate species. Differs from in the depressed form, the absence of spines on the posterior tibia, longer 5th joint of the posterior tarsi, and the non-emarginate tongue.
- Antennae strongly geniculate. Median frontal furrows well marked, long, parallel, the lateral very short, indistinct, and oblique from the anterior border of the eye. Neck very slender. Gular sutures fused.
- Elytra distinctly imbricate. Labrum rather small, transverse, emarginate in the middle and furnished with long set. Mandibles stout, pointed, the right with a rather obscure obtuse tooth, the left with a small pointed tooth before the middle, outer margin sulcate from base nearly to the apex. Maxillary palpi with the 1st joint small, 2nd rather short, a little dilated towards the apex, the 3rd distinctly longer, almost cylindrical, with slender, subulate, a good deal shorter than the preceding. Apex of outer and inner margin of the inner lobes of maxilla densely ciliate.
- Mentum transverse, corneous. Tongue very small membranous, rounded in front. Paraglossae well developed, membranous densely ciliate externally, finely dentate within, extending beyond the 1st joint of the labial palpi. Labial palpi with the 1st joint short, 2nd more than twice as long, slightly curved cylindrical, 3rd a little shorter than the preceding, subulate. Neck-plate of the prosternum nearly semi-circular, emarginate in the middle in front.
- Prosternum well developed, deflexed behind, this deflexed portion

separated by a transverse ridges from the anterior part, angulate in the middle behind and obliquely truncate on each side. Pronotal epipleura narrow, the superior lateral line not deflexed. Mesosternum short, its process short and broad, rounded behind, not much produced between the coxae, these widely separated. Metasternum long, its process broad and separated from that of the mesosternum by a suture, anterior and middle tibiae spinose, and the posterior with a few setae only.

- Tarsi short, the first four joints scarcely differing in length, the 5th about as long as the four preceding together.

13*. Mitomorphus* sp., Kr.

Diagnostic characters

- Distinguished from the other genera by the narrow sub-cylindrical build and long oval head with short median and obsolete lateral sulci. Labrum small, rounded in front, and furnished with long setae, in the middle with an acute triangular notch. Mandibles each with a small tooth internally, sulcate throughout externally. Maxillary palpi with 1st joint small, 2nd short, slightly curved and widened towards the apex, the 3rd longer, obconical, the 4th conical, at least as long as the preceding. Mentum transverse, corneous. Tongue broad, membranous, and feebly emarginate in front. Paraglossae well developed, ciliate, extending to the level of the apex of the 1st joint of the labial palpi, these with the 1st joint a little shorter than the 2nd, which is cylindrical, 3rd as long as but much narrower than 2nd.
- Prosternum well developed carinate in the middle deflexed behind, its posterior margin angulate in the middle and obliquely truncate on each side Pronotal epipleura narrow, the superior lateral line not deflexed until the anterior angles, not uniting with the inferior lateral line. Mesosternum short, its process short and broad, rounded behind and not extending much between the coxae, these widely separated. Metasternum with long process reaching that of the mesosternum.
- Tibiae spinose. Anterior tarsi simple, the first four joints short, sub-equal, the 5th much shorter than the four preceding together, the middle and posterior longer, the first four joints gradually decreasing in length.

- The genus is known only from the Oriental region; the species appear to live in damp places amongst detritus.

Key to the Indian species of genus *Xantholineus*

1. Pitchy brown, head rather sparingly and very finely punctured

……… piceus Cam.

14*. Xantholineus piceous*, Cam.

Diagnostic characters

- Narrow, elongate, shining, pitchy black. Abdomen brown, the apex blackish. Head oblong ovate, finely sparingly punctured. Thorax with dorsal row on either side of fifteen or sixteen rather fine punctures. Antennae with the first three joints shining, ferruginous, the rest pitchy-red, opaque. Palpi testaceous. Legs testaceous. Length 5.75 mm.
- Head slightly narrowed in front, the temples slightly widened, co-arctate with the base, oval oblong, a little broader but shorter than the thorax, the eyes small; frontal furrows fine, short parallel, the lateral well marked, not united with the former; puncturation fine and rather sparing, broadly impunctate along the middle.
- Antennae, with the 3rd joint half as long as the 2nd, 4th to 10th transverse, the penultimate about twice as broad as long.
- Thorax much longer than broad slightly narrowed and sinuates behind, with a dorsal row on either side of fifteen or sixteen rather fine punctures, the sides rather closely and finely punctured, leaving a narrow impunctate space adjacent to the dorsal row except in front, where the puncturation is more or less confused with the dorsal row. Scutellum bipunctate, transversely strigose.
- Elytra a little broader but shorter than the thorax, scarcely longer than broad, pitchy-brown, finely, superficially, sub-serially and moderately closely punctured, the epipleura impunctate.
- Abdomen very finely, moderately closely punctured, finely pubescent.

Species account of rove beetles (Staphylinidae) from Simbalbara WLS

Micropeplus sp.

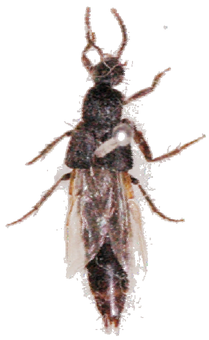
Holosus brevipennis

Pseudolispinoides bistriatus

Trogophloeus lunatus

Pinophilus sp.

Cryptobium bernhaueri



Mitomorphus sp.

Belonuchus sp.

Plate 19

15*. Belonuchus* sp., Nordm.

Diagnostic characters

- Genus is closely related to *Philonthus* and *Hesperus* but of a more depressed build than is usual in these genera, with stouter antennae, quadrate head, and more trapezoidal thorax, the anterior angle; more prominent, and usually with an emargination behind them. The mouth-parts resemble those of *Philonthus*, the palpi being less elongate than in *Hesperus*.
- The mesosternal process is broader than in the majority of species of, but less broad than in *Hesperus*. The superior lateral line of the thorax is more deflexed than in *Philonthus*. In the ♂ posterior femora are furnished below with a, double row of spines.
- The first joint of the posterior tarsi always shorter than the last. In the ♂ the head is always larger than in the ♀. The anterior tarsi with the first four joints slightly dilated in both sexes.
- The genus is found throughout the warmer parts of the world in decaying fruit, under bark, etc.

V. Coleoptera: Cerambycidae (Borers) (Plate 20 to 24)

Identifying characteristics for the family Cerambycidae include:

- Long filiform antennae, ranging from one-half to over two times the length of the body.
- Body usually elongate and cylindrical; 2-60 mm in length.
- Eyes generally notched with antennae arising within the notch.
- Tarsi apparently 4-4-4, really 5-5-5 with the 4th segment small and inconspicuous.
- Adults of many species feed on flowers; others feed on leaves and bark.
- Larvae of many species are the round headed borers found in the wood of living, dying, and dead trees.
- Most of the borers are wood boring in their larval stage, and many species are very destructive to shade, forest, and fruit tress and to freshly cut logs. The adults lay their eggs in crevices in the bark, and the larvae bore in to the wood. Different species attack different types

of trees and shrubs. A few will attack living trees, but most species appear to prefer freshly cut logs or weakened and dying trees or branches. A few girdles twigs and lay their eggs just above the girdled band. Some bore into the stems of herbaceous plants. The larvae (or grubs) are elongate, cylindrical, whitish, and almost legless.

- The Cerambycidae thus play an important role in nutrient recycling in forest ecosystems. This feature, however, makes then serious pests in timber and wood products.
- Over 20,000 species described worldwide; 800 in India (Gupta 2004).

Key to the Indian species of genus *Lophosternus* Guérin

1. Mandibles long, curving downwards and backwards and backwards, narrowing towards apex. Antennae serrate but not imbricate; lobes of third basal joint rounded at apex. Pronotum strongly convex; marginal teeth rather short

……… buqueti Guér

Pronotum closely and finely punctured in front more strongly at sides. Sternum not pubescent

……… indicus Hope

Sternum pubescent

……… hugelii Redt.

1. ***Dorystenes (Lophosternus) buqueti*, Guér**

Diagnostic characters

- ♂. Chestnut-red in colour, the head somewhat darker than the prothorax and elytra.
- Head closely and rather strongly punctured above; last joint of palpi widest at about one-fourth from the apex; eyes very large, narrowly and not very deeply emarginate, the upper lobe extending forward to the antenniferous tuber.
- Antennae nearly as long as the body; first joint reaching by about one-fifth of its length beyond the hind margin of the eye, third almost rectangular at the apex, fourth acute at the apex, fifth to tenth produced each into a sharply angulate process at the apex.

- Pronotum closely punctured at the sides, sparsely elsewhere; hind angles slightly projecting but scarcely acute.
- Elytra rather strongly punctured, the interstices rugulose and finely but not very closely punctulate; each with two obtuse and feebly raised costae. Hind breast covered with tawny pubescence. Last ventral segment with a feeble sinuate margination at the apex.
- Length, 26-38 mm; breadth, 9-13 mm.

2. *Dorystenes (Lophosternus) indicus*, Hope (*Prionus*)

Diagnostic characters

- ♂ Dark brown or almost black in colour. Head coarsely punctured; eyes rather narrow, the upper lobe at a distance of at least half its own width from the antennal tuber.
- Antennae from three-fourths to live-sixths of the length of the body; first joint reaching to a short distance beyond the hind margin of the eye; third slightly dilated, but not sharply angulate at the apex; fourth slightly acute at the apex, fifth to tenth produced into an acute angular process at the apex on the anterior side.
- Pronotum closely and finely punctured in front and for some distance back along each side of the middle line, closely but more strongly punctured at the sides; hind angles more or less obtuse, often rounded off.
- Elytra more or less rugulose and punctate, with the little ridges closely and finely punctulate. Hind breast bare of pubescence.
- ♀ Antennae reaching only to the middle of the elytra, much more slender than in the male. Last ventral segment with rounded hind margin. Legs smooth underneath.
- Length, ♂ ♀ 25-50 mm; breadth, 11-15 mm.

3. *Dorystenes (Lophosternus) hugelii*, Redtenbacher (*Cyrtognathus*)

Diagnostic characters

- ♂ Chestnut-red in colour, the head and prothorax somewhat darker than the elytra, the front and hind margins of the pronotum almost black.
- Head strongly and closely punctured. Last joint of palpi gradually widened towards the extremity. Eyes large, the upper lobes rather closely

approximated to the antennal tubers in front.

- Antennae a little shorter than the body; first joint not reaching beyond the hind margin of the eye, third to tenth acutely produced at the apex on the anterior side, third with sharp anterior edge near which it is finely and very closely punctulate.
- Pronotum finely and closely punctured in front and for some distance back along each side of the middle line, more strongly punctured towards the sides; its hind angles more or less obtuse, sometimes slightly projecting.
- Elytra rugulose, the ridges finely punctured; each with two or three feebly raised obtuse costae. Hind breast covered with a tawny-coloured silky pubescence. Last ventral segment sinuate at the apex.
- ♀ Antennae hardly reaching to the middle of the elytra, more slender than in the male, the joints, from the fifth only, acutely angulate at the apex. Hind breast bare of pubescence. Last ventral segment with rounded hind margin. Legs smooth underneath.
- Length, ♂ ♀ 29-53 mm; breadth, 11-15 mm.

Key to the Indian species of genus *Cantharocnemis* Guérin

1. Prothorax transverse lateral edges projecting at about one third of their length. Elytra less than twice as width across base, obtusely rounded at apex

……… downesi Pascoe

4. *Cantharocnemis downesi*, Pascoe

Diagnostic characters

- Reddish brown, varies to a somewhat darker tint. Head sparingly punctured on the vertex, closely and rugosely on the clypeus, sides and the lower part of the antennal supports; vertex marked with an impressed line which widens out into a channel in front between the eyes and antennal supports; clypeus limited above by two oblique or somewhat arcuate lines that converge towards the channel between the depressed transversely directed antennal supports; mandibles of male falciform, with tooth at base and an emargination forming two teeth at the apex, the upper border carinate, those of the female very much shorter, straight or but slightly diverging from the base and incurved towards the tip, the inner edge of each with one or two feeble teeth.

- Antennae of ♀ scarcely reach beyond the base of the prothorax; those of the ♂ are longer and stronger; joints third to tenth angulated in front at the apex, more acutely so in the ♂ than in the ♀, rather sparingly punctured behind, closely and rugosely punctured in front.
- Prothorax transverse, the lateral edges projecting in an angle at about one-third of their length, from the base; disk convex with as light depression in the middle, sparingly punctured and glossy over the whole of the middle area, closely rugose-punctate towards the sides.
- Elytra much less than twice as long as their width across the base, obtusely rounded at the apex, irregularly rugose and punctate in the ♀, smoother and less punctate in the ♂, each with two feebly-raised dorsal lines. Tibiae of the anterior two pairs rather sparingly punctured in front, closely behind, those of the hind pair densely and coarsely punctured on both sides; third joint of tarsi completely bilobed. Hind breast sparsely clothed with longish tawny hairs; abdomen finely and rather closely punctate; last ventral segment of ♀ rounded behind and fringed with tawny setae.
- Length, ♂ 38 mm, ♀ 25 mm.

Key to the Indian species of genus *Macrotoma* Serville

1. Third antennal joint much longer than the first. Hind angles of prothorax not directed backwards

………. crenata Fabr.

5. *Macrotoma crenata*, Fabr. (*Prionus*)

Diagnostic characters

- ♂. Dark brown, with the elytra of a somewhat lighter brown tint that becomes darker towards the base; the intermediate joints of the antennae, the hind legs and the tarsi more or less reddish.
- Head somewhat strongly punctured in front and between the eyes, finely granulose behind. Antennae reach to the apical third or fourth of the elytra; first joint relatively short, only about one-third longer than broad, coarsely

punctured; third thickened, slightly channeled and sparsely punctured above, somewhat denticulate below, equal in length to the fourth, fifth, and nearly half of the sixth united.

- Prothorax with its sides converging in slightly curved lines in front; the disc with two triangular, strongly punctured and slightly depressed, nitid areas in front, two small rugose spots external to these and a transverse nitid band at the base, this basal band produced obliquely at its extremities; at the middle it is produced forwards in a narrow triangle which sometimes extends to and unites with the inner angles of the triangular spaces in front.
- Elytra densely granulose, the granules stronger and the surface rougher towards the base, especially near the suture.
- Metasternum devoid of pubescence, with a sparsely punctured triangular area clearly marked off by a slightly raised line from the closely punctured part on each side. Front legs asperate, spinose beneath, the femora thickened, the tibiae elongated and slightly curved; the middle and hind legs much less spinose; first joint of the tarsi scarcely so long as the next two joints united.
- ♀. Antennae shorter, not reaching beyond the middle of the elytra, with the first and third joints much less thickened than in the male, third not asperate.
- Prothorax with its edges more strongly spined, and more convergent in front; the notum strongly and rather closely punctured towards the sides, less closely in the middle and there also more or less glossy.
- Metasternum pubescent at the sides as well as in the middle, rather closely granulate punctate. Front legs similar to the other two pairs.
- Length, 37-52 mm; breadth, 9-11 mm.

Key to the Indian species of genus *Hypoëschrus* Gahan

1. Front coxae contiguous. Prothorax wider in the middle than at each end; third antennal joint not shorter than fourth or succeeding joints. Eyes emarginate; prothorax with median lobe at base

   ………. indicus

6. ***Hypoëschrus indicus*, Gahan**

Diagnostic characters

- Light brown in colour. Head and prothorax very finely granulate and dull. Antennae sparsely fringed with pale setose beneath.
- Elytra somewhat glossy, very closely punctured each with seven raised lines, the first running very close to the sutural edge posteriorly but diverges slightly from it in front, the third and fifth somewhat more strongly raised, connected with one another and with the seventh by means of oblique cross lines posteriorly; the sixth and seventh obsolete in front, and the sixth obsolete also posteriorly.
- Length, 12-20 mm; breadth, 3-4 mm.

Key to the Indian species of genus *Xystrocera* Oliv.

1. Front coxae distinctly separated by prosternal process. First antennal joint sharply angulate or spined at apex, basal margin of prothorax rounded in middle

………. globosa Guér

7. ***Xystrocera globosa*, Olivier (*Cerambyx*)**

Diagnostic characters

- Reddish brown; prothorax with the front and hind borders, a narrow median longitudinal band (sometimes obsolete) and a broader lateral band, which in the ♂ runs obliquely from the side of the thorax in front towards the medio-basal lobe behind, metallic blue or green; elytra testaceous yellow, the outer and apical borders and, on each, a median longitudinal band, which anteriorly is directed obliquely towards the shoulder, also metallic blue or green.
- Head densely punctate. First joint of antennae asperate, with spiniform anterior process at the apex; third to fifth strongly asperate, each in the ♂ with the apex thickened and dentate beneath; third joint thicker and about one-fourth shorter than the fourth.
- Prothorax densely and finely granulated on the disc in the ♂, less densely granulated in the ♀; prosternum of the male with a transversely striated glossy band of metallic colour, close to the front margin, the rest of its surface as well as the lower part of the sides of the prothorax forming a

convexly raised, very minutely and densely punctate, area of a dull red colour; the corresponding area in the female more or less concave, sparsely granulated and not extended on to the sides, whence the lateral bands run straight back instead of taking an oblique direction as in the male.

- Elytra densely and rather strongly punctured; each with three slightly raised longitudinal lines - two dorsal and one lateral.
- Length, 15-32 mm; breadth, 7-9 mm.

Key to the Indian species of genus *Stromatium* Serville

1. Antennal supports sharply angulate or spined, especially in the ♂, on the inner side; prosternal process more abruptly sloped posteriorly and narrowed at apex. Prothorax of ♂ with a large tomentose depression on each side

……… barbatum Fabricius

8. *Stromatium barbatum*, Fabricius

Diagnostic characters

- Varies in colour from brownish black to reddish brown, faintly covered with tawny pubescence.
- Head densely and rather coarsely punctured above and at the sides, as densely but less strongly punctured in front.
- Prothorax very densely covered with strong coarse punctures; the disc with five slightly raised tubercles, less distinct in the ♂, placed two anteriorly, one behind the middle, and two near the base; the sides broadly and obtusely protuberant except near base, in the ♂; straighter and marked each with a large tomentose depression, extending along the greater part of its length, in ♀.
- Elytra coarsely and very densely punctured; each with two tolerably distinct dorsal and one or two short lateral costae, the latter sometimes obsolete; a short sutural tooth at apex.
- Length, 12-29 mm; breadth, 5-8 mm.

Key to the Indian species of genus *Plocaederus* Newman

1. Acetabula of front coxae angulated on outer side, or but very feebly so. Prothorax with strong, sharp, and slightly recurved spine on each side. Elytra very finely and closely punctulate all over

   ………. ferrugineus Linnaeus

   Elytra very finely and closely punctulate but punctures hardly visible

   ………. obesus Gahan

2. Prothorax with a rather short, conical spine on each side

   ………. pedestris White

9. *Plocaederus ferrugineus*, Linnaeus

Diagnostic Characters

- Reddish brown, the head and thorax dark brown or almost black, the sides of the breast and the greater part of the antennae also, inclining to a dark brown colour; clothed with a yellowish grey pubescence which is somewhat longer and denser on the underside of the body, but very short and faint on the upperside, especially on the elytra.
- Antennae of ♂ twice as long as the body, very minutely granulated; joints fifth to tenth angulate in front at the apex; antennae of ♀ scarcely longer than the body, not granulate, joints fifth to tenth more distinctly angulate than in the ♂. Prothorax armed with a strong, sharp, slightly recurved spine on each side, strongly and irregularly corrugated above.
- Elytra very finely and closely punctulate all over not less finely near the base than towards the apex; very faintly pubescent at the sides and almost bare of pubescence on the disc; apices dentate at the suture and somewhat acute at the outer angles.
- Length, 26-45 mm; breadth, 8-10 mm.

10. *Plocaederus obesus*, Gahan

Diagnostic characters

- Of a reddish-chestnut or testaceous colour, clothed with a short but rather dense tawny-grey pubescence, which on the upperside, as well as on the underside of the body, almost completely covers the derm; prothorax blackish at the front and hind margins; elytra more or less black along the sutural and lateral edges; antennae ferruginous, with the intermediate joints usually tipped with black at the apex.

- Antennae of ♂ much longer than the body; first joint stout, rugulose-punctate; the remaining joints very finely granulate, fifth to tenth acutely angulate in front at the apex; antennae of ♀ scarcely longer than the body, not granulate; joints fifth to tenth acutely angulate at the apex.
- Prothorax armed with a strong, sharp, slightly recurved spine on each side; strongly corrugate above, the ridges sometimes very irregular, sometimes more or less transverse and wavy.
- Elytra very finely and closely punctulate all over; the truncate apices shortly spined at each of the angles.
- Length, 27-45 mm; breadth, 9-11 mm.

11.*Plocaederus pedestris*, White (*Hammaticherus*)

Diagnostic characters

- Almost black, with the antennae and legs ferruginous; clothed with a faint grey pubescence.
- Antennae of the ♀ a little longer than the body; joints fifth to tenth denticulately produced at the anterior apical angle.
- Prothorax armed with a rather short conical spine on each side; strongly and irregularly corrugate above.
- Elytra slightly narrowed backwards; finely and closely punctate, the punctures on the basal half, especially near the base a little larger and more crowded together than those on the apical half; the truncate apices dentate at each of the angles.
- Length, 25-28 mm; breadth, 9-10 mm.

Key to the Indian species of genus *Aeolesthes* Gahan

1. Acetabula of front coxae not angulate on outer side, or but very feebly so.
   Head with obtuse median carina between upper lobes of eyes

   ………. holosericea Fabricius

   Head between cheeks very clearly defined, and strongly arched backwards in the middle

   ………. induta Newman

12. *Aeolesthes holosericea*, Fabricius (*Cerambyx*)

Diagnostic characters

- Dark brown, sometimes reddish brown, densely covered with silky pubescence of a greyish or a light-brown colour; the elytra exhibit bands or patches, some duller, some brighter, like watered-silk, which change in brilliancy according to the incidence of the light; antennae and legs with a thinner and more uniform greyish pubescence.
- Head with a straight or very feebly bisinuate furrow beneath between the cheeks. Third joint of the antennae smooth, gradually thickened at the apex.
- Prothorax rounded at each side; irregularly wrinkled above, with a sub-central smooth space which is limited on each side by a longitudinal impression and marked sometimes, especially near its anterior end, with a median groove.
- Length, 20-35 mm; breadth, 9-10 mm.

13. *Aeolesthes induta*, Newman (*Hammaticherus*)

Diagnostic characters

- Extremely like *A. holosericea*, Fab., in size, form and coloration, but with the furrow which crosses the underside of the head between the cheeks very clearly defined, and strongly arched backwards in the middle; this character alone serves to distinguish it from *holosericea*, in which the furrow is either straight, slightly arched forwards, or feebly bisinuate, and not quite so deep and well defined.
- Length, 28-38 mm; breadth, 9-11 mm.

Key to the Indian species of genus *Hoplocerambyx* Thomson

1. Acetabula of front coxae not angulate on outer side, or but very feebly so. Antennae spined behind the apex of joints 3 to 10

   ………. spinicornis, Newman

14. *Hoplocerambyx spinicornis*, Newman

Diagnostic characters

- Brownish black, the elytra varying in colour from piceous to reddish brown;

a fine grey pubescence covers the head, prothorax, antennae, legs, and underside; the elytra more densely covered with a silky pubescence of a fulvous grey tint and somewhat banded in lighter and darker shades which alter with the incidence of the light.

- Head with the eyes well separated above and the space between marked with a deep median groove; a shallower groove, bounded on each side by a slight carina, extends thence between the antennal tubers; gular area with three strong transverse ridges. Antennae of the male longer than the body by from one-fifth to one-third of their length, according to the size of the individual; faintly pubescent; first joint sparsely and strongly punctured, third to sixth or seventh more or less asperate at the edges, flattened or slightly canaliculate above.
- Antennae of the female shorter than the body, more pubescent than those of the male, the first joint sparsely punctured, the third and succeeding joints somewhat flattened above, but not roughened at the edges.
- Prothorax a little longer than broad; the disc with a slightly raised oblong space in the middle, the rest of the surface rather strongly transversely wrinkled but with the ridges more or less broken and convolute towards the sides.
- Elytra with a slight elevation close to the suture at about one-fourth of their length, from the base; each elytron obliquely truncate at the apex, with a spine at the suture and a feeble tooth at the outer angle; the surface, especially where rubbed bare of pubescence, has two kinds of punctures, some minute and very dense, others larger and less densely spread. The claw-bearing joint of the tarsi long and the paronychium nearly always distinctly visible between the claws.
- This species varies in size to a remarkable extent. It varies also in the relative length, of the male antennae; these are shorter in proportion in small specimens and longer in the larger and more fully developed ones.
- Length, 20-60 mm; breadth, 6-7 mm.

Key to the Indian species of genus *Diorthus* Thomson

1. Antennal supports more or less depressed. Antennae not spined behind. First antennal joint with narrow cicatrix at apex

………. cinereus, White

15. *Diorthus cinereus*, White(*Hammaticherus*)

Diagnostic characters

- Varies in colour from black to reddish brown, not very densely covered with short pubescence of a greyish or brownish-grey tint.
- Head with a median impressed line or groove above, between the eyes. Antennae not quite so long as the body in the ♀, and from one and a half times to nearly twice as long as the body in the ♂, fringed with short delicate grey hairs beneath; third and fourth joints nodose at the apex, the third much longer than the fourth; fifth to tenth compressed and angulated anteriorly at the apex.
- Prothorax rounded at the sides, somewhat constricted in front, irregularly and not very strongly wrinkled above in a general transverse direction, marked on the disc with some feeble longitudinal and oblique grooves which together form a somewhat crown-shaped impression.
- Elytra truncate at the apex, with a short spine from each at the sutural angle; the pubescence covering them more or less glossy, and generally somewhat thinner on each side in front of the middle so that the colour of the underlying derm becomes more apparent there.
- Length, 16-29 mm; breadth, 4-8 mm.

Key to the Indian species of genus *Pachydissus* Newman

1. Acetabula of front coxae not angulate on outer side, or but very feebly so. Antennae not spined behind. Femora not carinate

………. parvicollis Gahan

16. *Pachydissus parvicollis*, Gahan

Diagnostic characters

- Dark chestnut-brown, not very densely covered with a short silky, somewhat golden-yellow pubescence, and so arranged on the elytra as to give faint wavy reflexions in certain lights.
- Head marked above with a short median groove which extends from between the eyes to a little distance beyond them posteriorly; antennal

supports separated by a narrow groove-like interval; eyes rather large, the genae somewhat short.

- Antennae slightly shorter than the body in the ♀, exceeding it by from one-third to nearly half of their length in the ♂; third to fifth joints sub-nodose at the apex; third and fifth sub-equal, each about one-third longer than the first or fourth.
- Prothorax slightly protuberant at the middle of each side, narrowed towards base and apex, transversely and not very strongly rugose above, with the ridges more or less sinuate and irregular; its length, about equal to its width across the middle.
- Elytra long, narrowed gradually and very slightly from the base for about four-fifths of their length, and then more strongly; each truncate at the apex and armed with a short sutural spine.
- Femora nearly parallel-sided, the hind pair not reaching to the apex of the elytra in the ♂.
- First joint of the hind tarsi about equal in length, to the second and third united. Intercoxal process of prosternum sub-vertical and very feebly tuberculate posteriorly.
- Length, 30-32 mm; breadth, 9-11 mm.

Key to the Indian species of genus *Derolus* Thomson

1. Antennal supports more or less depressed. Antennae not spined behind. First antennal joint with narrow cicatrix at apex. Femora finely carinate along each side

……… volvulus, White

Antennae slender, not reaching past the middle of the elytra

……… demissus, Pascoe

17. *Derolus volvulus*

Diagnostic Characters

- ♂. Head, prothorax and base of elytra reddish-testaceous, the rest of the body and elytra yellowish-testaceous or fulvous in colour; covered above with a very short pale tawny pubescence; the underside sparsely pubescent.

- Head closely punctate. Antennae about one-fifth longer than the body; the joints from the third to the tenth acutely angulate at the apex on the anterior side, the third and fourth somewhat less acutely so than the others.
- Prothorax slightly transverse, sub-cylindrical, a little rounded at the middle of each side and without lateral margins; the notum very closely punctured at the sides, somewhat less closely in the middle.
- Elytra densely punctured, much broader than the prothorax and three times as long as broad; each with two very feebly raised dorsal lines. Hind femora and hind coxae with a channel and thick fringe of hairs beneath; middle femora with a short channel and thick fringe of hairs near the base; the front femora flattened or slightly concave beneath, with a sparse fringe of hairs at each side. Third joint of tarsi left to the middle. Last ventral segment truncate at the apex.
- ♀. Like the male in form; the femora not channeled nor fringed with hairs beneath; the last ventral segment rounded at the apex.
- Length, 21-22 mm; breadth, 5 mm.

18. *Derolus demissus*, Pascoe (*Cerambyx*)

Diagnostic characters

- Pitchy-brown, rather thinly covered with greyish pubescence. Eyes large, almost contiguous above in the male.
- Antennae of the ♂ one-fifth or so longer than the body, those of the ♀ shorter; third and fourth joints feebly nodose at the apex, the fourth only a little shorter than the third.
- Prothorax rounded at the sides, transversely plicate above, occasionally nearly smooth on the middle of the disc; with a narrow, glabrous, and smooth excised area on each side.
- Elytra minutely and densely punctulate, the pubescence rather thin, each elytron sub-truncate and unarmed at the apex. Metasternum with a small but distinct process projecting forwards at each of the antero-lateral angles, these processes partly but not completely shut off the epimera from the acetabula of the middle coxae.
- Length, 15-17 mm; breadth, 7 mm.

Key to the Indian species of genus *Trinophylum* Bates

1. Prothorax broader than long, strongly rounded at sides. Antennae sparsely ciliated, third joint not longer than first

……… cribratum Bates

19. *Trinophylum cribratum*, Bates

Diagnostic characters

- Chestnut-brown in colour, more or less nitid, sparsely furnished above with short semi-erect fulvous brown hairs.
- Head and basal joints of antennae finely rugulose-punctate.
- Prothorax closely and rather strongly punctured; marked with a feeble sinuate groove or depression near the apex and another near the base; the disc slightly depressed along the middle, with a very narrow impunctate space behind.
- Elytra closely and strongly punctured, less strongly near the apex. Body beneath reddish brown, sparsely pubescent, less closely and rather finely punctured; prosternum transversely depressed a little behind the front margin; abdomen narrowed posteriorly, first segment longest, second to fourth successively shorter. Legs reddish brown, minutely and sparsely punctate.
- Length, 11-13 mm; breadth, 6-9 mm.

Key to the Indian species of genus *Ceresium* Newman

1. Prothorax broader than long, strongly rounded at sides. Antennae sparsely ciliated, fourth joint longer than first

……… simplex Gyll.

20. *Ceresium simplex*, Gyll. (*Stenochorus*)

Diagnostic characters

- Brownish testaceous; antennae and legs yellowish.
- Head rather densely covered above with pale yellowish pubescence.
- Antennae a little longer than the body in the ♂, not quite so long as it in the ♀; third joint not longer than the first, distinctly longer than the fourth; fifth and sixth sub-equal, each longer than the third.

- Prothorax almost as broad as it is long, slightly rounded at the sides, these covered with greyish pubescence; disc faintly covered with greyish pubescence in the middle, marked with two spots or a longitudinal band of dense tawny-yellow pubescence at each side; a narrow median and some small laterally placed callosities, smooth and glabrous, the intervening spaces sparsely and irregularly punctured. Scutellum covered with pale fulvous pubescence.
- Elytra closely and strongly punctured from the base to the middle, the punctures nearest the base somewhat granulate; less strongly punctured behind the middle, the punctures become gradually feebler as they approach nearer to the apex; the punctures also carry each a pale decumbent seta. Femora fusiform-clavate, thickened gradually almost from the base.
- Length, 11-16 mm; breadth, 7-9 mm.

Key to the Indian species of genus *Nothopeus* Newman

1. Last four or five joints of antennae narrower as a rule than those preceding them, sometimes slightly thicker; hind femora gradually thickened. Antennae less robust, generally rather slender, longer as a rule than body in ♂ usually black or metallic. Elytra dehiscent, either very short or else considerably narrowed posteriorly

………. tibilalis Ritsema

Prothorax transverse, much narrower than the elytra

………. fuscatrix Ritsema

21. *Niphona (Nothopeus) tibialis*, Ritsema (*Aphrodisium*)

Diagnostic characters

- Of a pale fulvous-brown colour, with the tips of the mandibles, the apical four joints of the antennae, the anterior and posterior margins of the prothorax, the margins of the scutellum and of the metasternum, and the base of the ventral segments of the abdomen black; covered with short pubescence which on the pronotum, scutellum and elytra is somewhat velvety in appearance.
- Antennae reach to the middle of the elytra in the ♀, and to a little beyond

the base of their posterior third in the ♂.

- Prothorax strongly tuberculate on each side; disc with two obsolete tubercles in front, two posteriorly, and a slight median carina on the posterior half; anterior margin somewhat rounded in the middle.
- Elytra extending a little beyond the apex of the abdomen, dehiscing slightly from about the middle of their length, gradually narrowed posteriorly, each rounded at the apex and furnished above with two feeble costae. Hind femora do not quite reach to the apex of the abdomen; hind tibiae sub-cylindrical, thickest near the middle, narrowed towards base and apex and very slightly constricted a little before the apex. Fifth ventral segment of the ♀ feebly sinuate at the apex, the sixth deeply emarginate at the apex, impressed with a line along the middle.
- Length, 29-35 mm; breadth, 9-11 mm.

22. *Niphona (Nothopeus) fuscatrix*, Ritsema (*Aphrodisium*)

Diagnostic Characters

- Cinnamon-brown; antennae tipped with dark brown at the apex of each joint; prothorax with two black-brown spots on the disc and a narrow dark band towards each side; elytra marked each with two oblique black-brown bands that appear to be made up of a series of elongate spots placed side by side; the oblique apical margin of the elytra blue-black, the lateral margins not dark as in the preceding species.
- Head rugulose-punctate. Antennae reach past the apex of the elytra by about three joints in the ♀, and by more than four in the ♂; first joint very densely and very finely rugulose-punctate; third to sixth not spined in either sex; all the joints pubescent, the pubescence longer and somewhat denser on the underside, slightly constricted and marked with a transverse groove near base and apex, a little dilated and strongly tuberculate at the middle of each side; the dark spots on the disc placed on two slight elevations, between which is a median canaliculate depression; the surface densely rugulose punctate, sparsely clothed with longish pubescence.
- Each elytron with two feebly raised dorsal costae which unite at about the middle of the posterior dark band, a single costa continued thence almost

up to the apical border; the surface very finely rugulose-punctate, covered faintly with short grey pubescence. Tips of the femora and tibiae and lateral borders of the metasternum, black. Last ventral segment sinuate at the apex in the ♂, broadly truncate and fringed with reddish-brown hairs in the ♀. Intercoxal process of prosternum abruptly declivous in front.

- Length, 30-37 mm; breadth, 9-11 mm.

Key to the Indian species of genus *Pyrestes* Pascoe

1. Eyes emarginate. Lateral margins of the elytra more or less deeply sinuate near base

……… pyrrhus Gahan

23. *Pyrestes pyrrhus*, Gahan

Diagnostic characters

- ♂. Prothorax, elytra and abdomen red, the last somewhat darker in colour at the base of the first segment; head, antennae, legs, meso- and metathorax black.
- Head finely and very densely punctulate above, less densely and less finely punctate in front.
- Antennae about as long as the body; first joint densely rugulose-punctulate; fifth to tenth compressed, moderately broad, angulated at the apex on the anterior side.
- Prothorax sub-nitid, slightly protuberant at the middle of each side, narrowed towards the apex and to a less extent towards the base, transversely and rather deeply striated over the upper surface, the striae slightly irregular in places, with some small punctures scattered amongst them; the sides also striated, with the striae more or less curved or oblique, and the punctures more densely placed.
- Elytra slightly nitid, very sparsely covered with short red pubescence, rather strongly and very thickly punctured; the punctures a little larger and more distinct near the base and gradually smaller towards the apex; the lateral margins rather strongly sinuate near the base.
- Meso- and metathorax densely and rather strongly punctured; the abdomen more finely punctate. Middle and hind femora feebly carinate on

each side near the base, the clavate portions slightly angulate on the ventral side and fringed with short grey hairs; the hind femora do not extend past the second segment of the abdomen. Tibiae slightly curved the middle ones thickened beneath at the apex.

- Length, 13 mm; breadth, 5 mm.

Key to the Indian species of genus *Xylotrechus* Chevrolat

1. Antennae more or less widely separated at base, the head between them either not raised or only slightly raised at the sides. Head carinate in front. Eyes large, extended on to the front; the face correspondingly contracted in the middle; pygidium of ♀ emarginate at apex.

   Lateral carina oblique or slightly curved.

   ………. smei Lap. et Gory

   Lateral carina extended downwards as far as middle of the front border of the eyes

   ………. subscutellatus Chevr.

24.*Xylotrechus smei*, Chevr.

Diagnostic characters

- Brown above; with a greyish or yellowish pubescence that covers the head and most of the prothorax and forms bands and spots on the elytra, disposed as follows :—(1) a transverse band on each at the base, followed a little behind by (2) a short transverse spot; (3) a narrow band which begins near the scutellum, passes close by the suture, diverges a little from it posteriorly and at a short distance before the middle curves outwards to the side, thence it bends forward a little before reaching the margin; (4) a narrow, obliquely transverse, somewhat wavy band, placed a little behind the middle; (5) an apical band, which is slightly produced forwards at the suture.
- Body beneath marked with spots or bands of whitish pubescence. Vertex of head marked with a fine carina which divides anteriorly into two finer carinae; front with four carinae, the intermediate two converge downwards and unite so as to form a single median carina on the lower part of the face.

- Prothorax rounded at the sides, widest behind the middle, narrowed gradually in front more strongly towards the base, slightly raised and sub-asperate along the middle of the disc; marked with two rounded dark brown spots on the disc and a smaller one on each side ; the disc more or less infuscate in the middle, especially towards the base.
- Length, 11-17 mm; breadth, 3-5 mm.

25.*Xylotrechus subscutellatus*, Chevr.

Diagnostic characters

- Dark brown, with a tawny or greyish-tawny pubescence that covers the head and prothorax and forms bands on the elytra; prothorax with a median asperate band which is widened towards the base, two lateral spots on the disc, and a small spot on each side, black; the elytral bands arranged as follows:- (1) a band which crosses the base of each elytron from the shoulder, curves backwards near the scutellum and runs close along the suture for a short distance, then diverges from the suture and curves outwards to the side at about one-third from the base, turning forward a little before it reaches the outer margin; (2) a short, slightly oblique, transverse band on each a little behind the base; (3) a band that passes obliquely outwards from the suture at about two-thirds of its length, from the base; (4) a band at the apex.
- Body beneath with a large spot of yellowish-white pubescence on the hinder half of each of the metathoracic episterna, sometimes with a smaller spot on the anterior part; a lateral transverse spot of the same kind on the posterior half of each of the first three abdominal segments. Vertex of head with a fine median carina which divides anteriorly into two finer ones; front with four carina; the intermediate pair converge and unite below so as to form a single median carina on the clypeus.
- Antennae reach a little past the base of the prothorax in the ♀, slightly longer in the ♂; the last two or three joints somewhat thickened. Prothorax rounded at the sides, widest behind the middle, narrowed gradually in front, more strongly towards the base.
- Length, 10-17 mm; breadth, 4-6 mm.

Key to the Indian species of genus *Caloclytus* Chevrolat

1. Antennae not widely separated at base, two approximate, divergent elevations on head between them. First joint of hind tarsi much longer as a rule than second and third united. Antennae rather closely approximated at base, third joint little or not longer than first; elytra moderately long

……… arciferus, Chevr.

26. *Chlorophorus (Caloclytus) arciferus*, Chevr. (*Amauraesthes*)

Diagnostic characters

- Densely covered above with an ochreous-yellow pubescence, varied with black markings disposed as follows:- a median bilobed spot on the disc of the prothorax and a small spot on each side just before the middle; three bands on each elytron; the first curved inwards from the shoulder passes backwards along the disc rather nearer to the suture than to the side, then curves outwards and ends near the edge of the disc at about a third of its length, from the base; the second band is narrow, transverse, median, with a spot-like dilatation at the suture and another at the outer end, which is slightly removed from the margin; the third band, also narrow and transverse, is placed a little nearer to the apex than to the median band.
- Antennae about half as long as the body, blackish, with a grey pubescence.
- Prothorax longer than broad strongly rounded at the sides, not quite as wide in the middle as the base of the elytra.
- Elytra truncate at the apex, feebly dentate at the angles. Body beneath greyish pubescent along the middle, more densely pubescent and whitish at the sides. Legs black, with greyish pubescence; middle and hind femora carinate on each side, the hind pair feebly so.
- Length, 11-14 mm; breadth, 4-6 mm.

27. *Ostedes sp.*, Thomas

Diagnostic Characters

- ♂. Head, pronotum, body beneath and legs black; elytra dark grey, glossy.
- Antennae extended to about the middle of the elytra; first joint sparsely

punctured, almost as long as the next three joints united, the third thicker but very little longer than the fourth.

- Pronotum widest at about one-third of its length from the base, thence narrowed gradually in front and more strongly behind; its edges armed with a series of small spines, one of which at the lateral angle is recurved; upper surface with four ill-defined, sparsely punctured, shiny spaces across the middle and a narrow transverse one near the base, the last turned obliquely forwards at each end.
- Elytra glossy over almost the whole surface. Tarsi long and narrow; first joint of hind tarsus longer than the other joints united.
- Length, 12-14 mm; breadth, 3-5 mm.

Key to the Indian species of genus *Olenecamptus* Fabr.

1. Lateral edge of prothorax distinct from the base to the anterior margin.

……… bilobus

Prothorax large, transverse, nearly as wide as elytra, little depressed above

……… indianus

Prothorax with sides converging slightly; curved lines in front; the disc with two triangular nitid areas

……… pseudostrigosus Fabr.

2. Elytra slightly narrowed backwards; finely and closely punctate

……… anogeissi

28. *Olenecamptus bilobus*

Diagnostic Characters

- ♂. Dark brown; varying on the elytra, underside and legs to reddish brown. Antennae a little longer than the body; first three joints asperate and opaque, the third four times as long as the first and equal in length to the three succeeding joints united.
- Prothorax with its lateral edge distinct from the base to the anterior margin, furnished with a spine at the base, a short spine just behind the middle and a projecting angle or tooth(sometimes obsolete) close to the front

margin; notum convex closely punctured, furnished with sparse erect hairs towards the sides.

- Elytra more than 21/2 times as long as broad, bare of pubescence and very closely granulate or rugulose; each with two distinct dorsal costae, the inner costa less strongly raised beyond the middle and united with the outer one at about one fifth from the apex. First three tarsal joints united about equal in length to the claw-joint, the third joint only slightly wider than the second. Last ventral segment emarginate in the middle behind.
- ♀. Antennae reach to about the posterior third of the elytra, third joint closely and somewhat asperately punctured towards the base, less closely towards the apex. Fifth ventral segment with a broad, deep, arcuate emargination at the apex. Ovipositor short, dorso-ventrally compressed.
- Length, 40-45 mm; breadth, 10-12 mm.

29. ***Olenecamptus indianus***

Diagnostic Characters

- ♂. Maroon-patchy; elytra with dark brown lateral margins, marked each with two black-brown spots placed obliquely between the base and the middle, with another large oblique spot or band a little beyond the middle.
- Head densely rugulose punctate. Antennae extended by about two or three joints past the apex of the elytra; first joint very stout, densely granulate, third to sixth armed posteriorly at irregular intervals with short spines, third nearly twice as long as the first.
- Prothorax large, transverse, nearly as wide as elytra, little depressed above, strongly rounded at the sides but drawn in at the base and furnished behind the middle with a feeble tubercle; the surface densely rugulose-punctate, sparsely covered with rather long pubescence.
- Each elytron with two feebly raised dorsal costae which unite at about the middle of the posterior dark band, a single costa continued thence almost up to the apical border; the surface very finely rugulose-punctate, covered faintly with short grey pubescence. The intercoxal process of the prosternum is gradually sloped in front.
- Length, 48 mm; breadth, 9-11 mm.

30. ***Olenecamptus pseudostrigosus*, Fabr.**

Diagnostic Characters

- ♂. Dark brown, with the elytra of a somewhat lighter brown tint that becomes darker towards the base; the intermediate joints of the antennae, the hind legs and the tarsi more or less reddish.
- Head somewhat strongly punctured in front and between the eyes, finely granulose behind. Antennae reach to the apical third or fourth of the elytra; first joint relatively short, only about one-third longer than broad, coarsely punctured; third thickened, slightly channeled and sparsely punctured above, somewhat denticulate below, equal in length to the fourth, fifth, and nearly half of the sixth united.
- Prothorax with its sides converging in slightly curved lines in front; the disc with two triangular, strongly punctured and slightly depressed, nitid areas in front, two small rugose spots external to these and a transverse nitid band at the base, this basal band produced obliquely at its extremities; at the middle it is produced forwards in a narrow triangle which sometimes extends to and unites with the inner angles of the triangular spaces in front.
- Elytra densely granulose, the granules stronger and the surface rougher towards the base, especially near the suture. Metasternum bare of pubescence, with a sparsely punctured triangular area clearly marked off by a slightly raised line from the closely punctured part on each side. Front legs asperate, spinose beneath, the femora thickened, the tibiae elongated and slightly curved; the middle and hind legs much less spinose; first joint of the tarsi scarcely so long as the next two joints united.
- ♀. Antennae shorter, not reaching beyond the middle of the elytra, with the first and third joints much less thickened than in the male, third not asperate.
- Prothorax with its edges more strongly spined, and more convergent in front; the notum strongly and rather closely punctured towards the sides, less closely in the middle and there also more or less glossy. Metasternum pubescent at the sides as well as in the middle, rather closely granulate punctate. Front legs similar to the other two pairs.
- Length, 28-32 mm; breadth, 9-11 mm.

31. *Olenecamptus anogeissi*

Diagnostic Characters

- Reddish brown or ferruginous in colour, the elytra of a more reddish or testaceous tint, suffused with dark brown at the shoulders and sometimes also along the sides; the femora sometimes tipped with dark brown at the apex.
- Antennae of the ♂ a little longer than the body, those of the ♀ much longer and with a thicker first joint; joints fifth to tenth denticulately produced at the anterior angle; the punctures on the basal half, especially near the base a little larger and more crowded together than those on the apical half; the truncate apices dentate at each of the angles.
- Length, 22-32 mm; breadth, 6-8 mm.

32. *Anomophysis* sp.

Diagnostic Characters

- ♂. Head elongated behind the eyes, much narrower than the prothorax; mandibles short and oblique, with sharp toothless inner edge; eyes emarginate in front, lower lobes distant from base of mandibles. Antennae longer than the body; first joint stout, reaching almost to the front margin of the prothorax, armed with a strong spine behind, close to the apex; third joint nearly five times as long as the first, slightly curved; fourth joint a little longer than the first, also curved; the joints from the third to the sixth with a short thick fringe of tawny hairs beneath.
- Prothorax with its lateral edge distinct from the base to the apex, a strong dentiform process at the base, and with a short tooth at the middle and a blunt angular process at the apex.
- Elytra each with two strongly raised dorsal costae and a short lateral costa which is distinct only near the apex.
- Tarsi moderately broad, with the first joint scarcely longer than the third and the claw-joint almost as long as the first three joints united. Last ventral segment rounded at the apex.
- ♀. Antennae more slender than in the male, scarcely reaching beyond the middle of the elytra, without a fringe of hairs beneath.
- Length, 48-50 mm; breadth, 9-11 mm

Key to the Indian species of genus *Celosterna* Fabr.

1. Prothorax with its lateral edge distinct from the base up to the anterior margin

……… scabrator Fabr.

33. *Celosterna scabrator*, Fabr.

Diagnostic Characters

- ♂. Dark grey-brown; with the elytra somewhat greyish, naked, punctate and glossy. Antennae longer than the body; third joint slightly thickened, three times as long as the first, both closely granulated; fourth joint sparsely punctured, less than half the length of the third and very little longer than the fifth.
- Prothorax with its lateral edge distinct from the base up to the anterior margin, furnished with a spine at the base, another just behind the middle and with an angulate or dentiform process in front; notum convex, very closely punctured, sparsely setose towards the sides.
- Elytra each with two dorsal costae, the inner one disappears a little beyond the middle, the outer costa is continued back to end a short distance before the apex.
- Tarsi narrow; the first three joints of equal width, together about as long as the claw-joint. Last ventral segment arcuately emarginate at the apex.
- ♀. Antennae reach to about the posterior third of the elytra; the third joint not thickened and less closely granulated than in the male. Fifth ventral segment deeply emarginate in the middle at the apex. Ovipositor short, dorso-ventrally compressed.
- Length, 22-46 mm; breadth, 6-12 mm.

34. *Sophronica* sp.

Diagnostic Characters

- ♂. Head short, almost vertically deflexed in front; mandibles short, abruptly incurved and acute at tip, crossing one another when closed; labrum very short and broad; eyes large and prominent, emarginate in front; upper lobes not widely separated from each other, lower lobes closely approximated to base of mandibles in front.

- Antennae a little longer or shorter than the body; first joint short, obconical; third to tenth strongly compressed, longitudinally carinated, produced into a sharp angle or tooth at the apex on the posterior side; third twice as long as the first, broader, but scarcely longer, than the fourth; fifth to tenth successively shorter and narrower.
- Prothorax transverse, with distinct lateral edge placed at some distance from the outer angle of the acetabulum and produced into an acute spine in the middle each flank with a closely punctured area, sometimes completely circumscribed by a raised margin, lying between the prosternal suture and the anterior half of the lateral edge.
- Elytra broader than the prothorax, twice or more than twice as long as broad, rounded and unarmed at the apex; each with three distinctly raised costae. Legs moderately long, laterally compressed; first joint of hind tarsus a little longer than the second and third united. Prosternum strongly arched between the coxae, slightly projecting beyond them posteriorly. Last ventral segment slightly sinuate at the apex.
- ♀. Antennae shorter and much narrower than those of the male, the third and fourth joints scarcely broader than the fifth and following joints; the third nearly half as long again as the fourth. Elytra relatively longer than in the male.
- Length, 10-12 mm; breadth, 3-5 mm.

Key to the Indian species of genus *Polyzonus*

1. Prothorax with short conical tubercle on each side

………. tetraspilota

35. *Stibara (Polyzonus) tetraspilota*

Diagnostic Characters

- ♂. Head strongly exserted, gradually narrowed backwards from the eyes; eyes transverse, large and prominent, with feebly sinuate front margin; front very short; clypeus short, transverse, sub-membranous near its front margin; mandibles stout, abruptly incurved below, with sharp sub-truncate or bidentate apical edge; maxillae bilobed, their palpi very long, with the second joint five or six times as long as the first, the third very short, the fourth nearly as long as the second and furnished with a long bent ramus arising near its base; labial palpi short, with thickened terminal joint; mentigerous process of sub-mentum distinct and rather long.

- Antennae inserted very close to the base of the mandibles, extended some distance beyond the middle of the elytra, sparsely pubescent; first joint as long as the head, slightly curved, gradually thickened towards the apex; third shorter than first and slightly longer than fourth; fourth to eleventh sub-equal in length but successively narrower.
- Prothorax with a short conical tubercle on each side. Mesonotum with stridulatory area, divided by a median groove.
- Elytra gradually but slightly narrowing backwards, rounded at the apex, very strongly sub-seriately punctured.
- Legs moderately long, with strongly thickened femora, the hind pair longer and thicker than the others and either denticulate or spinulose beneath; tarsi rather broad, the third joint not cleft down the middle, but deeply channeled above, with the minute fourth joint inserted in the normal position at its base. Front coxae slightly angulate on the outer side, rounded and almost contiguous on the inner, the prosternal process very short and the coxae separated only by a thin vertical plate; their acetabula open behind. Acetabula of middle coxae extend to the epimera. Metathoracic episterna very narrow, acuminate posteriorly.
- ♀. Maxillary palpi normal, but with the second joint relatively long. Antennae a little shorter than in the male, and the hind femora less thickened.
- Length, 35-38 mm, breadth, 5-8 mm.

Key to the Indian species of genus *Acalolepta*

1. Prothorax smooth and glossy with deep anterior constriction and groove with short conical tubercle on each side

………. rusticatrix

36. ***Acalolepta rusticatrix***

Diagnostic Characters

- Straw-brown, glossy; the antennae, tibiae, tarsi, the dorsal borders of the femora, and the post-humeral spines of the elytra black.

- Head impressed with a fine median line along the vertex and front, the sides finely and sparsely punctate, the vertex with two slight tubercular elevations followed by a median depression near where the short neck begins. Antennae of female reach to the middle of the elytra.
- Prothorax smooth and glossy, with a characteristic appearance owing to the deep anterior constriction and groove preceded by the raised and laterally projecting apical border.
- Elytra finely but not very densely punctate all over, less nitid and a little paler in colour than the prothorax; the spine near each shoulder directed outwards and upwards.
- Metasternum marked with a deep median groove which ends in front in a small pit just where the triangular lobe which projects between the middle coxae begins. Hind tarsi very long, the first joint nearly twice as long as the next two united; third joint cleft to the middle, claw-joint long.
- ♀. Prothorax above, except along the front and hind borders, and the whole of the elytra, red. Antennae not extended beyond the middle of the elytra, with the fourth joint distinctly shorter than the third. Last ventral segment with a shallow groove along the middle; rounded at the apex; pygidium slightly emarginate in the middle at the apex.
- Length, 11-15 mm; breadth, 3.5-5 mm.

Key to the Indian species of genus *Arhopalus*

1. Pronotum, owing to the arrangement of the pubescence, appears to have a broad shallow groove with short conical tubercle on each side ………. oberthueri

37. *Arhopalus oberthueri*

Diagnostic Characters

- Head on top, pronotum, and elytra red, rather densely covered with a somewhat velvety pubescence of a bright red colour; body beneath, legs and antennae black; head more or less black in front, at the sides and beneath.
- Antennae reach to the posterior third of the elytra in the ♂, barely to the

middle in the ♀, densely covered with short black pubescence; the joints from the third to the tenth flattened and triangular, projecting strongly at the apex on the anterior side, sub-equal to one another in length in the ♀, successively and very gradually longer in the ♂, each as broad as it is long or almost so in the ♀ and longer than broad in the ♂.

- Pronotum, owing to the arrangement of the pubescence, appears to have a broad shallow groove along the middle and a slight depression on each side near the base.
- Elytra furnished each with four narrow slightly raised longitudinal costae, the two inner more distinct than the outer. Body beneath and legs minutely and densely punctulate, thinly clothed with blackish pubescence. First joint of hind tarsus narrower than the second or third, nearly as long as these two united.
- Length, 16-21 mm; breadth, 3-5 mm.

38. ***Pothyne* sp.**

Diagnostic Characters

- Light brown in colour; head and prothorax very finely granulate and dull. Antennae sparsely fringed with pale setae beneath.
- Elytra somewhat glossy, very closely punctured each with seven raised lines, the first running very close to the sutural edge posteriorly but diverges slightly from it in front, the third and fifth somewhat more strongly raised, connected with one another and with the seventh by means of oblique cross-lines posteriorly; the sixth and seventh obsolete in front, and the sixth obsolete also posteriorly.
- Length, 12-20 mm; breadth, 3-4 mm.

Key to the Indian species of genus *Desisa*

1. Elytra rounded at the apex, truncate near suture and armed each with sutural spine

……… subfasciata

39. *Desisa subfasciata*

Diagnostic Characters

- Dull brownish in colour, rather densely covered with brownish-grey pubescence, the elytra marked each with two closely approximated ivory-like spots just behind the middle and a similar spot at the base, the inner of the two sub-median spots usually smaller than the outer one.
- Prothorax rather broad in front and narrowed towards the base in the ♂, almost as narrow at the apex as at the base in the ♀; the disc with two small but distinct tubercles placed transversely just before the middle.
- Elytra rounded at the apex, a little truncate near the suture and armed each with a sutural spine; the surface rather thickly clothed with rather large but shallow sub-nitid punctures front edges of which are slightly raised; each with two very feebly raised and almost obsolete dorsal lines. Antennae, scarcely long as the body in the ♀; about one-third longer than the body in the ♂.
- Length, 15-20 mm; breadth, 4-6 mm.

Key to the Indian species of genus *Clyzomedus*

1. Elytra transversely truncate at the apex, with the outer angles obtuse and the sutural ones spined

……… indicus

40. *Clyzomedus indicus*

Diagnostic Characters

- ♂. Blackish-brown, covered all over with short pubescence of a uniform greyish tint.
- Antennae not quite twice the length of the body; the first joint short and thick, not reaching to the front margin of the prothorax, sharply edged and angulate in front at the apex; third half as long again as the first, and strongly thickened from the middle towards the apex; fourth sub-equal in length to the first, thickened less strongly than the third; fifth longer than the third and shorter than the sixth; sixth to eighth sub-equal in length; ninth and tenth shorter; eleventh nearly twice as long as the tenth; sixth to tenth angulated at the apex in front, unarmed posteriorly.

- Prothorax somewhat rounded at the sides, constricted a little behind the apex, marked with one transverse furrow near the apex and with two near the base; the whole of the upper surface between these grooves coarsely and irregularly corrugated.
- Elytra transversely truncate at the apex, with the outer angles obtuse and the sutural ones spined. Intercoxal process of prosternum truncate and prominent posteriorly. First joint of hind tarsus about equal in length to the second and third united.
- Length, 15 mm; breadth, 5 mm.

Key to the Indian species of genus *Apomecyna*

1. Elytra truncate at the apex, with a short spine from each at the sutural angle

………. histrio

41. *Apomecyna histrio*

Diagnostic Characters

- Varies in colour from black to reddish brown, not very densely covered with short pubescence of a greyish or brownish-grey tint.
- Head with a median impressed line or groove above, between the eyes. Antennae not quite so long as the body in the ♀, and from one and a half times to nearly twice as long as the body in the ♂, fringed with short delicate grey hairs beneath; third and fourth joints nodose at the apex, the third much longer than the fourth; fifth to tenth compressed and angulated anteriorly at the apex.
- Prothorax rounded at the sides, somewhat constricted in front, irregularly and not very strongly wrinkled above in a general transverse direction, marked on the disc with some feeble longitudinal and oblique grooves which together form a somewhat crown-shaped impression.
- Elytra truncate at the apex, with a short spine from each at the sutural angle; the pubescence covering them more or less glossy, and generally somewhat thinner on each side in front of the middle so that the colour of the underlying derm becomes more apparent there.
- Length, 16-20 mm; breadth, 4-6 mm.

42. *Exocentrus* sp.

Diagnostic Characters

- Chestnut-brown in colour, more or less nitid sparsely furnished above with short semi-erect fulvous brown hairs.
- Head and basal joints of antennae finely rugulose-punctate.
- Prothorax closely and rather strongly punctured; marked with a feeble sinuate groove or depression near the apex and another near the base; the disc slightly depressed along the middle, with a very narrow impunctate space behind.
- Elytra closely and strongly punctured, less strongly near the apex.
- Body beneath reddish brown, sparsely pubescent, less closely and rather finely punctured; prosternum transversely depressed a little behind the front margin; abdomen narrowed posteriorly, first segment longest, second to fourth successively shorter. Legs reddish brown, minutely and sparsely punctate.
- Length, 7-10 mm, breadth, 3 mm.

43. *Rondibilis* sp.

Diagnostic Characters

- ♂. Long and narrow. Entirely black, with a short ashy-grey pubescence that covers the body beneath, the legs and the greater part of the antennae, and is faintly visible on the upperside.
- Head finely rugulose-punctate, with a somewhat granulate appearance above. Antennae a little longer than the body; first joint closely and finely punctured, marked with a narrow cicatrix and carina at the apex; third about one-third longer than the first or fourth; fifth to tenth sub-equal in length to the third; each denticulately produced at the apex in front; eleventh a little longer than the tenth.
- Prothorax sub-cylindrical, much longer than broad, slightly constricted and marked with a transverse groove near the apex, transversely and rather finely wrinkled over the whole of the upper surface.
- Elytra parallel-sided, narrowed and truncate at the apex, finely and very closely punctured and spotted throughout, but somewhat less finely near the base.

- Hind femora extend a little beyond the hind margin of the second abdominal segment; first joint of hind tarsus as long as the next two united.
- Length, 8 mm; breadth, 2 mm.

44. ***Ropica*** **sp.**

Diagnostic Characters

- Brown to dark brown in colour; scantily clothed with greyish depressed pubescence interspersed with moderately long sub-erect tawny setae. Head densely punctate, marked above with a feeble median groove which extends anteriorly between the antennal supports.
- Prothorax densely rugulose-punctate, somewhat sparsely asperate at the sides; the disc with a postero-median and two nearly obsolete anterior callosities.
- Elytra densely punctate, the punctures somewhat unequal in size, rather strong on the anterior half and gradually smaller towards the apex; each elytron with one or two feebly raised longitudinal lines.
- Metasternum, except at the side, and the abdomen very sparsely punctate, femora almost impunctate; the tibiae punctate.
- Length, 4-6 mm; breadth, 2-3 mm.

Key to the Indian species of genus *Metamecyna*

1. Elytra finely and somewhat sparsely punctate on disc from base to middle ………. uniformis

45. ***Metamecyna uniformis***

Diagnostic Characters

- Reddish; the elytra itself and the shoulders somewhat paler in colour than the surrounding parts.
- Antennae, except the basal joint, covered with very short fulvous pubescence.
- Prothorax obtusely tuberculated at the middle of each side; constricted strongly at the base and very slightly in front of the lateral tubercles; minutely and sparsely punctate, sparsely furnished with longish erect

hairs.

- Elytra finely and somewhat sparsely punctate on the disc from the base to the middle.
- Femora rather gradually and not strongly clavate. First joint of hind tarsi shorter than the second and third united.
- Length, 5-6 mm; breadth, 2-3 mm.

Key to the Indian species of genus *Dihammus*

1. Head with the lateral carinae oblique, slightly curved, extending below almost to level with the lower margin of the eyes. Elytra sub-glabrous ………. cervinus

46. *Dihammus cervinus*

Diagnostic Characters

- Black; head and prothorax clothed with grey pubescence; the prothorax with four small brown spots in a transverse row across the middle—two dorsal and two laterals.
- Elytra sub-glabrous, testaceous black-brown, narrowly covered with grey pubescence at the base, marked with some small spots of ashy-grey pubescence; the apex also narrowly bordered with ashy grey. Body beneath covered with grey pubescence, a rather large posterior spot on each of the metathoracic episterna ashy white.
- Head with the lateral carinae oblique, slightly curved, extending below almost to a level with the lower margin of the eyes; front narrowed between the eyes, furnished with two prominent convergent carinae, which are united below.
- Antennae less than half the length of the body; third one slightly longer than the first. Prothorax widest behind the middle, very slightly narrowed in front, strongly narrowed towards the base; disc with a median asperate carina, which is broader and more strongly raised behind than in front. Femora rather strongly thickened; the hind pair extending a little past the apex of the elytra. First joint of hind tarsi twice as long as the second and third united.
- Length, 35-38 mm; breadth, 8-10 mm.

Species account of long-horned beetles (Cerambycidae) from Simbalbara WLS

Dorystenes (Lophosternus) indicus

Dorystenes (Lophosternus) huegelii

Cantharocnemis downesi

Hypoeschrus indicus

Xystrocera globosa

Stromatium barbatum

Plocaederus obesus

Plocaederus pedestris

Aeolesthes holosericea

Aeolesthes induta

Hoplocerambyx spinicornis

Pachydissus parvicollis

Derolus volvulus

Trinophylum cribratum

Ceresium simplex

Niphona tibialis

Plate 21

Niphona fuscatrix

Pyrestes pyrrhus

Xylotrechus subscutellatus

Chlorophorus arciferus

Ostedes sp.

Olenecamptus bilobus

Olenecamptus indianus

Olenecamptus pseudostrigosus

Plate 22

Olenecamptus anogeissi

Anomophysis sp.

Celosterna scabrator

Sophronica sp

Stibara tetraspilota

Acalolepta rusticatrix

Arhopalus oberthueri

Desisa subfasciata

Plate 23

Clyzomedus indicus

Apomecyna histrio

Exocentrus sp.

Exocentrus sp.

Rondibilis sp.

Ropica sp.

Metamecyna uniformis

Dihammus cervinus

Plate 24

5.6 Discussion

Approximately 60,000 species of insects are identified and described in India and a few groups have so far been painstakingly catalogued and monographs published on them. It is estimated that a minimum of 4,00,000–6,00,000 or more Indian species are yet to be discovered; there is still a long way to go to have a sound taxonomic knowledge of the fauna of Indian insects. According to Roonwal (1989), approximately 1,00,000 species of insects occur in India and a recent global biodiversity assessment estimates it to be 10 to 15 times more than this number.

There are at present hardly 100 Indian workers who are really competent, capable and actively engaged in the taxonomic studies of Indian insects. The number needs to be multiplied many times if the fauna is to be explored, taxonomic research conducted and identification manuals published; resources are limited and the task is tremendous. Very little contributions are made by Indian workers to the taxonomy of Indian insects. While some orders like Hymenoptera, Diptera and Hemiptera are better worked out, others are not. There are several problems to overcome in Indian taxonomic research. More funding, introduction of taxonomy in the curricula of UG and PG students of biology, training in taxonomy, enough library facilities for taxonomic literature, enough journals to undertake large revisionary works and the need for more identification service centres and repositories are all essential for the development of taxonomic research in India (Whitehead 1990, Narendran 2001).

Species whose presence or abundance readily reflect some measure of the character of the habitat within which they are found are often identified as bioindicators, most frequently to monitor changes within a particular habitat. In spite of the intuitive appeal of bioindication, largely as a consequence of its cost-effectiveness in the face of urgent conservation issues, indicator studies frequently fall short of providing spatially explicit and objectively determined indicator species or species subsets. One method used to quantify the bioindicator valueof a range of taxa is the indicator value (IndVal) method developed by Dufrêne and Legendre (1997). This method combines measurements of the degree of specificity of a species to an ecological state, for example a habitat type, and its fidelity within that state (Dufrêne and Legendre 1997). Species with a high specificity and high fidelity within a habitat will have a high IndVal. High fidelity (frequency of occurrence) of a species across sample sites is generally associated with large abundance of individuals (Brown 1984, Gaston et al. 1997). Both these characteristics facilitate sampling and monitoring, which is an important requirement for a useful bioindicator (Jenkins 1971, Kremen et al. 1994).

The IndVal method has numerous advantages over other measures used for ecological bioindication (McGeoch and Chown 1998). For example, the IndVal is calculated independently for each species, and there are no restrictions on the way in which sites (habitats) are categorized, i.e. these may be grouped subjectively or quantitatively (McGeoch and Chown 1998). None the less, the usefulness of this method is ultimately dependent on the degree to which species maintain high and significant indicator values (IndVals) when tested in different locations and times. Although habitat specificity is a comparatively inflexible species-specific trait (Southwood 1977, Greenslade 1983), the abundance of species (and thus their fidelity) in an assemblage may vary over time in at least two ways (Rosenzweig 1995). The sensitivity of the IndVal to such changes will ultimately determine its usefulness for bioindication.

Comparative studies have been conducted on various insect groups and have generally been found to decrease in diversity along the disturbance gradients (Rosenzweig and Abramsky 1993). Beetles were chosen in this study because of their extreme diversity in form and function (Hammond 1995), and especially because a high level of taxonomic expertise was available. Such indicator species can facilitate environmental monitoring if it is substantially easier to measure their presence or abundance than it is to measure the phenomena they are purported to indicate (Duelli and Obrist 1998, McGeoch 1998). Species that are strongly correlated with high diversity sites could be especially useful because such species could be used to prioritize conservation measures (Oliver and Beattie 1996). It would be much easier to identify the presence of a few species than to measure overall biological diversity of a community.

Carabidae as Bioindicators

Ground beetles are abundant and diverse in most ecological systems and therefore serve as an appropriate group for which to make inter-regional comparisons. The majority of ground beetles are predatory. Thus carabids are good integrators of a substantial amount of ecological information about the biological communities to which they belong because they may be primary or secondary predators in forest soils (Day and Carthy 1988). Carabid beetles have received considerable attention as potential biodindicators of the effects of disturbance in forests (Niemelä 2001, Rainio and Niemelä 2003). They have been used to reflect forest habitat changes associated with a variety of management conditions including specific harvesting practices, such as clear-cutting (Niemelä et al. 1993, Koivula et al. 1999), partial-cut harvesting (Siira-Pietikainen et al. 2003) or thinning (Lemieux and Lindgren 2004), and harvesting followed by site preparation (Duchesne et al*.* 1999), for making comparisons between silvicultural treatments and natural disturbances such as wildfire (Gandhi et al. 2001), and for determining effects of intensive fiber production, such as plantation forestry and ligniculture (Duchesne and McAlpine 1993, Allegro and Sciaky 2003).

Carabids can be divided into geographically wide-ranging generalist (ubiquitous) species, species occupying a wide range of habitats (eurytopic), and specialists occurring in one or a few habitats (stenotopic). Each habitat type has certain species assemblage with generalist and specialist species. Thus, individual carabid species or species assemblages can be used as bioindicators. However, because of the high number of generalist species carabids have been criticised as bioindicators.Carabids show different levels of habitat selectivity, ranging from specialists to generalists (Niemelä 1990, Pohl et al. 2007), carabid assemblages can used to characterise disturbance in various habitats like forests and as an indicator guild to quickly and cheaply assess the biotic sensitivity of a forest. Carabid beetles exhibit responses that are sensitive enough at small scales such that they may be used appropriately to indicate edge conditions, and to assess how quickly sites recover and re-establish old-growth communities. Three aspects of carabid diversity are modulated by the environment; relative catches of each species within a particular forest site, absolute population size of individual species, and presence or absence of species within assemblages.

Cicindelidae as Bioindicators

Tiger beetles (Coleoptera: Cicindelidae) provide a relatively discrete taxonomic unit whose history is well documented (Pearson and Cassola 1992). The tiger beetles are a small but distinct group of over 2600 species whose biology is also well known (Pearson and Vogler 2001). These beetles are attractive, fast-flying and fast-running insect predators that occur in many diverse habitats around the world. Many of the same characteristics of tiger beetles that have generated considerable interest among amateurs and professional biologists have also contributed to their increasing role in conservation studies.

Most important among these characteristics is the ease with which most species can be found and identified in the field, their habitat specificity, and their value as indicators of habitat health and of biodiversity (Fretwell and Lucas 1970, Franklin 1993, Gaston 2000a & b). Also, because they have been well-collected and studied, their past and present distributions are known sufficiently to evaluate historic trends of decline in range or abundance (Desender et al. 1994, Knisley and Fenster 2005). There is an extensive knowledge of taxonomy and distribution records of tiger beetles that lent themselves to early studies of declining populations and extinctions. As such, several species and populations of tiger beetles became some of the first insects declared legally endangered or threatened with extinction. Field studies of tiger beetle species throughout the world show consistent habitat specialization (Pearson 1988 and 1992, Acciavatti and Pearson 1989, Pearson and Juliano 1991, Uniyal et al. 2007).

The reason for this pattern of narrow habitat use is most likely due to physiological adaptations of the larvae and limited dispersal capacity of the adults (Mury Meyer 1987, Knisley and Juliano 1988). Larval stages occur in a narrower range of microhabitats than adults, and appear to tolerate less variation of many physical factors, especially soil moisture, soil composition and temperature (Van Straalen 1997). Female choice of oviposition site contributes to habitat specialization as well, as it is highly specific to soil type.
Among the consequences of habitat conversion from closed canopy to secondary and agricultural forests is the change in microclimatic conditions (Dunn 2004, 2005). In particular, soil humidity decreases and air temperature increases. Tiger beetle larvae are sensitive to these changes; during hot, dry periods, larval tiger beetles plug their burrows and become inactive (Willis 1967, Knisley 1987). If soil desiccation reaches extreme levels, larvae leave their burrows and relocate. Such changes in species assemblages and abundances most likely reflect changes in microclimatic conditions as disturbance increases.

Future studies of tiger beetles as monitoring indicators, therefore, should focus on the precise determination of the ecological correlates of larval survival for each species involved. Few insects are well-enough known globally to document these types of population decline. Because of the rich collections of tiger beetle specimens available for study, however, the disappearance of species from former parts of the range can be authenticated.

From these historical records, some long-term changes in the environment can also be deduced (Goldstein and DeSalle 2003, Horgan and Chavez 2004, Mawdsley 2005). Thus, tiger beetles help offer a window into our past and can provide insight as to where protective measures are needed (Babione 2003). A common approach to resolving the problems in conservation biology has been to use indicator taxa as test organisms that purportedly represent other taxa in a complex environment. By focusing studies on a small but representative subset of the habitat or ecosystem, patterns of habitat degradation and population losses can be more quickly and clearly distinguished (Noss 1990).

Scarabaeidae as Bioindicators

Dung beetles compose an extremely abundant and species rich group of organisms, as well as taxonomically and functionally well defined (Finn et al. 1999), hence being especially suitable for community studies. Their efficiency in locating and removing debris (Janzen 1983, Gill 1991), controlling parasites and secondarily dispersing seeds (Janzen 1983, Estrada and Coates-Estrada 1991, Shepherd and Chapman 1998) make them important components in the functioning of terrestrial ecosystems. Both adults and larvae are detritivorous, and food resources are composed mainly of feces, along with carrion and fallen fruits (Favila and Halffter 1997). Dung patches provide islands of an energetically rich feeding resource, and are often used for mating and oviposition as well.

However, dung constitutes a resource spatially and temporally unpredictable and ephemeral, what influences significantly the spatial distribution and the competitive relationships within and between species that depend on it (Hanski and Niemelä 1990, Cambefort 1991, Hanski and Cambefort 1991, Hirschberger 1998). Thus, some degree of niche partitioning (ecological, temporal or spatial) is expected to be important in promoting species coexistence within a guild (Janzen 1983, Gill 1991, Hirschberger 1998). Indeed, most coprophagous beetles do not disperse long distances to find food and have a stenotopic distribution in relation to vegetation types (Cambefort and Hanski 1991). Because of this, they usually are very sensitive to environmental changes and are considered well-suited as bioindicator organisms (Howden and Nealis 1975, Klein 1989, Favila and Halffter 1997). Variations in assemblage patterns across habitats provide clear evidence on how organisms perceive and respond to environmental changes, even at small (or micro) scales. Dung beetles (Scarabaeidae) have been frequently used as bioindicators of habitat quality due to their sensitivity to environmental changes.

Assemblage patterns of dung beetles (abundance, richness, diversity, species composition) were found to be more similar between dung patches within a same habitat than between patches located in different habitat, regardless of the distance between patches. Also, dung beetles showed changes associated in assemblage structure across habitats and between gradients of human influenced habitats.

Density of individuals and species were higher in the control plots with protected forest than in the human dominated areas. Further, the overall richness was also higher in control sites than experiment sites. Species composition differed greatly between habitats, and shared species were consistently more abundant in one or another habitat. This demonstrated that there was a significant effect on the populations, demonstrated by consistent changes of assemblage parameters according to the degree of human influence. Since, dung beetle assemblages in each habitat were sharply distinct, and this distinctiveness could be detected at a very fine scale. It confirmed the stenotopic character of dung beetles in relation to habitat use and their suitability as bioindicators of habitat quality.

Staphylinidae as Bioindicators

The family Staphylinidae is one of the largest beetle families and is distributed worldwide in almost all types of ecosystems. Half of the staphylinid species are found in litter, forming one of the most common and ecologically important insect components of the soil fauna. Knowledge of the broad habitat requirements of common staphylinid species and the fact that the family is distributed in practically all semi-natural and man-made habitats; are two features that make staphylinids attractive as potential bioindicators (Pohl et al. 2007).

Staphylinids can be cost-effective, rapid, contrasting, and strong tools to produce objective and confident criteria to prioritize the establishment and evaluation of protected areas. In spite of this, staphylinids are used less often in bioindicative studies compared with ground beetles, primarily because of the practical difficulties associated with staphylinid taxonomy (Bohac 1999).

Cerambycidae as Bioindicators

Longhorned beetles (Coleoptera: Cerambycidae) might potentially be excellent indicator species of the health of the wood decomposer community because of their habitat specificities, and because they are relatively easy to identify (Speight 1989). Saproxylic (dependent on dead wood) beetles in general are regarded as excellent indicators of woodland biodiversity (Dajoz 2000, Nilsson et al. 2001). The larvae of most longhorned beetles develop within either living or dead wood and feed by mining galleries in the wood. There is a great range in the breadth of host tree species that may used by the larvae of different species (Hanks 1999). This range of habitat specificity within the family extends from monophagous species specialized on a single host tree species to generalist species that can make use of a large variety of tree genera. While there may be many cerambycid species that could function as valuable indicators, it would be beneficial to carefully pair different longhorned beetle species with sites containing different assemblages of trees.

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CHAPTER 6

BIOINDICATOR FAMILIES AS INDICATOR OF HUMAN INFLUENCE ON FOREST ECOSYSTEMS

6.1 Introduction

Forests and woodlands occupy about 38% of the earth's surface, and they are more productive and have greater biodiversity than other types of terrestrial vegetation (Olson and Dinerstein 1998, 2000). The benefits of the forests are well known as forest stands frequently exert a positive influence on the environment and the economy (Piussi and Farrell 2000). Forests are multi-functional; they provide an often complex array of goods and services. It is important to understand that describing, and where possible quantifying, these functions does not always entail that the functions can co-exist under particular management regimes. Forests managed for eco-tourism may not be usable for timber extraction; forests conserved for the supply of genetic information from the canopy can similarly not be converted to other uses, and so on.

Humans have converted forest to agricultural and urban uses, exploited species, fragmented wildlands, changed the demographic structure of forests, altered habitat, degraded the environment with atmospheric and soil pollutants, introduced exotic pests and competitors, and domesticated favored species (Bengtsson 2000, Bengtsson et al. 2000). None of they activities is new; perhaps with the exception of atmospheric pollution, they date back to prehistory. All have impacted genetic diversity (i.e., species diversity and genetic diversity within species) by their influence on the evolutionary processes of extinction, selection, drift, gene flow, and mutation, sometimes increasing diversity, as in the case of domestication, but often reducing it. Even in the absence of changes in diversity, mating systems were altered, changing the genetic structure of populations (Brooks and Grant 1992a & b, Thomas 1992).

Demographic changes (i.e., conversion of old-growth to younger, even-aged stands) influenced selection by increasing the incidence of disease (introduction of exotic diseases), insects, mammalian herbivores, and competing vegetation has had the best-documented effects on genetic diversity, reducing both species diversity and intraspecific diversity (Noble and Dirzo 1997, Kräuchi et al. 2000, Führer 2000). Deforestation has operated on a vast scale to reduce diversity by direct elimination of locally-adapted populations. Atmospheric pollution and global warming will be a major threat in the near future, particularly because forests are fragmented and migration is impeded (Schulze and Mooney 1994, Farrell et al. 2000). Past impacts can be estimated with reference to expert knowledge, but hard data are often lacking. Baselines are needed to quantify future impacts and provide an early warning of problems. Genetic inventories of indicator species can provide the baselines against which to measure changes in diversity (Piussi and Farrell 2000).

Changing patterns of land use and the impact of socio-economic factors on forest management practices have brought about major changes in forest ecosystems. Though abandoned land on its own particularly undergoes a process of colonisation by tree and shrub species with implications for carbon sequestration, wood production, regional biodiversity and soil stability (Bloemers et al. 1997), such processes are quite slow in nature and take enormous amount of time before repair from current anthropogenic induced landscape modification and ensuing damage can be made; for example desertification is occurring particularly where the frequency of fire and/or grazing pressure are high. Therefore, multiple use of the forest has usually been described as a way of combining timber utilisation with other uses of forest products and forest land (Kräuchi et al. 2000, Führer 2000).

Major factors leading to biodiversity loss are habitat loss and degradation, invasive alien species, overuse of resources and pollution. Due to the complexity of these factors, various approaches and strategies are being used to reduce biodiversity loss. All, however, require the best available scientific information that allows the development and implementation of sound management strategies. Still there is a need to study the influence of management strategies on the forest ecosystem stability and social dependency, especially in regions where forest areas and human settlements are situated in proximity to one another (Kellert 1986). The broad view of the forest as an environmental resource (with regard to air quality, space for recreation, landscape with scenic value, as an area supporting a variety of organisms and micro-environments deserving protection, etc.) often limits or even excludes timber utilisation, usually to satisfy aesthetic requirements or to preserve biodiversity (Menge and Olson 1990). It also gives rise to discussion on how forest areas could be better managed. The options seem to be between restricting harvesting to small areas and managing other areas for conservation and ecosystem-maintenance purposes or practising all over multiple use principles (Führer 2000, Piussi and Farrell 2000).

There is a need to study the influence of multiple use management on ecosystem stability and social structures, especially in regions where forest areas and human settlements are situated in proximity to one another. Traditional practices, such as grazing, for instance, could be prohibited without understanding enough the consequence of such a change in traditional land-use practice. Similarly, the impact of forestry and forest management cannot be evaluated independently from other land uses in a region (Piussi and Farrell 2000). The present study takes into consideraton the application of selected bioindicator familes to assess the human influence in protected forest ecosystem in north western Himalaya.

6.2 Index of Staphylinid Communities (IS)

Rove beetles are known from every type of habitat that beetles occur in and their diets include just about everything except the living tissues of higher plants. Most rove beetles are predators of insects and other kinds of invertebrates, living in forest leaf litter and similar kinds of decaying plant matter. They are also commonly found under stones, and around freshwater margins. Several types are known to live on ocean shores that are submerged at high tide, several species have adapted to live as inquilines in ant and termite colonies, and some live in mutualistic relationships with mammals whereby they eat fleas and other parasites, benefiting the host. A few species are parasitoids of other insects, particularly of certain fly pupae. The ecological Index of Staphylinid communities (IS, Bohac 1999) that incorporates these beetles was used as a measure of environment status and human influence (Descender and Turin 1989, Bohac and Fuchs 1991) on forest ecosystem in Simbalbara Wildlife Sanctuary, Himachal Pradesh.

6.2.1 Sampling Method

Beetles were collected by pitfall trapping and by taking soil quadrat samples (Section 4.2). The material was collected for the whole study period and the same method was used to compare various biotopes.

6.2.2 Data Analysis

Species diversity of rove beetles (Coleoptera: Staphylinidae) was calculated from diversity indexes using richness and evenness of species in the sample. The evaluation of the degree of human influence on forest ecosystem was calculated on the basis of dividing the beetles into ecological groups according to their relation to the naturalness of biotopes (Bohac 1999). These groups were: Group R which included the species remaining from communities of past periods, or only occurring in the remains of forest stands, which because of their high species diversity resemble recent climax forests; Group A encompasses species of both natural and managed forests; and Group E comprises eurytopic species that successfully occupy deforested sites and are also found in areas strongly affected by man. The index of staphylinid communities (IS) is a mathematical expression covering all the three ecological groups (R, A, E). It is defined as:

$$IS = 100 - [E\ (i = 1,n) + A\ (i = 1,n)]$$

The value of index ranges from 0 (only eurytopic species are present and the community is highly affected by man) to 100 (only species form Group R are present and the community is virtually unaffected by man). Thus, it was possible to characterize the degree of man's influence in the examined communities by a single figure, thus avoiding dubious comparisons with sparse controls. In addition, the relationship between index values for a given biotope and the species abundances within the communities can be employed as an index of the sensitivity of various species to human-induced stress (Bohac 1999).

6.2.3 Results

Rove beetles were found to be relatively rich in the mixed forest habitats (Fig. 6.1) characterised by decaying leaf litter, decomposing wood and moist condition of the habitats. They were least found in PM, SFF, KF and EPE; such habitats were characterised by slightly alkaline soil (pH=8.6-9.0) and with little or no understorey vegetation, lack of leaf litter or any organic debris. Their little presence in experiment and fire plots is attributed to increased habitat degradation and lack of adequate forest litter (Panzer and Schwartz 1998).

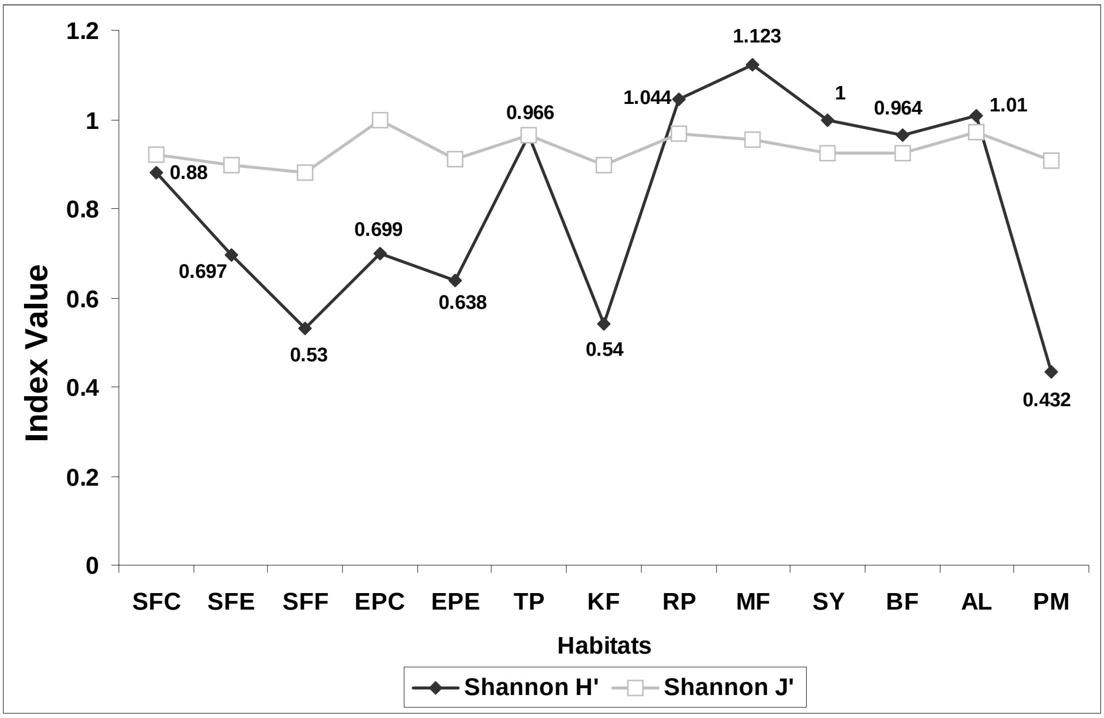

Fig. 6.1 Species diversity of rove beetles (Coleoptera: Staphylinidae) in different habitats of Simbalbara WLS

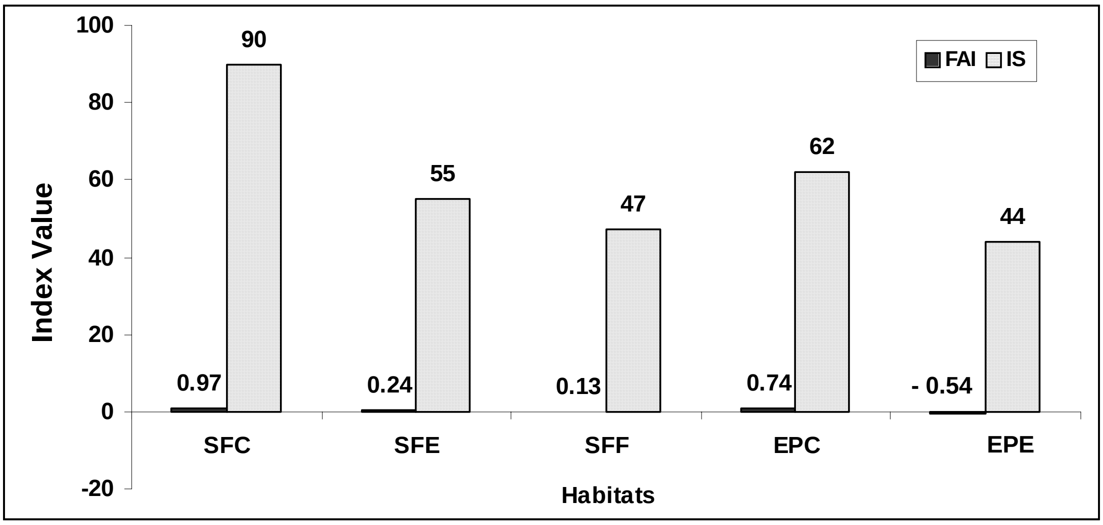

Fig. 6.2 Assemblage of rove and ground beetles in control and experiment plots of Sal (*Shorea robusta*) and *Eucalyptus citrodora* located within and outside the Simbalbara WLS respectively

The IS plot (Fig. 6.2) showed a high numerical value of 90 comapred to SFE at 55 and SFF at 47. Similarly, IS showed a numerical value of 62 in EPC and 44 in EPE. These results show the present state of Sal dominated forest ecosystem of Simbalbara WLS in which the degree of human influence is rated at moderate level.

6.3 Forest Affinity Index (FAI)

6.3.1 Sampling method

To obtain an accurate evaluation of the FAI, sampling was carried out with a minimum of four pitfall traps during the study period. Moreover, captures were carried out in the central part of the sites to minimize disturbance due to immigration from the surrounding habitats; and the neighbouring habitats were taken into account to correctly interpret the composition and co-existence of the assemblage (Kharboutli and Mack 1993, (Lemieux and Lindgren 1999).

6.3.2 Data Analysis

Specific diversity of an assemblage is not always correctly correlated to the ecological stability or to the naturalistic value of the habitat. It is well known that even strongly perturbing environments initially can host rich assemblages, which are abundant in pioneer species tending in time to give way to a more limited number of specialized organisms as the habitat evolves towards the climax stage. This index is thus able to assess the relative quality of the habitat by comparing it to a reference habitat. It is formed by the sum of species (p_i) weighed by a coefficient (F_i), ranging from –1 to +1, which expresses the bond of species with the forest habitat (Allergo and Sciaky 2003). Thus,

$$\text{FAI} = \Sigma\,(i = 1, n)\ (piFi)$$

For convenience, the F values are grouped under five levels, which express the higher or lower forest specialization of species:

+1 strictly forest species

+0.5 tendentially forest species

0 species indifferent to forest coverage

-0.5 tendentially steppic species

-1 strictly steppic species.

6.3.3 Results

The species diversity of caraid beetles was found maximum in the KF, RP, MF and AL habitats mainly due to increased prey base availability. FAI plot (6.2) revealed that the experiment plots of *Eucalyptus* are showing presence of tendentially steppic (eurytypic) species while the experiment and fire plots of Sal are having tendentially forest species. Such pattern of species assemblage suggests a much greater anthropogenic induced modificaition of habitats like intensive agriculture near the protected areas. Various anthropogenic pressures like grazing, logging, lopping, fire, collection of NTFP's etc. are thoroughly influencing the habitat and diversity of carabid beetles (Heyborne et al. 2003). The diversity patterns of other bioindicator families are shown for comparison purpose only (Fig. 6.4, 6.5 and 6.6)

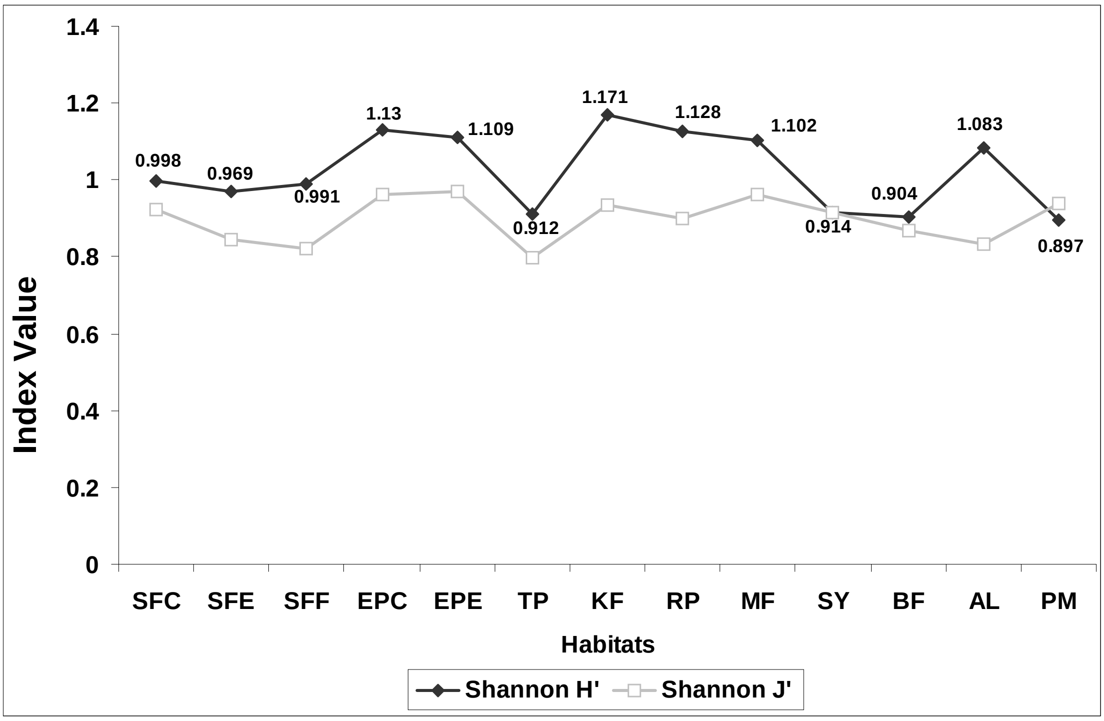

Fig. 6.3 Species diversity of ground beetles (Coleoptera: Carabidae) in different habitats of Simbalbara WLS

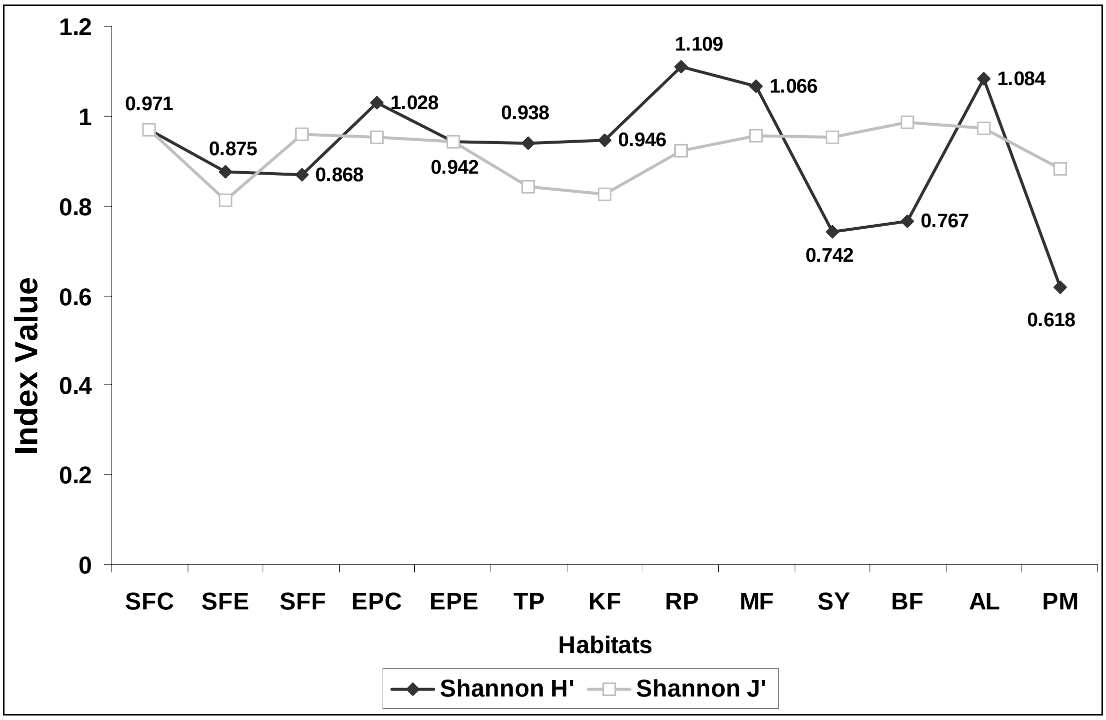

Fig. 6.4 Species diversity of tiger beetles (Coleoptera: Cicindelidae) in different habitats of Simbalbara WLS

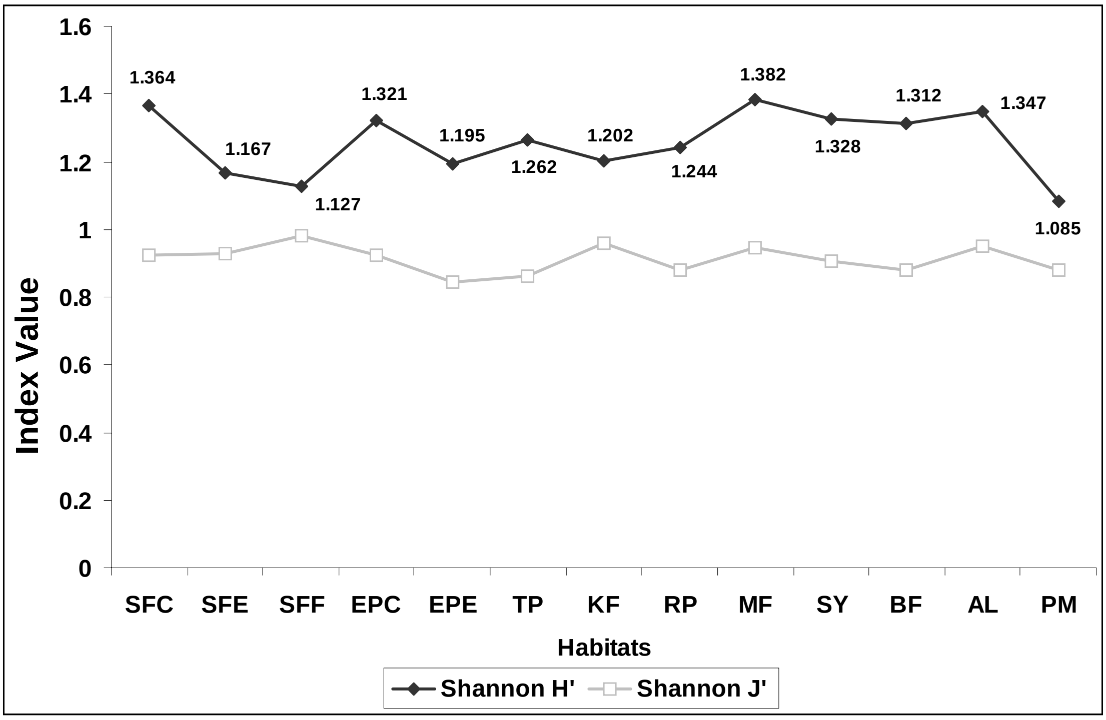

Fig. 6.5 Species diversity of dung beetles (Coleoptera: Scarabaeidae) in different habitats of Simbalbara WLS

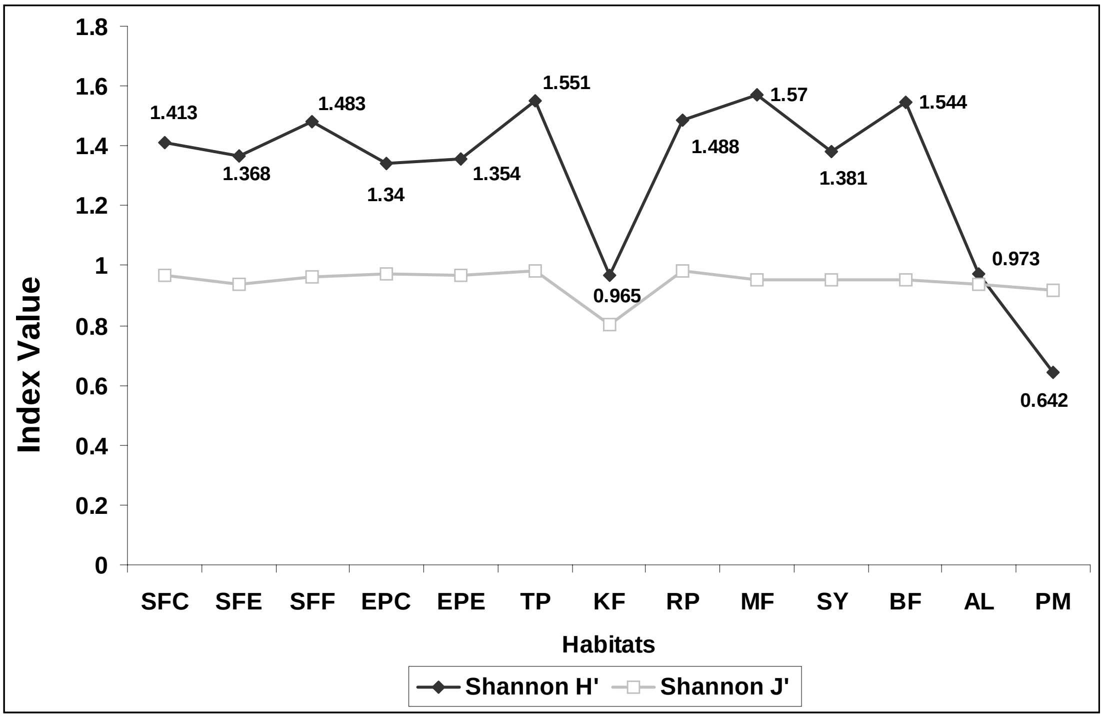

Fig. 6.6 Species diversity of borers (Coleoptera: Cerambycidae) in different habitats of Simbalbara WLS

6.4 Habitat Quality in Study Sites

6.4.1 Sampling Methods

In each of the selected habitats of the study sites including (protected/reserved area and degraded/disturbed/village area), the existing trails through the forests were located and 300m–500m transects were marked along them. These transects were surveyed between 0900h and 1700h, the time of the day when the beetles show maximum activity (Pearson 1988). Relative abundances are estimated by capturing the individuals with different methods (described in sampling methods) along the trail or in the nearby under story vegetation.

In each case, habitat will be considered adequately sampled (surveyed) when increasing the sampling effort will not result in the addition of new species (this will be determined using species richness curve). Adult beetle abundances are highly seasonal, and their populations respond quickly to the initiation of the rainy season (Pearson and Derr 1986, Pearson 1988). Visits to field sites are therefore designed to coincide with times of maximum activity and abundance.

Following habitat (biotic and abiotic) variables were quantified following different methods; and are as under:

1. Vegetation characteristics (herb, shrub, and tree richness and abundance): All parameters were quantified using stratified random sampling by point-centered quarter sampling methods.
2. Canopy cover: Canopy cover or closure is a measure of the fraction of the landscape covered by vegetation. The measurement of canopy cover was made with a simple instrument called as canopy densitometer.
3. Soil characteristics (pH, organic content, texture): Soil samples were collected from each of the vegetation types at an interval of 100m and were analyzed at the research laboratory of Wildlife Institute of India, Dehradun using standard protocols.

4. Litter characteristics: It was determined using the method given by Faith et al. 1998). In each of the habitat types, three 50m long parallel transect were established approximately 10m apart in which litter depth was measured at 2m intervals along each transect for a total of 25 depth measurements per transect. It was measured by inserting a sharpened wooden dowel (3mm diameter) into the litter at each 2m mark. The top of the litter layer was marked along the dowel and the litter was pushed aside until the interface of the litter layer with the humus layer was reached. The difference between these two points was measured. Thus, the relative area of ground covered by litter is calculated by dividing the total frequency of each litter depth interval by the total number of depths measured.
5. Disturbance variables: Intensive sampling was done in the areas of the sanctuaries prone to fire incidences and anthropogenic pressure like grazing, logging, lopping. The relative composition of beetles in these sites was also compared to control sites in the similar well protected areas.

6.4.2 Data Analysis

Habitat quality was evaluated by correlating the species abundances of beetles in different vegetation types with following variables viz. vegetation characteristics, canopy cover, soil characteristics, litter characteristics, litter characteristics in canonical correspondence analysis (ter Braak 1987, ter Braak 1988, ter Braak and Prentice 1988, ter Braak and Juggins 1993, Clarke 1993, ter Braak and Šmilauer 1998).

6.4.3 Results

Broad assemblages of beetle species in responses to habitat variables are displayed in the form of a biplot (biplot r^2 cutoff = 0.25) derived from the canonical correspondence analysis (Fig. 6.7). The axis summary statistics results of the CCA are presented in Table 6.1 a & b. The arrows depict the relative influence of the habitat variables on the composition of the beetles' assemblage, with the line length relative to the other variables, rather than an absolute degree of influence (ter Braak and Verdenschot 1995).

Mixed forest habitats were characterized by high tree and shrub density while riverine area was characterised by large open tracts with grass cover at the interfaces with forest and agriculture land. Interset correlations between eighteen habitat variables identified average tree density, % organic content of soil and average girth at breast height (GBH) of trees statistically significant variables and were found to have significant influence on the species composition across habitats (de Bruyn 1997) (Table 6.2).

CCA using habitat variables viz. soil, vegetation, microclimate and disturbance variables, without the confounded effects of seasons, revealed significant patterns for all canonical axes (P<0.001). For species-environment data, the first two axes represented more than 51 percent of variation, while family-environment data, the percentage variation explained was 90 percent (Table 6.1 a). In species matrix, plantation sites were well separated from the other mixed forest sites on CCA axis 1 (Fig. 6.7). Mixed forest sites did not segregate in their response to the habitat variables, but the ordination suggests that the mixed forest sites are intermediate in response between plantation and experiment plots.

The second axis of CCA was strongly associated with average tree and shrub density, leaf litter, canopy cover, % organic content and decreasing disturbance like fuelwood collection and grazing, while in contrary first axis represents increase of disturbance and decrease in heterogeneity. CCA for species-environment association showed that canopy cover (r=0.70), % organic content (r=0.75), average tree density (r=0.64), average leaf litter (r=0.60) were positively associated with CCA axis 2, but this axis was negatively associated with pH (r= -0.13) and bamboo abundance (r= -0.25). Plantation and experiment sites had vegetation characterized by low herb and shrub cover, less variation in tree species richness and disturbance factors. CCA for family-environment association exhibited that grazing (r=-0.14) and NTFP collection (r=-0.14) were negatively correlated with this gradient.

Other habitat variables like canopy cover and leaf litter made only a minor significant contribution to the observed differences in species composition. The first axis of the CCA explained the most variance in the data, while axes 2 explained relatively little at the Monte-Carlo test at the 0.05 level (Table 6.2). Further the the effect of eighteen habitat variables on each family is presented subsequently in which the most determining factors for assemblage were identified; Carabidae – canopy cover, % organic content, leaf litter and average GBH; Cicindelidae – canopy cover, average GBH and grazing; Scarabaeidae – average tree density, canopy cover, average GBH, leaf litter and % organic content; Staphylinidae – fire, average GBH and temperature, and Cerambycidae – average tree density, canopy cover, average GBH, leaf litter and % organic content (Fig. 6.8 a to e).

Table 6.1 a Cumulative Canonical Correspondence Analysis (CCA): Axis summary statistics of beetle assemblage in Simbalbara WLS

Number of canonical axes			3
Total variance ("inertia") in the species data			6.4789
	Axis 1	**Axis 2**	**Axis 3**
Eigenvalue	0.511	0.361	0.303
Variance in species data			
% of variance explained	7.9	5.6	4.7
Cumulative % explained	7.9	13.5	18.1
Pearson Correlation, Spp-Envt*	0.907	0.87	0.869
Kendall (Rank) Corr., Spp-Envt.	0.561	0.67	0.63
Monte Carlo Randomisation Test, 998 runs; *P<0.001			

Table 6.1 b Inter-set correlations for 18 habitat variables

	Correlations		
Variable	**Axis 1**	**Axis 2**	**Axis 3**
Temperature	0.033	0	-0.052
Relative humidity	-0.259	0.151	0.108
pH	-0.39	-0.118	0.045
% Organic content	0.687	0.002	-0.007
Average leaf litter	0.548	0.075	0.013
Canopy cover	0.642	0.242	0.066
Average girth at breast height	0.617	0.223	-0.198
Average tree density	0.588	0.264	-0.353
Average Shrub density	0.51	0.149	-0.216
Bamboo abundance	0.136	-0.219	0.137
Termite mound abundance	0.073	0.237	-0.094
Grazing	-0.148	0.347	-0.194
Lopping	0.135	-0.186	0.05
Grass cutting	0.195	-0.417	-0.077
Fuelwood collection	0.127	-0.615	0.086
NTFP collection	-0.147	-0.22	0.091
Hunting or poaching	-0.023	-0.111	0.169
Fire	-0.067	0.255	-0.387
Monte Carlo Randomisation Test, 998 runs; P<0.001			

Table 6.2 Canonical Correspondence Analysis (CCA) of beetle assemblage showing correlations and biplot scores in Simbalbara WLS

	Correlations*			Biplot Scores		
Variable	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 1**	**Axis 2**	**Axis 3**
Temperature	0.037	0	-0.06	0.022	0	-0.037
Relative humidity	-0.285	0.173	0.124	-0.169	0.107	0.077
pH	-0.43	-0.135	0.051	-0.254	-0.084	0.032
% Organic content	0.757	0.002	-0.008	0.448	0.001	-0.005
Average leaf litter	0.604	0.086	0.015	0.357	0.053	0.009
Canopy cover	0.707	0.277	0.076	0.418	0.172	0.047
Average girth at breast height	0.681	0.255	-0.228	0.402	0.158	-0.141
Average tree density	0.648	0.303	-0.407	0.383	0.188	-0.252
Average Shrub density	0.563	0.17	-0.248	0.333	0.106	-0.154
Bamboo abundance	0.15	-0.252	0.157	0.089	-0.156	0.097
Termite mound abundance	0.08	0.271	-0.109	0.047	0.168	-0.067
Grazing	-0.163	0.398	-0.224	-0.096	0.247	-0.139
Lopping	0.148	-0.213	0.058	0.088	-0.132	0.036
Grass cutting	0.215	-0.478	-0.089	0.127	-0.296	-0.055
Fuelwood collection	0.14	-0.705	0.099	0.083	-0.437	0.062
NTFP collection	-0.162	-0.252	0.105	-0.096	-0.156	0.065
Hunting or poaching	-0.025	-0.127	0.195	-0.015	-0.079	0.121
Fire	-0.074	0.293	-0.445	-0.044	0.181	-0.276
Correlations are "intraset correlations" of ter Braak (1986); P<0.001						

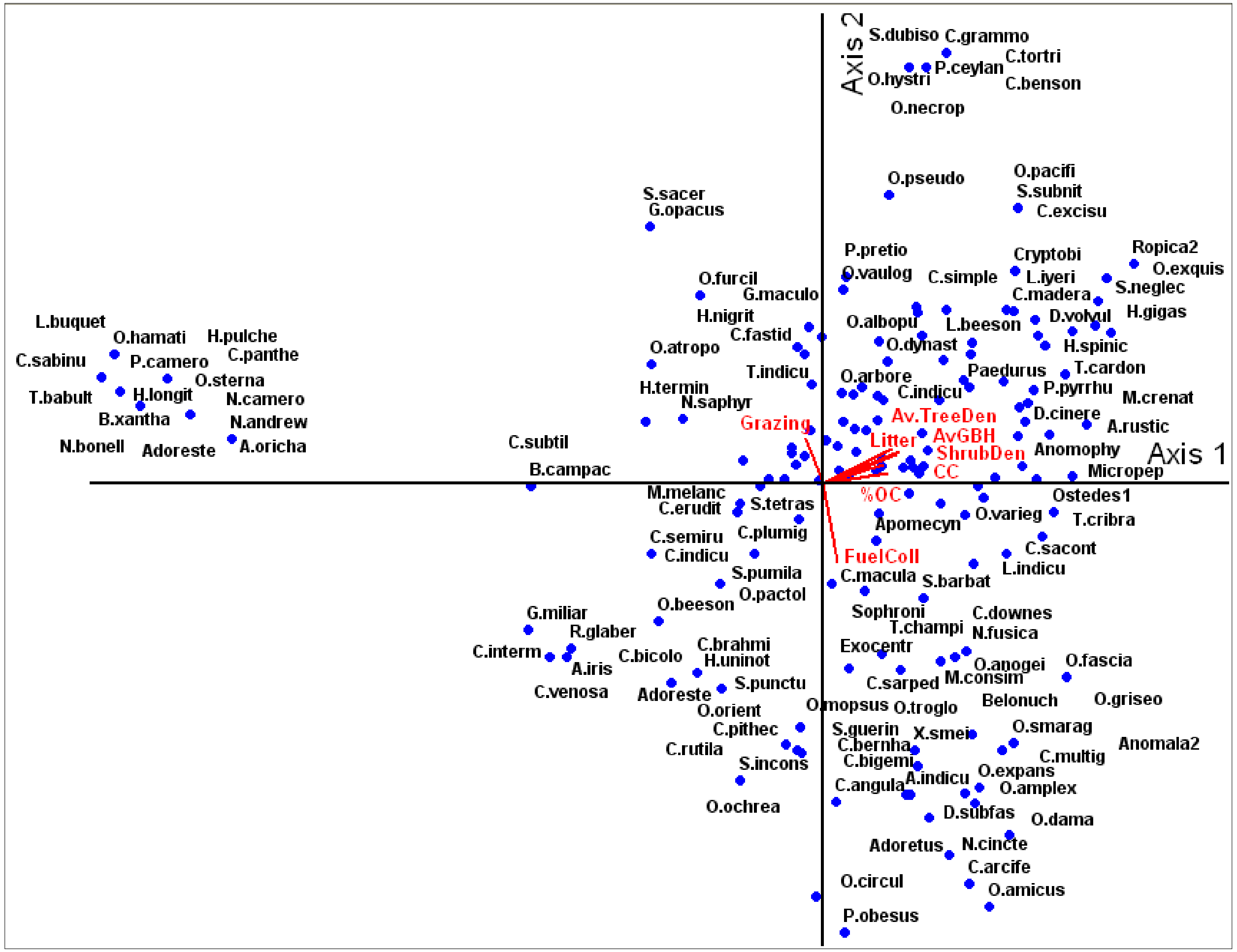

Fig 6.7 Cumulative CCA of beetles' assemblages in Simbalbara WLS

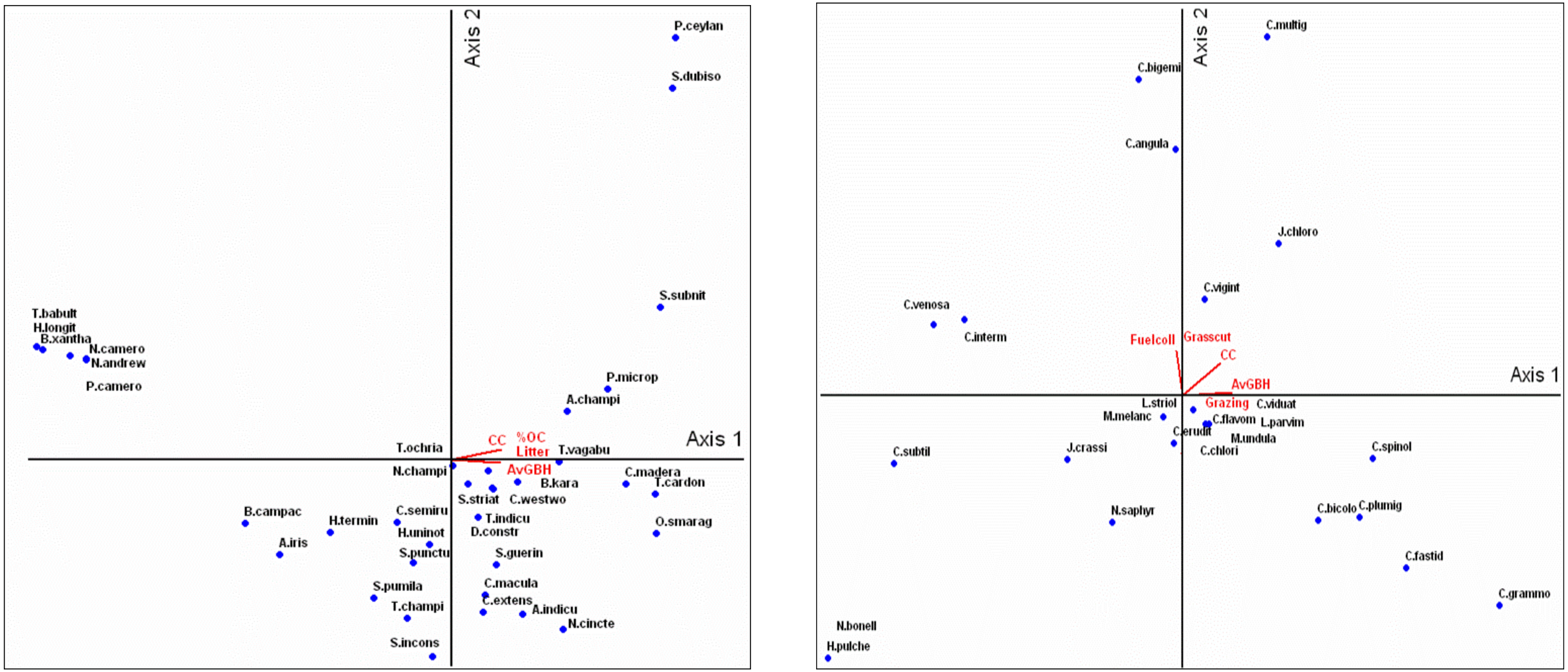

Fig 6.8 a CCA Carabidae and, b Cicindelidae beetles' assemblages in Simbalbara WLS

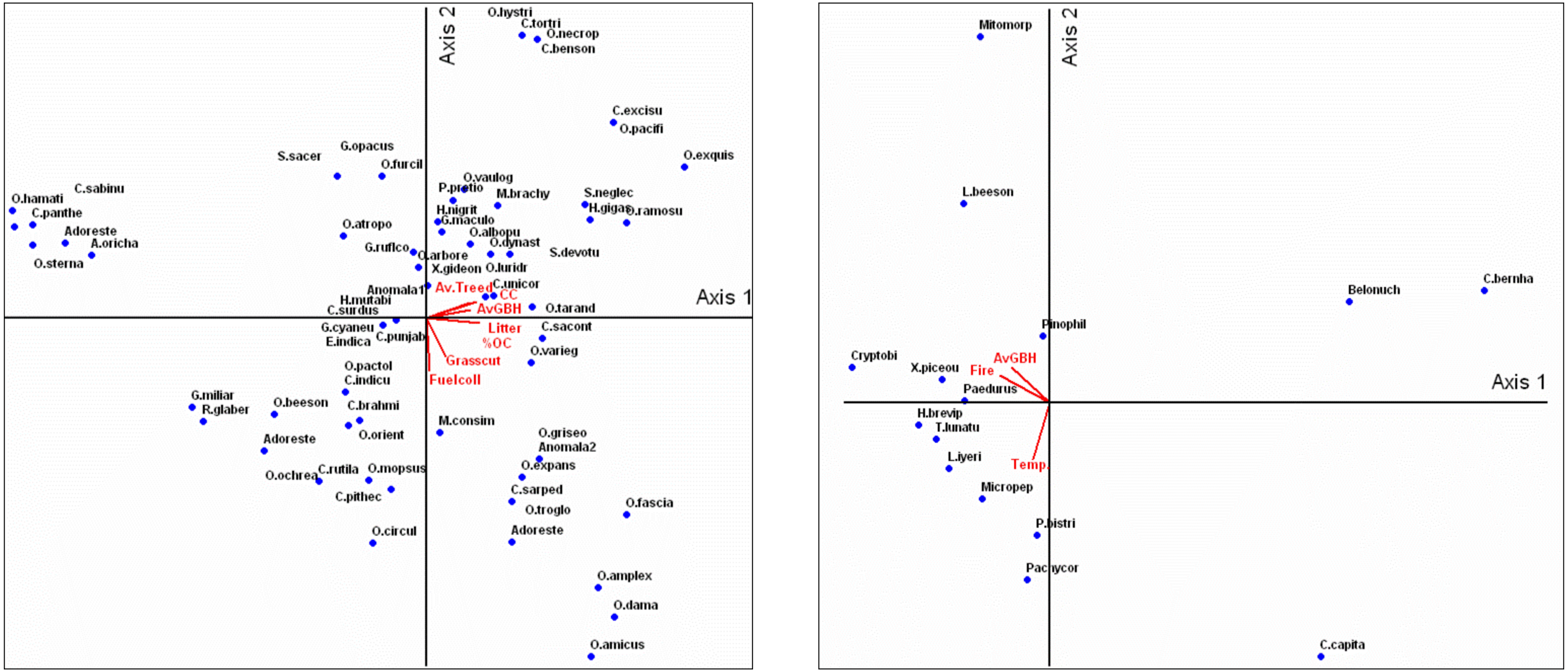

Fig 6.8 c CCA Scarabaeidae, and d Staphylinidae beetles' assemblages in Simbalbara WLS

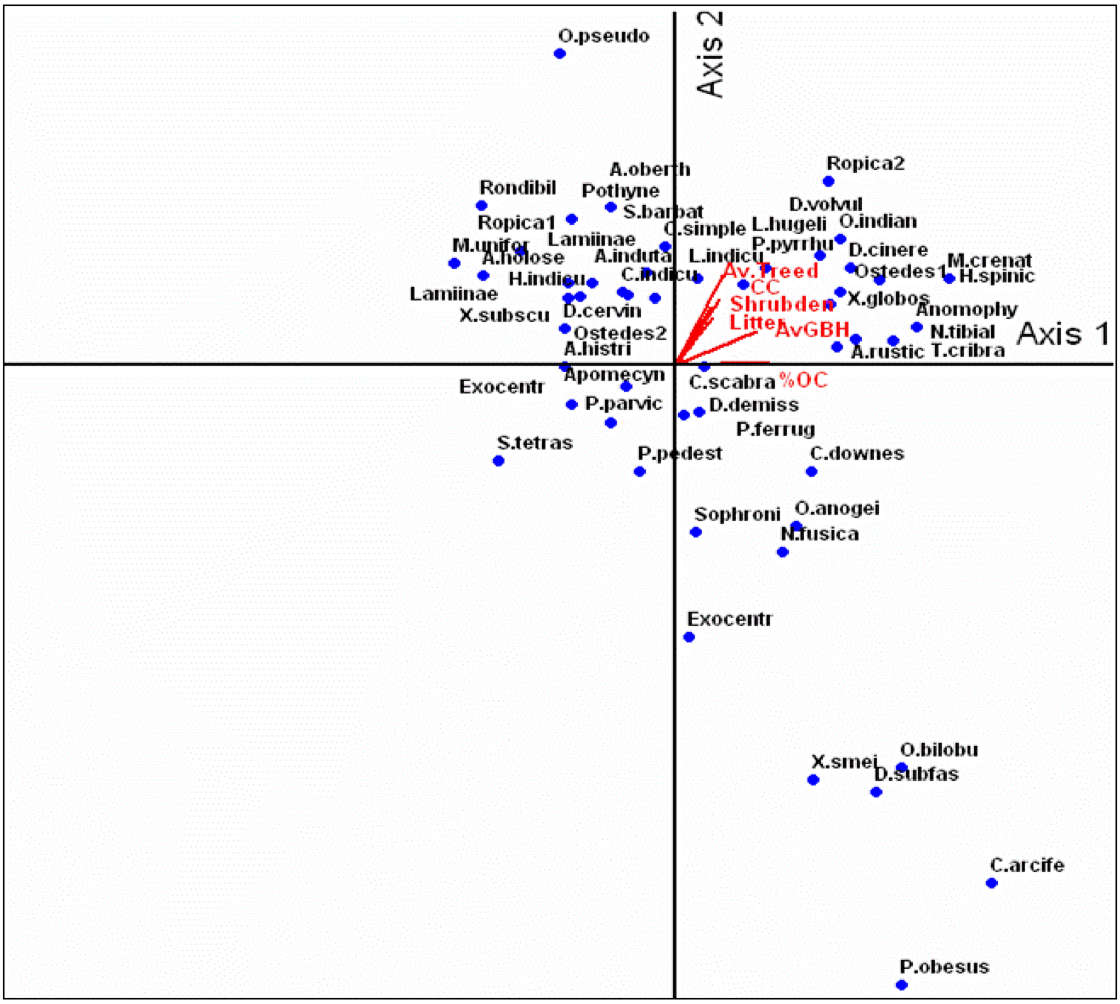

Fig. 6.8 e Cerambycidae beetles' assemblages in Simbalbara WLS

Since the 18 habitat variable also contained some qualitative variables like incidence of logging, lopping, grazing and fire, it was ambiguous from CCA ordinations about the most important factor that determined the nature of assemblage of beetle species in environmental space. Thus, multiple regression (SPSS ver 16.0) was performed to find out the most predictor habitat variable of assemblage patterns; that identified average leaf litter, GBH and pH (R=.714) as most predictor of assemblage patterns(Table 6.3 a & b).

Table 6.3 a Model summary of multiple regression analysis of habitat variables

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.588[a]	.345	.335	9.945	.345	33.207	1	63	.000
2	.680[b]	.462	.445	9.083	.117	13.528	1	62	.000
3	.714[c]	.510	.485	8.746	.047	5.856	1	61	.019
a. Predictors: (Constant), Litter									
b. Predictors: (Constant), Litter, AvGBH									
c. Predictors: (Constant), Litter, AvGBH, pH									

Table 6.3 b Coefficients of multiple regression analysis of habitat variables

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	9.868	2.111		4.675	.000		
	Litter	.970	.168	.588	5.763	.000	1.000	1.000
2	(Constant)	3.340	2.620		1.275	.207		
	Litter	.861	.157	.522	5.501	.000	.964	1.037
	AvGBH	.106	.029	.349	3.678	.000	.964	1.037
3	(Constant)	-66.996	29.174		-2.296	.025		
	Litter	.897	.152	.543	5.918	.000	.955	1.047
	AvGBH	.124	.029	.408	4.313	.000	.901	1.110
	pH	10.047	4.152	.227	2.420	.019	.915	1.093
a. Dependent Variable: Abundance Beetles								

Similarly, non-metric multidimensional scaling (NMDS) ordinating the habitat variables (all including qualitative ones) in habitat space produced the plot with six separate clusters (Fig. 6.9); in which MF, SFC, SFF, SFE formed one cluster; RP, PM, KF and AL formed separate clusters; and TP, EPC, EPE and BF formed one cluster with some degree of overlapping suggesting the overlap of habitat conditions (Fasham 1977). Cumulative species NMDS plot ordinated all the habitats, with some degree of overlapping (Fig. 6.10). The ordination of species of bioindicator families is also presented for the purpose of comparison respectively showing specific patterns in assemblage in habitat space (Fig. 6.11 a to e).

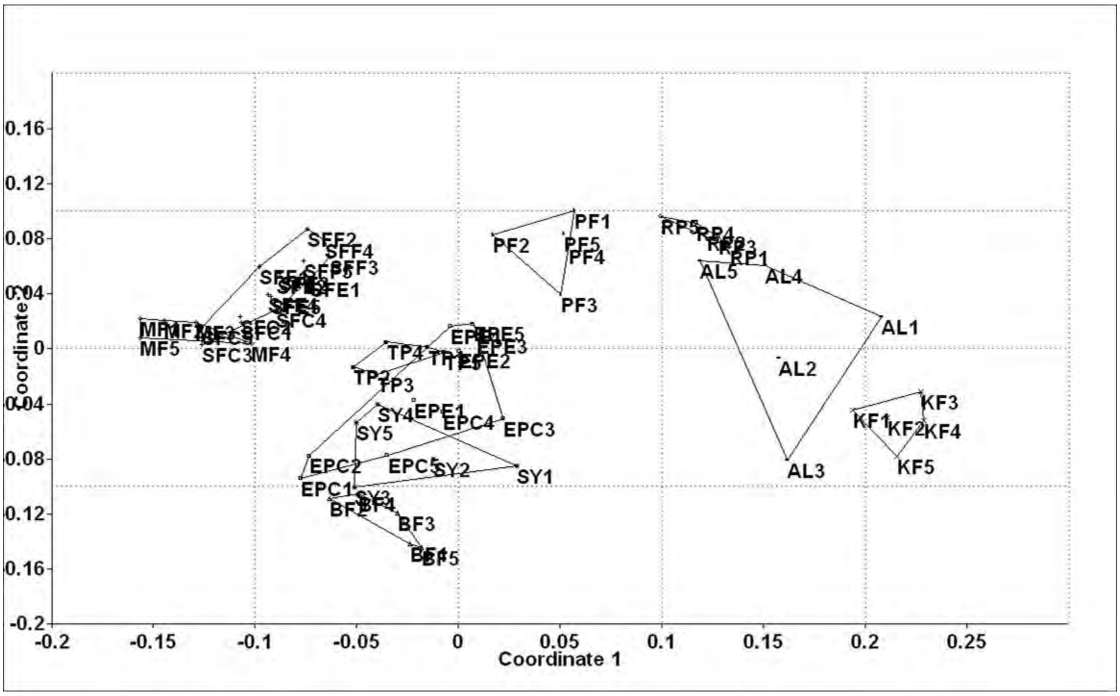

Fig. 6.9 NMDS plot showing ordination of environment variables in habitat space

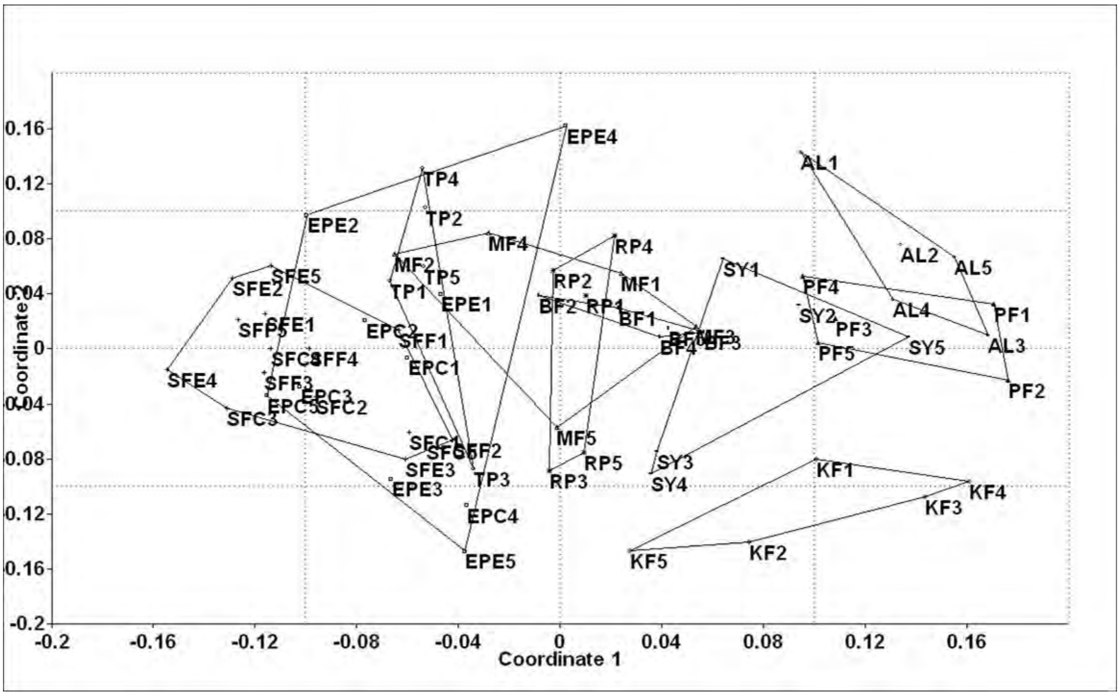

Fig. 6.10 NMDS plot showing ordination of cumulative species assemblage in habitat space

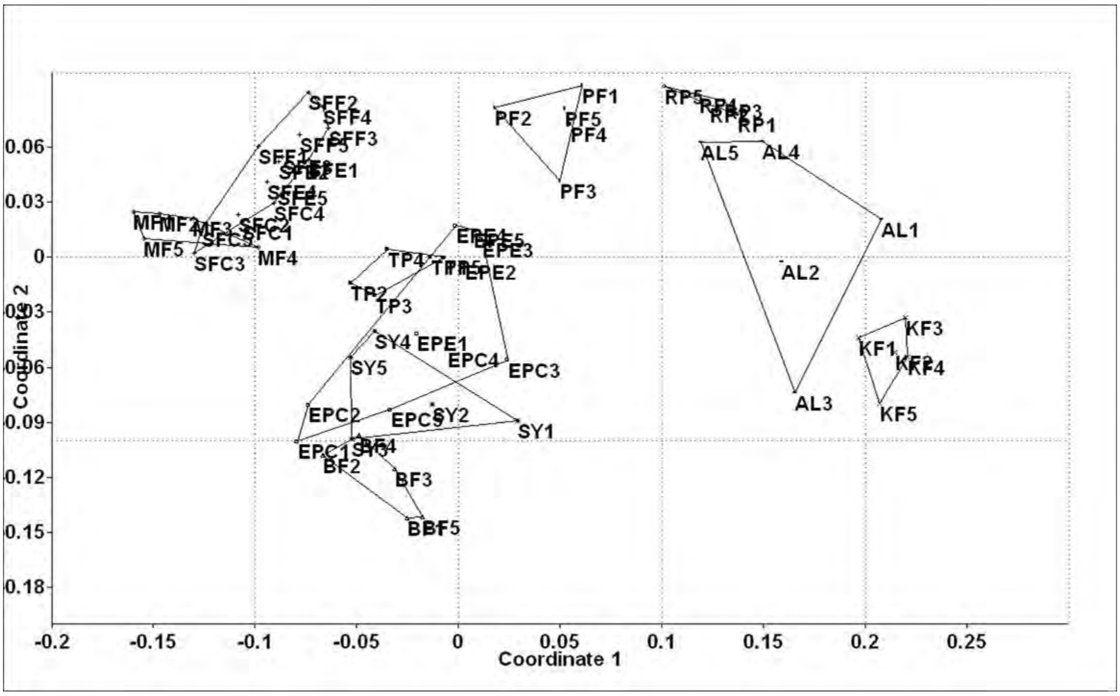

Fig. 6.11 a NMDS plot showing ordination of cumulative species assemblage in qualitative variables

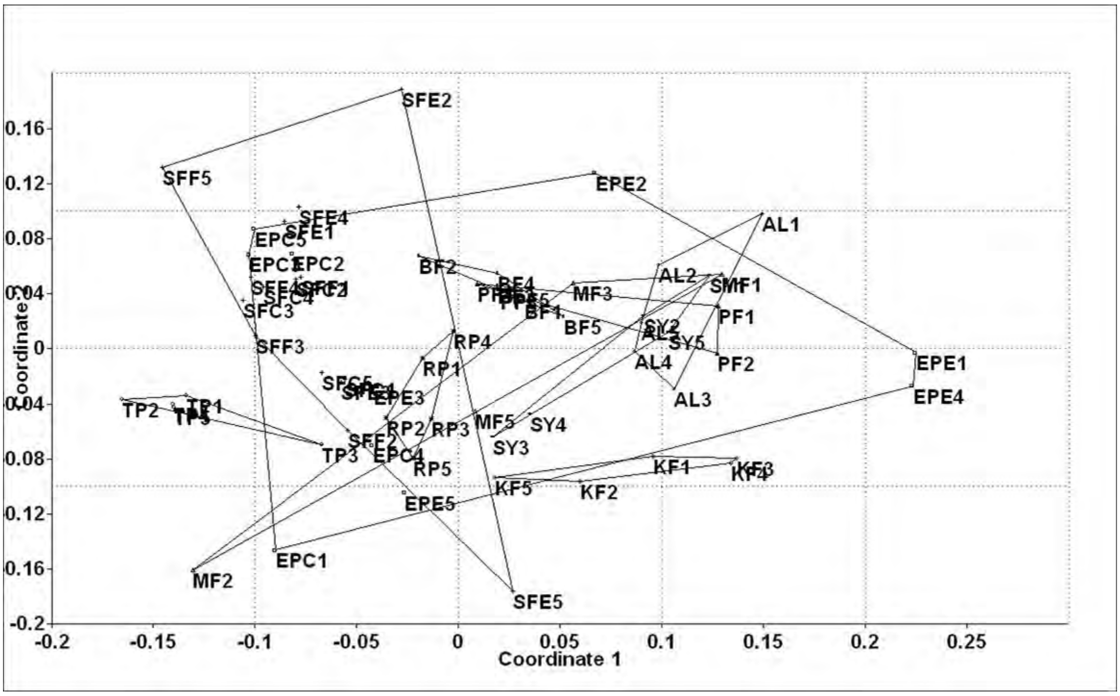

Fig. 6.11 b NMDS plot showing ordination of Carabidae species assemblage in habitat space

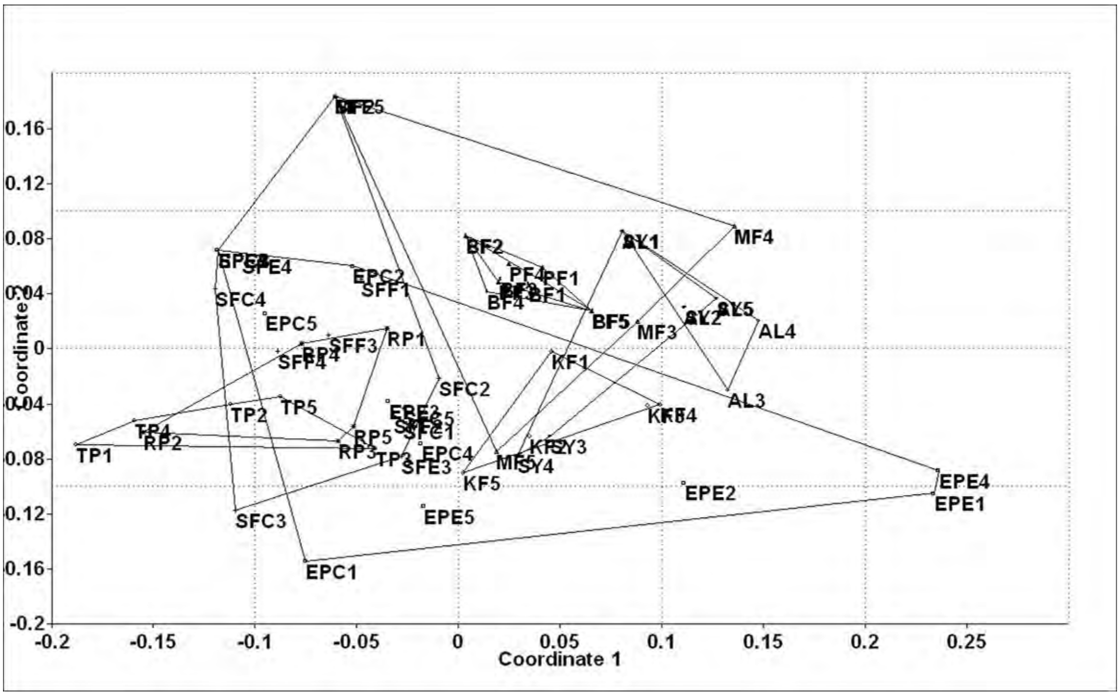

Fig. 6.11 c NMDS plot showing ordination of Cicindelidae species assemblage in habitat space

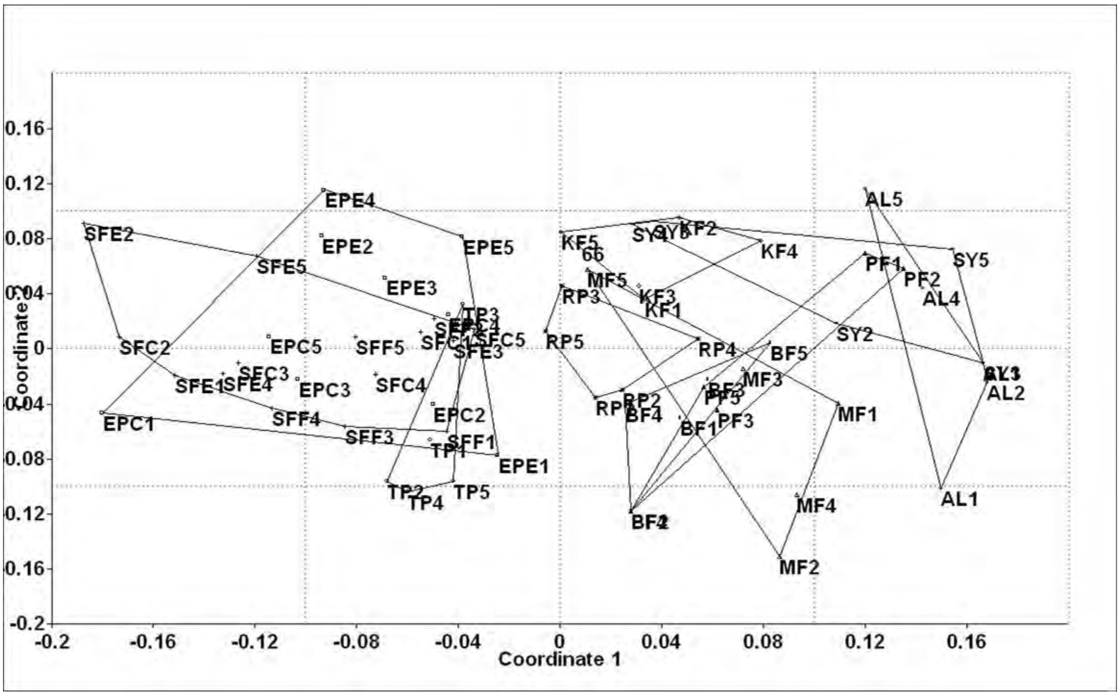

Fig. 6.11 d NMDS plot showing ordination of Scarabaeidae species assemblage in habitat space

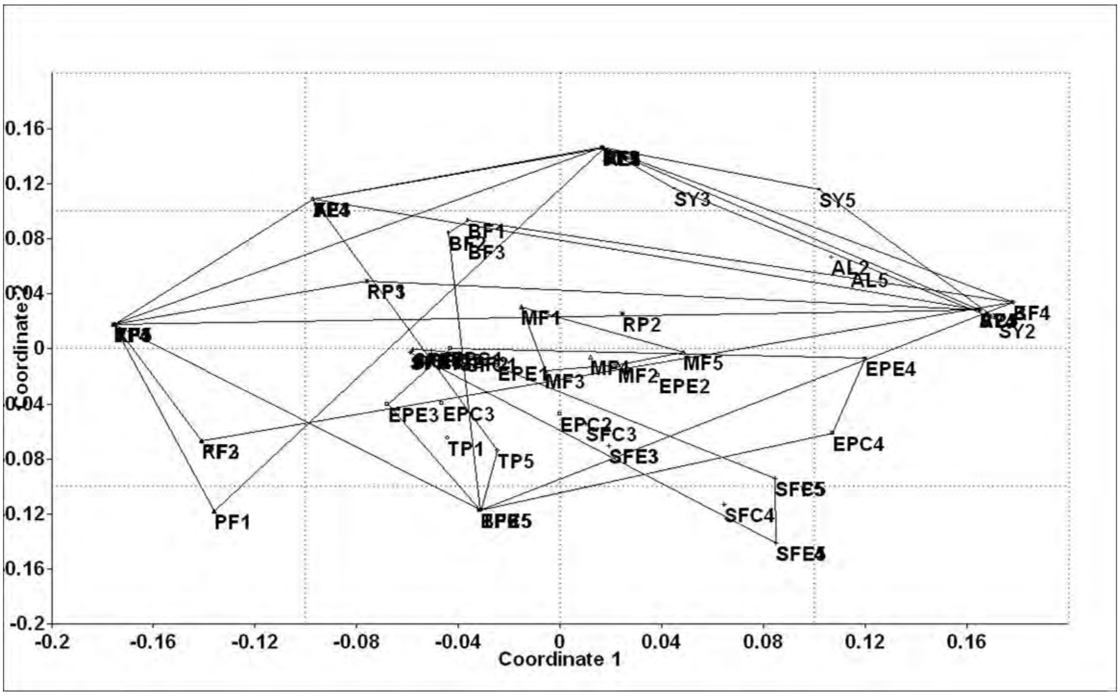

Fig. 6.11 e NMDS plot showing ordination of Staphylinidae species assemblage in habitat space

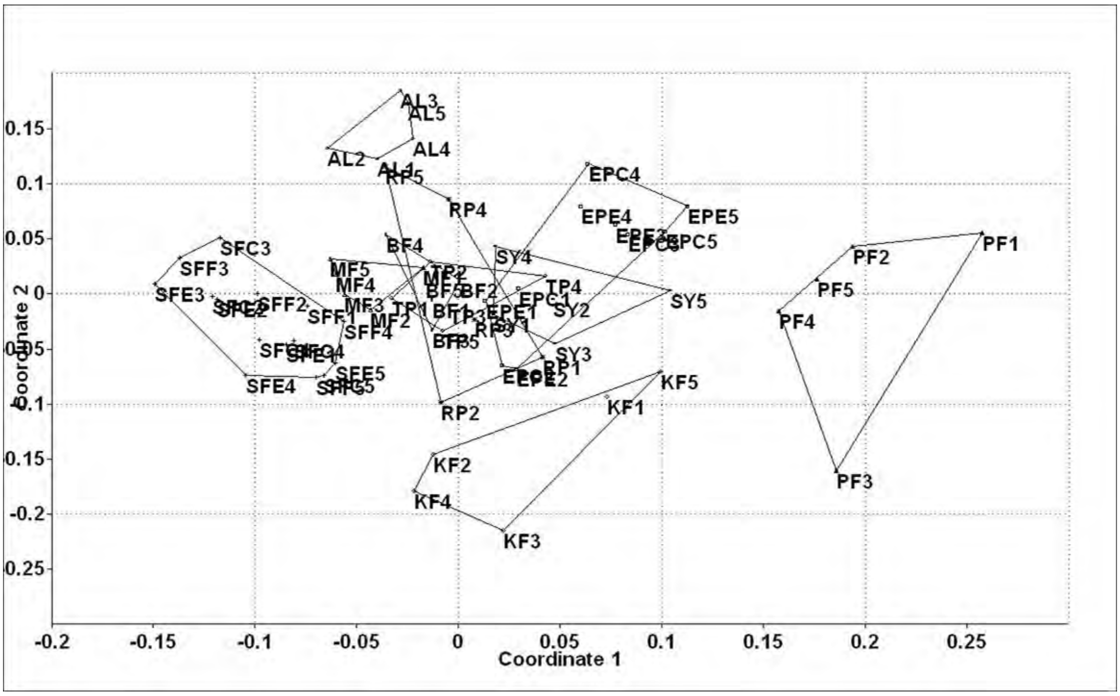

Fig. 6.11 f NMDS plot showing ordination of Cerambycidae species assemblage in habitat space

6.5 Discussion

Environmental changes, such as logging for timber production and conversion of natural habitats for agriculture, human settlement, recreation, amenity or industry, greatly affect organism diversity (Longino 1994, McNeely et al. 1995). Although insects may seem to be small and inconspicuous compared with vertebrates (Greenwood 1987, Whitmore 1990), they are extremely important, arguably dominant elements within the ecosystems (Janzen 1987). Many insects respond rapidly and dramatically to changes in environmental conditions, making them potentially useful indicators of habitat condition.

Species at both ends of the disturbance spectrum have smaller habitat breadths than those in intermediate positions. In ecological communities that are periodically perturbed, diversity is often higher at intermediate levels of disturbance (Connell 1978). Therefore, it is not surprising that the species found associated with intermediate disturbance have larger habitat breadths. Species of primary and highly disturbed habitat may have evolved adaptations to their narrower microclimatic conditions. Species richness and abundance of subterranean and understorey beetles were considerably lower in the plantations (khair and bamoo mixed forest) than in the mixed forests. Species composition was also significantly different between sites, but assemblages in the secondary forest of experiment and fire plots of SFE, SFF and EPE tended to be much more similar to each other than to the primary forest assemblages. KF, AL, and PM beetles were, however, distinctly different from the rest of the sites.

There were only seven families of beetles (out of 22 prominent and 66 recorded) in the khair plantation which had more than one plant species, implying a low diversity of plants in the plantation. In other mixed forest sites, on an average 10 most speciose families were found; as expected, Sal (Dipterocarpaceae) dominated the primary forest and *Mallotus* spp. were common in such forest. Plant species richness and canopy cover in mixed forests were significantly higher than those in the plantations. There were more saplings in the primary forest than in other sites. Comparatively, there were also more trees in mixed forest types than the plantations and experiment plots. In the plantations, the only trees that were more than 10 cm GBH were found (i.e. khair), so these habitats were very homogenous and low in diversity.

The CCA ordination plots shows that primary forest beetle samples were closely associated with the amount of litter, number of saplings, trees and plant species while the logged forest beetle samples were more closely related to high soil pH and canopy cover. The plantations beetles are are closely associated with high canopy cover, while mixed forest species were more associated with vegetation cover (Basset et al. 1998, Aubert et al. 2003). Some environmental variables had apparently contributed to the changes in the beetle assemblage. The amount of leaf litter correlated with the species richness, abundance and composition of subterranean beetles. Plant species richness, tree and sapling densities had correlated with the species richness, abundance and composition of understorey beetles while ground cover had only correlated the species richness and abundance of these beetles. Canopy cover correlated only with arboreal beetle abundance. Further, average tree density, shrub density and amount of litter explained significant variation in beetle species composition (Monte Carlo permutation test, 999 random permutations, $p<0.001$).

In all trapping methods, CCA eigenvalues for the first two axes were not markedly lower than eigenvalues for DECORANA (Appendix 3), and all species-environment correlations were high, indicating that the measured environmental variables explained the major variation in species composition across sites. In all trapping methods, beetles in experiment and fire plots showed high similarity and were dissimilar from the primary forest samples that were eventhough closer to the logged forests suggesting that the beetle composition of such plantation and experiment/fire plots was very different from other sites and was greatly determined by human influence on forest ecosystems. The results suggested that the forest and plantation and experiment/fire environments were qualitatively very different and thus potentially having an influence on beetle species richness, abundance and composition.

The effect of disturbance was significant between primary and logged forest. The number of plant species and trees, ground cover and canopy cover in the logged forest were not significantly lower than those in the primary forest; it indicates that the logged forests can recovered rapidly in floristics in a time dependent manner, thus maintaining understorey beetle numbers. In the soil and leaf litter fauna, however, the beetle abundance was significantly lower in the logged forests compared with the primary forest. Higher soil compaction and less leaf litter in the logged forest, could have resulted in the lower beetle numbers. The overall differences in floristics between the *Eucalyptus* plantation types within and outside the sanctuary did not show much difference except in the ground cover and understorey vegetation (Ferris et al. 2000). The higher percentage of understorey vegetation may have contributed to the higher numbers of beetles when compared with such plantations outside the sanctuary. Although there was more leaf litter in the *Eucalyptus* plantation, the numbers of soil and leaf litter-dwelling beetles did not differ significantly with those from outside the sanctuary.

The numbers of plant species, saplings, trees and canopy cover show significant positive relationships with beetle species richness and abundance. Interestingly, although there were significant linear relationships, the variables tend to cluster into two groups; forests and plantations/experiment plots as revealed from the NMDS plots. These NMDS plots concomitantly reveal the effect of of qualitiative variables like incidences of grass cutting, NTFP and fuelwood collection, logging, lopping, grazing, etc on beetles' assemblage patterns. The clustering, however, probably makes the regressions unstable statistically because of biomodality. The clusters may actually be implying qualitative change. A higher plant richness, and density of trees and saplings, as indicated in the forests, correlates to a higher species richness and abundance of beetles. It is interesting to note that there was a significant negative relationship between beetle numbers and the percentage of ground cover. There were more understorey beetles in the khair plantation, which has more ground cover, compared with the *Eucalyptus* plantation.

However, in the forest environments, beetles were very speciose and abundant even though the ground cover was less than 50% of the sampling area. This suggests that the thick layer of leaf litter provided suitable microhabitats for the subterranean and understorey beetles. Of all these environmental variables, plant species richness had the greatest influence on beetle numbers (estimated by the r^2 value). Mean values and multiple regression results of leaf litter, average GBH and soil pH in different study sites revealed a significant positive relationship between the amount of leaf litter and beetle numbers; but no significant relationship between beetle diversity and other variables; though temporal abundances were influenced by temperature and relative humidity in different seasons.

Therefore, maintaining the understorey vegetation or ground cover may be important for sustaining the diversity of beetles in plantations, even though the beetle composition is very different between plantations. Although there were significant reduction in overall species richness and abundance between logged forest and primary forests, the beetle species composition of *Eucalyptus* plantation showed high similarity with those of the logged forest, but at lower levels (i.e. it has a depleted subset of the logged forest composition). Thus, mixed forest plantation is a better environment for maintaining beetle composition than monoculture plantation. Therefore, conversion of forests into monoculture plantations will have a more adverse effect on the beetle fauna compared with mixed forest plantation. A few species in khair plantation became numerical dominant despite its low diversity. This can be detrimental because the target species is a potential pest. Some of the forest insects have become pests by increasing their population size and eating parts of commercially valuable tree species when faced with monocultures. The findings in this study have suggested that increasing and maintaining biodiversity in low diversity monocultures such as in *Acacia catechu* plantation may potentially help pest management by reducing the population of pest species and the prevalence of some of these species.

The findings in this study have suggested that increasing and maintaining biodiversity in low diversity monocultures such as in khair plantation may potentially help pest management by reducing the population of pest species and the prevalence of these species. There is some evidence indicating species diversity and complexity of association among species are essential to the stability of a community. The natural balance may regulate pest numbers and at the same time, maintain the diversity of a habitat. This may also help to promote conservation of biodiversity in compromising situations, especially when establishing large-scale plantations. Natural forest remnants act as reservoirs of diversity; retaining such forest remnants may help to secure a balanced ecosystem in the broad sense and specifically to shelter beneficial predatory species (Payne 1997).

Maintenance of such forests habitats can provide overwintering refuge sites for many predatory species of Araneae, Carabidae (Mitchell 1963 a & b) and Staphylinidae. From the pest management perspective, it is a possible management tool for integrated methods for biocontrol in forest ecosystems at agriculture-forest interfaces. The results from this study indicate that the loss of species richness and abundance of beetles, and changes in beetle composition can occur in severely disturbed environment. Consequently, these results support the establishment or maintenance of mixed forest patches in such environments.

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CHAPTER 7

CONCLUSIONS AND CONSERVATION IMPLICATIONS

Without biodiversity, life on earth would be impossible. Based on recent estimates, biodiversity accounts for between 319 billion and 33,000 billion dollars per year in value. Biodiversity encompases all of the species, food chains and biological patterns in an environmental system; as small as a microcosm or large as a landscape or a geographic region (Heywood and Watson 1995, Wilson 1988, Wilson 1997). The concept of biodiversity has grown with the perception of its loss due to increasing human impact and mismanagement of the environment (Wilson 1988). Whether on a local, regional or global scale, reduced biotic diversity is associated with increased environmental stress and reduced environmental heterogeneity (Erwin 1996).

The concept of biodiversity implies that any environment is rich in different organisms and can be read as a system in which species circulate and interact. Structure, scale, and features of the landscape also enter into the definition of biodiversity. The urgent need for the prioritization of areas for conservation has been necessitated by intense competition for land by agriculture, industry and urban development. Areas for conservation are prioritized by identifying optimal sets of viable but threatened areas for maximizing overall diversity (Margules et al. 1988). Our knowledge of the taxonomy and distribution of invertebrates is, however, poor and we are thus unable to provide detailed systematic evaluations of the group (Thomas and Morris 1994, Vane-Wright et al. 1994).

With the tailwind of the sustainability debate, views of the general public on the management of species and habitats have recently been gaining importance in the development of environmental policies (UNECE 1998, Renn 2006). Public consultation and participatory approaches are now frequently considered as central elements in identifying conservation priorities (Stewart 2006) and in the management of protected areas (Mulongoy and Chape 2004). However, despite increasing efforts in the social and interdisciplinary sciences to shed light on the way members of the public perceive and evaluate biodiversity-related issues (Christie et al. 2006), the understanding of public views on biodiversity management remains limited, often leading to serious doubts about the significance of public opinion.

The only alternative is to use taxa (groups of invertebrates or other organisms) that are better known and that will, with some predetermined degree of accuracy, represent wholesale biodiversity (Savage 1982, Vane-Wright et al. 1994, Williams et al. 1997). This concept may then be applied by using biodiversity indicator groups to identify priority areas for conservation (Walker 1995, Vane-Wright 1996). Biodiversity indicators save the time and expense that would be necessary for comprehensive biodiversity surveys (if such surveys were at all possible).

This is the first study for quantitative establishment of these narrow habitat use patterns among beetle species of the Shivalik region in north western Himalaya. The area is largely a sal dominated forest ecosystem and forms an important transition point from the plains and high mountainous regions. Further, the climatic conditions and vegetation largely represents tropical dry deciduous region, that favour increased insect diversity (Stork 1988). Beetles are well known worldwide (Weisner 1992) and generalizations of their biodiversity are reflected in other taxa (Pearson and Ghorpade 1989, Pearson and Cassola 1992, Pearson and Carroll 1998, 2001), hence they are one of the most studied taxa for conservation research. Pearson and Cassola (1992) and Pearson (1994) have thus elaborated on the usefulness of tiger beetles (Cicindelidae) as an indicator taxon for monitoring and inventory studies.

The major finding of this research work is on understanding the habitat association of beetles in relation to key habitat variables that define their assemblage pattern. It was observed that species diversity of beetles to be quite high in the mixed forest habitats of the protected area sampled. Present study of beetles also provides a background for identifying centers of species richness and abundance within the protected areas of the Shivalik landscape (Pressey and Nicholls 1989, Pressey et al. 1993). Such studies can provide a more scientific basis by which to plan and manage a system of protected areas around these centers in accordance with the Convention on Biological Diversity ((Williams 1993, Glowka et al. 1994, Williams 1998). Nevertheless, two habitats stood out amongst others pertaining to the cumulative abundance of tiger beetles *viz.* riverine area and mixed forest area, as these two habitats were found to be the repository of beetles.

The seasonality pattern shown by beetles was of a generalist nature, as may e found for other insect group would do so, but the most important thing was presence of some species like *C.chloris* even in the winter season utilizing different habitat conditions. Further, the species quickly emerged during summer season and gained peak in abundance concomitant to onset of monsoon season. In spite of Sal dominant forest ecosystems, it was apparent that these were not the obvious preference of beetles. Analysis showed distinct patterns of grouping amongst habitat types, and surprisingly mixed forest habitats were found most similar irrespective of the dominant tree species. This has a severe conservation implication because this is a direct instance of increased anthropogenic influence on forest ecosystems in these areas as species composition was quite similar in these habitats.

Future studies would thus give an insight into the degree of landscape modification using beetles as indicator species (Gaston and Williams 1993, Gaston and Blackburn 1995). Another interesting aspect of distribution of beetles was their subdued presence in *Eucalyptus*, *Khair* and *Syzygium* plantation mixed forest habitats. Again this has some implication for the management of protected areas for the park managers. It appears as if the habitat conditions in these plantation mixed forests were not appropriate for beetles directly and indirectly for its diverse prey species and/or trophic requirements. Thus, for better conservation and management of forests, it is thus indispensable to look for the effects of plantations on local species (Gaston and Williams 1996). Further, though one would expect tiger beetles more in open forest areas, but in our study we found many species to be particularly fond of forested habitats, so much so that one particular species *C.bicolor* was found only in the forested habitats with varying degree of canopy openness. Other belonging to the genera *Neocollyris* preferred forested habitats with reasonably good shrub cover to forage upon prey like chrysomelids.

The study shows strong correlations of beetle richness with vegetation variables like floral diversity, foliage density, shading and microhabitat temperature (Fanelli et al. 2006) and thus indirectly on the diversity and abundance of potential prey items for the beetles. Interesting aspect documented was the unique habitat utilization by tiger beetles. Though all habitats had one or other kind of species, their richness as well as abundance were quite dissimilar. Increased habitat specificity, one of the cardinal requirements of bioindicator species (Noss 1990, Pearson and Cassola 1992, Pearson 1994), could be observed for many species.

Further, indicator species could be observed for many habitat conditions, like canopy cover and ecotones. Although habitat loss is often a major cause of biodiversity loss (Descender and Turin 1989), often by this time many management options are no longer available. Using sensitive bioindicators to detect more subtle and earlier perturbations may be significant for habitat management by making remedial action less costly and timelier. Such habitat use patterns are thus critical both in justifying the use of these tiger beetles as surrogates and in establishing a baseline in long term monitoring. In spite of good pragmatic abundance of beetles, they showed a low degree of co-occurrence and niche overlap suggesting increased resource partitioning (Parmenter et al. 1989) and judicious microhabitat utilization by adult beetles along the lines of the Gause's law of competitive displacement (DeBach 1966). This was also reflected in the feeding guilds, as many of the species though belonging to same guild showed circadian and temporal variation and occupying different microhabitats with respect to feeding and reproduction. Also, many species were separated seasonally and had different times of emergence and peak populations (Gaston et al. 1995).

Present study also provide a firm basis to interpret changes in microclimatic conditions, caused by humans directly or though long term climate change by monitoring these species. For example, if future fires, over grazing, tourism pressure or other human perturbations are imposed intentionally or unintentionally on forest ecosystems of Shivalik Himalaya, we now have a measurement to quickly and readily measure the cause and effect of impacts. Presence-absence data as well as population trends of the beetle species in respective habitats can warn us of impending changes to the entire habitat long before they become evident in other inhabitants of these habitats, such as the more long-lived and less sensitive vertebrates and plants. In addition, results from studies at this relatively small spatial scale may have ramifications for other areas and at larger scales (Grimmond et al. 2000).

Several of the beetle species observed in this study are widely distributed across Asia. Their sensitivities and usefulness as bioindicators of habitat perturbation might well extend over their entire ranges (Carroll and Pearson 1998). So, beetles as bioindicators should be the excellent candidates for long term monitoring of forest ecosystems, ecosystem health and its measurement over a variety of landscapes. The concept of bioindicators is a trivial simplification of what probably happens in nature. It can be defined as a species or assemblage of species that is particulary well matched to specific features of the landscape and/or reacts to impacts and changes (Paoletti and Sommaggio 1996, Paoletti and Pimentel 1996).

Examples of bioindicators are species that cannot normally live outside the forest, species that live only in grasslands or in cultivated land, those that support high levels of pollutants in their body tissues, species that react to a particular soil management practice (Stork and Eggleton 1992), and those that support waterlogging. Bioindication is not a new term; instead, it has evolved from geobotany and environmental studies since the last century (Paoletti et al. 1991). It has become an important paradigm in the process of assessing damaged and contaminated areas, monocultures, contaminated orchards, disposal areas, industrial and urban settlements, and areas neighboring power plants. Using species or groups of taxa as indicators of the impact of environmental stressors on biotic communities (ecological indicators) is arguably perhaps the more critical objective in the field of bioindication.

Ecological understanding of anthropogenically induced effects on biota is essential if an attempt is to be made to ameliorate the impact of human activity and conserve biodiversity. This should be the primary goal of all conservation efforts. Studies on the impact of particular environmental stressors generally focus on single species, single assemblages or communities, or single groups of closely related taxa. Such bioindication studies serve two purposes. They indicate that a particular stressor does (or does not) have a biotic impact and they provided critical information for the conservation of the indicator taxa or group, particularly when the species are known to be rare and endangered (e.g. Butterfield et al. 1995). However, only restricted, indicator-related interpretations can be made from the results of single taxon or assemblage studies. The utility of ecological indicators would be substantially greater if their representativeness of other taxa could be demonstrated (Noss 1990, Dufrêne and Legendre 1997).

Further relational studies are thus required to determine whether the sensitivities demonstrated by the indicator reflect trends in related and unrelated taxa within the ecosystem or habitat. Few studies have progressed to this stage and there is presently little evidence to suggest that any taxon or group of organisms can be expected to qualify as an ecological indicator in this sense. Indeed, although groups of terrestrial taxa have been identified as potential indicators of climate change (Holloway 1990, Holloway and Stork 1991, Kremen 1992), evidence shows that the response of late Quaternary plant communities to global warming was individualistic and that communities of species did not shift as tightly linked assemblages in response to this change in environmental state (Woodward 1987, Graham and Grimm 1990). Perhaps Hammond's (1994) ‘shopping basket of taxa’ approach may prove successful here if the responses of carefully selected, different taxa, which each represent the response of a limited set of other taxa (perhaps most closely taxonomically or functionally related taxa, rather than communities), are investigated.

In combination, the taxa in this ‘shopping basket’ may then provide an adequate representation of the response of the community, habitat or ecosystem of interest to the stressor of interest. While the urgency of taking conservation measures may demand that decisions be made on the basis of single taxon, limited relational studies, such action should not deter biologists from extending studies by this further step to determine the representativeness of selected ecological indicators.

The aim of bioindicator-based studies is to use the living components of the environment under study (especially those with the highest diversity, the invertebrates), as the key to assess the transformations and effects, and, in the case of landscape reclamation, to monitor the remediation process in different parts of the landscape over time. This approach could improve policies aimed at reducing the stress placed on landscapes. For example, bioindicator-based studies could help in the process of amelioration and remediation of the rural landscape as result of implementation of policies such as the set-aside in Europe (Jordan 1993, Jorg 1994). Reduction in agricultural pesticide use could be adequately monitored by bioindicators to assess the benefit of a new policy (Pimentel 1997). Bioindicators could be used to assess and remediate contaminated or polluted areas to be reclaimed (Van Straalen and Krivolutskii 1996).

The objectives of monitoring programmes are to evaluate the changes over time in habitat structure, function and composition in response to natural factors, human activity or management practices (Noss 1990, Spellerberg 1991). Hellawell (1991) defines three general categories that summarize the motivations for instituting a biological monitoring programme and that are relevant here to the use of bioindicators : (i) assessing the effectiveness of policy or legislation, e.g. long-term survival of rare or endangered species in designated conservation areas; (ii) regulatory (performance or audit function), e.g. monitoring levels of soil pollutants; (iii) detecting incipient change (‘early warning’), e.g. effects of development on biodiversity (Kremen et al. 1994). Efforts directed towards sustainable development and the conservation of biodiversity arises from common societal values (Williams 1996). Irrespective of whether a society holds utilitarian or intrinsic values on attaining conservation objectives, the bioindication of environmental disturbance, stress effects on biota, or of biodiversity, necessitates this shared appreciation for bioindication objectives.

Future studies of beetles as bioindicators also need to focus on their response to specific prey and other less defined biotic or abiotic factors, within the context of dynamic successional stages of each habitat, whether naturally caused or from the influence of humans. Several claims have been made that the larval forms of beetles are even more specialized in habitat than the adults. The larvae in their tunnels are more difficult to observe, but they are also easier to use in laboratory experiments about the influence of feeding regimes, temperature, predation and competition on survival and fecundity (Pearson and Vogler 2001). An advantage of such biomonitoring is its comparatively low cost and the integrative recording character of ecosystems on the other (Johnson 1995, Fränzle 2006). Such ecological risk assessment and environmental monitoring are potentially complimentary activities (Van Jaarsveld et al. 1998, Suter 2001).

Monitoring a few indicator species therefore is a widely used method to measure the ecological sustainability and ecosystem health since it is often so difficult to measure and monitor the natural or anthropogenic induced landscape modification and their effects on all species or environmental conditions (Landres et al. 1988, Kuliopulos 1990, Hilden and Rapport 1993, Kremen et al. 1993). The degree of habitat specificity among the beetle species in this protected areas are similar to that found in beetle species around the world (Pearson and Vogler 2001). Since specialization is usually associated with sensitivity to habitat alteration (Pyle et al. 1981, Rosenberg et al. 1986, Pearson 1994), identifying the costs and benefits of a monitoring program will assist in the prioritization process more frequently, as the true costs of monitoring are not recognized and are, therefore, underestimated. Benefits from such monitoring studies are rarely evaluated, because they are difficult to quantify (Caughlan and Oakley 2001).

An ecosystem health approach is thus needed as it also allows for a more explicit connection between the state of the environment and human well being (Rapport et al. 1998, Rapport and Singh 2006). Even though the current study has focused mainly on protected area in the Shivalik landscape with its diverse habitat types, extrapolating the present study to different forest habitat types in different parts of the landscape and to even different geographical regions with different land use patterns would definitely strengthen our knowledge of response of bioindicators to various disturbance variables.

Environmental monitoring should thus determine the status and trends to determine whether the environment is improving or not (Montreal Process 2000). Continuous efforts are a prerequisite to make gathering of future data and continued monitoring as simple as possible. With this quality added to the biological characters that make tiger beetles so ideal, park guards, local volunteers, and residents can become involved with minimal training and maximum input into management plans and execution. Such applications of bioindicators can be expected to help not only in improving the environment but also in augmenting natural resource management, awareness of the living creatures in background of protected area management (PAM) cycle around so that a better appreciation of the crucial role in sustaining life on the planet is obtained.

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Appendix 1 List of families and sub-families of order Coleoptera recorded in Simbalbara WLS, Himachal Pradesh

Sub-order	Family*	Common Name	Sub-family
Myxophaga	1. Hydroscaphidae	Skiff beetles	
Adephaga	2. Gyrinidae	Whirligig beetles	Gyrininae
	3. Haliplidae	Crawling water beetles	
	4. Noteridae	Burrowing water beetles	Noterinae
	5. Amphizoidae	Trout-stream beetles	
	6. Hygrobiidae	Screech beetles	
	7. Dytiscidae	Predaceous diving beetles	Hydroporinae
	8. Rhysodidae	Wrinkled bark beetles	
	9. Carabidae**	Ground beetles	Omophroninae, Carabinae, Elaphrinae, Siagoninae, Scaritinae, Trechinae, Harpalinae, Brachininae
	10. Paussidae	Flat-horned beetles	Paussinae
	11. Cicindelidae**	Tiger beetles	Collyrinae, Cicindelinae
Polyphaga	12. Hydrophilidae	Water scavenging beetle	Georissinae, Hydrophilinae, Sphaeridiinae
	13. Histeridae	Hister beetles	Niponiinae
	14. Pselaphidae	Shot-winged mold beetles	Pselaphinae
	15. Hydraenidae	Minute moss beetles	Hydraeninae
	16. Scydmaenidae	Ant-like stone beetles	Scydmaeninae
	17. Staphylinidae**	Rove beetles	Microsilphinae, Omaliinae, Micropeplinae, Dasycerinae, Pselaphinae, Apateticinae, Scaphidiinae
	18. Lucanidae	Stag beetles	Lucaninae
	19. Passalidae	Bess beetles	
	20. Trogidae	Hide or skin or carcass beetles	
	21. Scarabaeidae**	Dung beetles	Geotrupinae, Scarabaeinae, Euchirinae, Melolonthinae, Rutelinae, Dynastinae, Cetoniinae
	22. Eucinetidae	Plate-thigh beetles	

Sub-order	Family*	Common Name	Sub-family
	23. Clambidae	Fringe-winged beetles	Clambinae
	24. Scirtidae	Marsh beetles	
	25. Dascillidae	Soft-bodied plant beetles	Dascillinae, Karumiinae
	26. Rhipiceridae	Cedar beetles	
	27. Buprestidae	Metallic wood borers	Buprestinae, Agrilinae
	28. Byrrhidae	Pill beetles	Byrrinae
	29. Dryopidae	Long-toed water Beetles	
	30. Heteroceridae	Variegated mud-loving beetles	Heterocerinae
	31. Psephenidae	Water-penny beetles	Psephininae
	32. Chelonariidae	Turtle beetles	
	33. Callirhipidae	Callirhipid beetles	
	34. Cerophytidae	Rare click betles	
	35. Eucnemidae	False click beetles	
	36. Elateridae	Click beetles	Agrypninae, Octocryptinae, Melanotinae, Dicrepidiinae, Conoderinae, Elaterinae, Cardiophorinae, Chelolepidiinae, Dentocollinae
	37. Lycidae	Net-winged beetles	Lycinae
	38. Lampyridae	Lightning bugs or fireflies	Lampyrinae, Photurinae
	39. Cantharidae	Soldier beetles	Cantharinae, Chauliognathinae
	40. Derodontidae	Tooth-necked fungus beetles	Derodontinae
	41. Nosodendridae	Wounded-tree beetles	
	42. Dermestidae	Skin beetles	Dermestinae
	43. Bostrychidae	Branch or twig borers	Bostrychininae
	44. Lyctidae	Powder-post beetles	Lyctinae
	45. Anobiidae	Deathwatch beetles or woodworm or wood borer	Anobiinae
	46. Ptinidae	Spider beetles	Ptininae

Sub-order	Family*	Common Name	Sub-family
	47. Trogossitidae	Bark-gnawing beetles	
	48. Cleridae	Checkered beetles	Clerinae
	49. Melyridae	Soft-winged flower beetles	Melyrinae, Dasytinae
	50. Sphindidae	Dry-fungus beetles	Sphindinae
	51. Nitidulidae	Sap beetles	Nitidulinae
	52. Cucujidae	Flat bark beetles	
	53. Coccinellidae	Ladybird beetles	Sticholotidinae, Chilocorinae
	54. Ciidae	Minute tree fungus beetles	Ciinae
	55. Melandryidae	False darkling beetles	Eustrophinae, Melandryninae
	56. Rhipiphoridae	Wedge-shaped beetles	Rhipiphorinae
	57. Tenebrionidae	Darkling beetles	Lagriinae, Tenebrioninae, Alleculinae
	58. Meloidae	Blister beetles	Meloinae
	59. Salpingidae	Narrow-waisted bark beetles	Ageleninae, Salpinginae
	60. Anthicidae	Antlike-flower beetles	
	61. Cerambycidae**	Long-horned beetles	Vesperinae, Oxypeltinae, Disteniinae, Philinae, Prioninae, Spondylidinae, Lepturinae, Cerambycinae, Lamiinae
	62. Chrysomelidae	Leaf beetles	Hispinae, Chrysomelinae, Galerucinae, Eumolpinae
	63. Anthribidae	Fungus weevils	
	64. Attelabidae	Leaf rolling weevils	
	65. Brentidae	Straight-snouted weevils	
	66. Curculionidae	Snout beetles	Brachycerinae, Curculioninae, Platypodinae

*** Following Lawrence and Newton (1995), Borror et al. (1992), Crowson (1981), Richards and Davis (1977)**
**** Bioindicator families**

Appendix 2 Cumulative SIMPER Analysis

Overall average dissimilarity = 87.44

Taxon	Contribution	Cumulative %	Mean abund 1	Mean abund 2	Mean abund 3	Mean abund 4	Mean abund 5	Mean abund 6	Mean abund 7	Mean abund 8	Mean abund 9	Mean abund 10	Mean abund 11	Mean abund 12	Mean abund 13
C. maderae	1.059	1.211	4.6	1.6	2	1	1	0	0	0.4	0	0	0.6	0	0.4
O. orientalis	1.025	2.383	0	0	0	0	0	0	3.2	0	0.8	2	2.4	1	2.4
S. punctum	1.025	3.555	0	0	0	0	0	0	3.2	0	0.8	2	2.4	1	2.4
C. bigemina	0.9561	4.649	0	0	0	0	0	0	0	0	1	2	2.4	2	2.4
A. indicum	0.9473	5.732	0	0	0	0	0	0	0	0	0.8	2	2.4	2	2.4
C. intermedia	0.8807	6.739	0	0	0	0	0	0	5	0	1	1	1.2	1	1.2
O. amicus	0.8569	7.719	0	0	0	0	0	0	0	0	3.8	0.6	0	3.4	0
C. fastidiosa	0.8562	8.698	0	0	0	0	0	5.8	0	4.4	0	0	0	0	0
C. vigintiguttata	0.8533	9.674	1.6	0	2	0.6	0	1.8	2	0	0	0	2	0	0.8
P. microps	0.849	10.65	1.2	0.6	2	0.6	0	3	0	2	0	0	1	0	0.8
S. guerini	0.8306	11.6	0	0	0	0	0	0	0	5	1	1	1.2	1	0.4
C. unicornis	0.8163	12.53	1.2	0.6	1.4	0.6	0	2.2	0	2	0	0	2	0	0.8
O. fasciatus	0.8128	13.46	0	0	0	0	0	0	0	0	5.2	0	0	1.8	0
O. tarandus	0.7929	14.37	1.2	1.2	1.4	0.6	1	0	0	0	0	0	2	0	1.6
L. hugelii	0.7862	15.26	0.8	2	1.4	0.4	0.8	0.4	0.4	1	1.2	0.6	0.8	0	0
L. indicus	0.7811	16.16	0.4	0.2	1.6	0	0	0.6	0	0	2.2	1.4	2.4	0	0
O. luridripennis	0.7804	17.05	0.8	0.6	0.8	0.6	0	2.6	0	2	0	0	2	0	0.8
A. induta	0.7749	17.94	0.8	1	1.4	0.6	1	1.2	0.4	0.4	1.2	0.8	1.6	0	0
Sophronica sp.	0.765	18.81	0.4	0.4	1.2	0.8	1.4	0.2	0	0.6	0.6	0.4	0.8	1.6	0
P. ferrugineus	0.7394	19.66	0.6	1	1	0.2	0.6	1.4	0.4	1	0.8	0.6	0.8	1	0
O. mopsus	0.7319	20.49	0	0	0	0	0	0	0	5	1	0.8	1.2	0.2	0.4
C. pithecius	0.7053	21.3	0	0	0	0	0	0	0	3.6	1	1	1.2	1	0.4

Taxon	Contribution	Cumulative %	Mean abund 1	Mean abund 2	Mean abund 3	Mean abund 4	Mean abund 5	Mean abund 6	Mean abund 7	Mean abund 8	Mean abund 9	Mean abund 10	Mean abund 11	Mean abund 12	Mean abund 13
M. consimilis	0.6928	22.09	0	0	0.2	0	0	0	0	4	2	0	1	0	1
C. brahminus	0.6911	22.88	0	0	0	0	0	0	2.4	0	0.8	0.6	1.8	0.4	1.6
C. sacontala	0.6873	23.67	0.6	1	1.2	1	0.2	0	0	0	0	0	2	0	1.6
J. chloropleura	0.6845	24.45	0.8	1.2	1.4	1	0.4	0	0	0.4	0	0	2	0	0.8
S. neglectus	0.6581	25.2	4.2	1.8	0	0	0	0	0	0	0	0	0	0	0
T. cardoni	0.65	25.95	2	1	1.6	1	0	0	0	0	0	0	1	0	0.6
O. dynastoides	0.6387	26.68	0.6	1	0.4	3.4	0.2	0	0	0	0	0	0	0	0
H. gigas	0.6274	27.4	3.8	1.8	0	0	0	0	0	0	0	0	0	0	0
X. globosa	0.6196	28.1	1	1	1	0	0	0.8	0	0	1.6	0	1.2	0	0
O. exquisitus	0.6024	28.79	1	0	4.4	0.6	0	0	0	0	0	0	0	0	0
A. championi	0.5918	29.47	0.4	0	2.4	0.2	0	1	0	3.2	0	0	0	0	0
C. spinolae	0.5918	30.15	0.4	0	2.4	0.2	0	1	0	3.2	0	0	0	0	0
T. cribratum	0.583	30.81	0.6	1.2	1.2	0	0	0	0	0	2.8	0.2	0.6	0	0
H. spinicornis	0.5774	31.47	1	1.8	1.2	0	0	1	0	0	0.8	0	0.2	0	0
L. striolata	0.5703	32.13	1	0	0.6	1.2	0.8	0.8	0.6	1	0.4	1	0	0	0
A. rusticatrix	0.563	32.77	1	1.8	1.2	0	0	0.4	0	0.4	0.4	0	0.8	0	0
G. maculosus	0.562	33.41	1.4	0.6	0.8	0.8	0.4	0.4	1	0.4	0.6	0	0	0	0
C. angulata	0.5607	34.05	0	0	0	0	0	0	0	1.8	0	0.4	1.4	0.4	1.4
Lamiinae sp.1	0.556	34.69	0.4	0.4	0.6	1	1	0.4	0	0.2	0.2	0.8	1.2	0	0
S. dubisosus	0.5467	35.32	0	0	1	0	0	5.2	0.2	0	0	0	0	0	0
C. bensoni	0.5467	35.94	0	0	1	0	0	5.2	0.2	0	0	0	0	0	0
O. necrophagus	0.5467	36.57	0	0	1	0	0	5.2	0.2	0	0	0	0	0	0
O. amplexus	0.5462	37.19	0	0	0	0	0.6	0	0	0	3	0	0	1.6	0
Exocentrus sp.1	0.5405	37.81	0.6	0.2	0.4	0.4	0.4	0.8	0.4	0.4	0.4	0.6	0.8	0.6	0.2
O. variegatus	0.5331	38.42	0.6	0.2	0.6	0.4	0.6	0.4	0.2	0.6	0.6	0.2	1	0.2	0

Taxon	Contribution	Cumulative %	Mean abund 1	Mean abund 2	Mean abund 3	Mean abund 4	Mean abund 5	Mean abund 6	Mean abund 7	Mean abund 8	Mean abund 9	Mean abund 10	Mean abund 11	Mean abund 12	Mean abund 13
O. expansicornis	0.532	39.03	0	0	0	0	0	0	0	0.2	0	0	2.8	0	2.2
C. grammophora	0.5277	39.63	0	0	1	0	0	5.2	0	0	0	0	0	0	0
R. glaberrima	0.5253	40.23	0	0	0	0	0	0	1.4	5.4	0	0	0	0	0
O. vaulogeri	0.5253	40.83	1.6	0.6	0.4	0.8	0.6	0.2	0.8	0	0	0	0	0	0
Apomecynini	0.5247	41.43	0	0	0	1	0.8	0.8	0	0.4	0.4	0.6	0.6	0	1
Adoretus sp.2	0.5155	42.02	0	0	0	0	0	0	6	0	0	0	0	0	0
N. cameroni	0.5155	42.61	0	0	0	0	0	0	6	0	0	0	0	0	0
C. multiguttata	0.5144	43.2	0	0	0	0	0	0	0	0	0.6	0	2	0	2
H. nigritarsis	0.5139	43.79	1.2	0.2	0.8	0.8	0.4	0.4	1	0.4	0.6	0	0	0	0
Rondibilissp.	0.5124	44.37	0	0	0	1	2	0.8	0	0	0	0.8	0.8	0	0
O. hystrix	0.5102	44.96	0	0	0	0	0	5.8	0	0	0	0	0	0	0
C. tortricornis	0.5102	45.54	0	0	0	0	0	5.8	0	0	0	0	0	0	0
P. ceylanicus	0.5102	46.12	0	0	0	0	0	5.8	0	0	0	0	0	0	0
D. cervinus	0.5096	46.71	0.2	0.2	0.6	0.6	1	0.8	0.4	0.4	0.4	0.2	0.8	0	0
A. oberthueri	0.5094	47.29	0.6	0.6	1	0.8	1.4	0.6	0	0	0	0	0.6	0	0
A. holosericea	0.5064	47.87	0	0	0	0.6	1.2	0.6	0.2	0.4	0.4	1.6	0.6	0	0
C. simplex	0.5051	48.45	0.6	0.6	1	0.4	0.8	0.8	0	0	0.4	0.4	0.4	0	0
B. kara	0.503	49.02	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
X. subscutellatus	0.4978	49.59	0	0	0.2	0.8	1	0.6	0	0.4	0.8	0.4	0.8	0	0.4
C. westwoodi	0.4964	50.16	1	0.2	0.4	0.8	0.6	0.8	0.4	1	0.2	1	0	0	0
S. barbatum	0.4961	50.73	0	0	0	0.8	0.8	0	0	0.4	1	0.4	1.4	0	0.6
S. striatulus	0.492	51.29	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
L. parvimaculata	0.492	51.85	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
C. viduata	0.492	52.41	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
C. surdus	0.492	52.98	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0

Taxon	Contribution	Cumulative %	Mean abund 1	Mean abund 2	Mean abund 3	Mean abund 4	Mean abund 5	Mean abund 6	Mean abund 7	Mean abund 8	Mean abund 9	Mean abund 10	Mean abund 11	Mean abund 12	Mean abund 13
E. indica	0.492	53.54	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
H. mutabilis	0.492	54.1	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
G. cyaneus	0.492	54.66	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
C. punjabensis	0.492	55.23	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
C. chloris	0.492	55.79	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
C. flavomaculata	0.492	56.35	1	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
M. brachycera	0.4893	56.91	0.8	0.4	1.8	0.4	0.4	0.4	0.4	0.4	0	0	0	0	0
Ostedes sp.1	0.4861	57.47	0.4	0.8	0.8	0	0	0.6	0	0	1	0.6	1	0	0
O. arboreus	0.4843	58.02	0.8	0.6	0.6	0	0.4	0.8	0.4	1.6	0.4	0	0	0	0
G. ruflcornis	0.4817	58.57	0.6	0.6	0.2	0.4	1.6	0.6	0.4	0.6	0.6	0	0	0	0
O. atropolitus	0.4755	59.12	0.2	0.2	0.2	0.6	0.4	0.8	1.6	0.8	0	0	0	0	0
O. furcillifer	0.4737	59.66	0.4	0.4	0.8	0.8	0.8	1.2	1	0	0	0	0	0	0
Exocentrus sp.2	0.4675	60.19	0	0	0	0.4	0.8	0.6	0	0.2	0.2	0	1	1.4	0
M. undulata	0.4655	60.73	1	0.2	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
Ostedes sp.2	0.4639	61.26	0.2	0.4	0.6	0.6	0.6	0.4	0.4	0.4	0.8	0.4	0.6	0	0
Paedurus	0.458	61.78	0.6	0.6	0.6	1	1	0.8	0	0.2	1	0	0.2	0	0
Anomala sp.1	0.4578	62.3	0.4	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
A. histrio	0.4518	62.82	0.2	0.2	0.4	0.2	0.6	1	0.4	0.6	1	0.6	0.4	0.2	0
X. smei	0.4517	63.34	0	0	0	0	0	0.4	0	0.8	0.6	0	0.8	1.8	0
T. lunatus	0.4284	63.83	0.6	0.6	0.6	0.8	0.8	0.6	0	0.2	1	0	0	0	0
S. devotus	0.4264	64.31	0.6	1.2	0.6	0.6	1.4	0	0	0	0	0	0	0	0
O. circulifer	0.4259	64.8	0	0	0	0	0	0	0	0	0	1.8	0	1	0.8
M. melancholica	0.4254	65.29	0	0.6	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0
P. pretiosa	0.4251	65.77	0.6	0.6	0.4	0.6	1.8	0.2	0	0	0	0	0	0	0
N. championi	0.4195	66.25	0.4	0.2	0.2	0.4	0.8	0.8	0.6	1	0.4	1	0	0	0

Taxon	Contribution	Cumulative %	Mean abund 1	Mean abund 2	Mean abund 3	Mean abund 4	Mean abund 5	Mean abund 6	Mean abund 7	Mean abund 8	Mean abund 9	Mean abund 10	Mean abund 11	Mean abund 12	Mean abund 13
G. miliaris	0.4171	66.73	0	0	0	0	0	0	1.4	4.2	0	0	0	0	0
C. bernhaueri	0.4152	67.2	0	0	0	0	0.6	0	0.2	0.8	0.2	1	0.2	1	0
C. indicus	0.4093	67.67	0	0	0	0.4	0.8	0.8	0	0.6	0.6	0.4	0.4	0	0
D. constrictus	0.4063	68.14	1	0.6	0.2	0.4	0.8	0.2	0.8	0.6	0.4	0.2	0	0	0
P. bistriatus	0.3959	68.59	0.6	0.6	0.6	0.2	0.2	0.2	0.2	0.8	0.2	0	0.8	0.2	0
T. babulti	0.3957	69.04	0	0	0	0	0	0	5.4	0	0	0	0	0	0
N. bonellii	0.3957	69.5	0	0	0	0	0	0	5.4	0	0	0	0	0	0
O. sternalis	0.3957	69.95	0	0	0	0	0	0	5.4	0	0	0	0	0	0
H. pulchella	0.3957	70.4	0	0	0	0	0	0	5.4	0	0	0	0	0	0
B. xanthacrum	0.3957	70.85	0	0	0	0	0	0	5.4	0	0	0	0	0	0
O. griseosotosus	0.3946	71.3	0	0	0	0	0	0	0	0	0.6	0	2	0	1.4
O. smaragdus	0.3946	71.76	0	0	0	0	0	0	0	0	0.6	0	2	0	1.4
Anomala sp.2	0.3946	72.21	0	0	0	0	0	0	0	0	0.6	0	2	0	1.4
C. maculata	0.3901	72.65	0.2	0.6	0.2	0.4	1	0	0.2	0.6	0.4	0.4	0	0.4	0.2
H. indicus	0.3889	73.1	0	0	0.4	0.4	0.4	0.6	0.4	0.4	0.4	0.8	0.4	0	0
X. gideon	0.3748	73.53	0.6	0.8	0.2	0.4	0.2	0.4	0.2	1.4	0.2	0	0	0	0
S. tetraspilota	0.3665	73.95	0	0	0.4	0	0	0.6	1	0.4	0.6	0.4	0.8	0	0.4
P. parvicollis	0.3658	74.36	0.4	0.2	0.6	0	0.4	0.6	0.4	0.6	0.4	0	0.2	0	0
Pachycorynus	0.3644	74.78	0.6	0.6	0.6	0.2	0.2	0	0	0.8	0.2	0	0.8	0	0
C. scabrator	0.3604	75.19	0.6	0.6	0.2	0.2	0.2	0.4	0.4	0.4	0.6	0.2	0.2	0.2	0
N. saphyrina	0.36	75.6	0	0	0.2	0	2.4	0	0	1.4	0.2	0	0	0	0
S. subnitens	0.3556	76.01	0.4	0	2.4	0.2	0	1	0	0	0	0	0	0	0
O. pacificus	0.3556	76.42	0.4	0	2.4	0.2	0	1	0	0	0	0	0	0	0
C. excisus	0.3556	76.82	0.4	0	2.4	0.2	0	1	0	0	0	0	0	0	0
C. semirubra	0.3553	77.23	0	0.4	0.2	0.4	0.4	0.2	0.8	1.2	0	1	0	0	0

Taxon	Contribution	Cumulative %	Mean abund 1	Mean abund 2	Mean abund 3	Mean abund 4	Mean abund 5	Mean abund 6	Mean abund 7	Mean abund 8	Mean abund 9	Mean abund 10	Mean abund 11	Mean abund 12	Mean abund 13
N. cinctella	0.349	77.63	0	0	0	0	0	0	0	0	0	0.4	1.4	0.4	1
Adoretus sp.3	0.349	78.03	0	0	0	0	0	0	0	0	0	0.4	1.4	0.4	1
C. erudita	0.3487	78.43	0.4	0.6	0	0	0.4	0.4	0.6	1	0.4	1	0	0	0
N. tibialis	0.3486	78.83	0.8	0.8	1.2	0	0	0	0	0	0.4	0	0.4	0	0
O. hamaticeps	0.3454	79.22	0	0	0	0	0	0	4	0	0	0	0	0	0
O. albopunctata	0.345	79.62	0.4	0.2	0.2	0.2	0.8	0.6	0.2	0.6	0.6	0	0	0	0
H. longithorax	0.3427	80.01	0	0	0	0	0	0	4.6	0	0	0	0	0	0
C. extensicollis	0.34	80.4	0	1.2	0.2	0	1	0	0	0	1	0	0	0	0
Ropica sp.1	0.3313	80.78	0	0	0	0.6	0.6	0.6	0	0.2	0.2	0.8	0.2	0	0
T. ochrias	0.3294	81.15	0.2	0	0.2	0.4	0.8	0.8	0.4	1	0.4	0.2	0	0	0
O. indianus	0.328	81.53	1	1	1.2	0	0	0	0	0	0	0	0	0	0
Cryptobium	0.3261	81.9	1.2	0	0	0.6	0.6	0	0	0	0.6	0	0	0	0
P. cameroni	0.3244	82.27	0	0	0	0	0	0	3.8	0	0	0	0	0	0
C. pantherinus	0.3244	82.64	0	0	0	0	0	0	3.8	0	0	0	0	0	0
H. terminata	0.3138	83	0	0	0	0	2.4	0	0	1.4	0	0	0	0	0
D. cinereus	0.3135	83.36	1	1	0.4	0	0	0	0	0	0.4	0	0.2	0	0
M. uniformis	0.3111	83.72	0	0	0	0.4	0.4	0.4	0.2	0.4	0.4	0.8	0	0	0
C. subtilesignata	0.3106	84.07	0	0	0	0	1.2	0	1	0	0	0.4	0	0.4	0
B. campactum	0.3106	84.43	0	0	0	0	1.2	0	1	0	0	0.4	0	0.4	0
C. plumigera	0.3099	84.78	0	0	0	0	0	1	0	2.6	0	0	0	0	0
C. sabinus	0.303	85.13	0	0	0	0	0	0	4	0	0	0	0	0	0
L. buqueti	0.303	85.47	0	0	0	0	0	0	4	0	0	0	0	0	0
D. demissus	0.3025	85.82	0.2	0.4	0.6	0	0	0.4	0.2	0.4	0.2	0.4	0.4	0	0
P. obesus	0.3021	86.17	0	0	0	0	0	0	0	0.6	0.4	0	0.2	1.4	0
C. venosa	0.2991	86.51	0	0	0	0	0	0	1	0.2	0	0.8	0	0.8	0

Taxon	Contribution	Cumulative %	Mean abund 1	Mean abund 2	Mean abund 3	Mean abund 4	Mean abund 5	Mean abund 6	Mean abund 7	Mean abund 8	Mean abund 9	Mean abund 10	Mean abund 11	Mean abund 12	Mean abund 13
A. iris	0.2991	86.85	0	0	0	0	0	0	1	0.2	0	0.8	0	0.8	0
H. brevipennis	0.2978	87.19	0.6	0	0.2	0.4	0.2	0.4	0.2	0.4	0.4	0	0	0	0.2
C. capitale	0.2972	87.53	0	0	0	0	0	0	0.2	0.2	0.8	0.4	0.4	0.4	0.6
S. pumila	0.2971	87.87	0	0	0	0	1.2	0	0	1	0	0.4	0	0.2	0.2
O. pactolus	0.2971	88.21	0	0	0	0	1.2	0	0	1	0	0.4	0	0.2	0.2
C. indicus	0.2971	88.55	0	0	0	0	1.2	0	0	1	0	0.4	0	0.2	0.2
P. pyrrhus	0.2956	88.89	0.4	0.4	0.8	0	0	0.8	0	0	0.6	0.2	0.4	0	0
Pinophilus	0.2933	89.22	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.6	0	0	0	0.2
Pothyne	0.2885	89.55	0.4	0.2	0.4	0.6	0.8	0.4	0	0	0	0	0.4	0	0
M. crenata	0.284	89.88	0.4	0.8	0.6	0	0	0	0	0	0.6	0	0.2	0	0
D. volvulus	0.2827	90.2	0.6	0.8	0	0	0	0.8	0	0	0.6	0	0	0	0
T. vagabundus	0.2817	90.52	0.2	0	0	0.6	0	0.4	0.2	0	0.4	1	0.4	0	0
Belonuchus	0.28	90.84	0	0	0	0	0	0	0	0	1	0.4	0.2	1	0
Mitomorphus	0.2779	91.16	0.8	0.8	0.8	0	0	0	0	0	0.4	0	0	0	0
L. beesoni	0.276	91.48	0.8	0.2	0.6	0.4	0.6	0	0	0	0.4	0	0	0	0
O. troglodyta	0.274	91.79	0	0	0	0	1	0	0	0	1	0	0	0.8	0
C. sarpedon	0.274	92.1	0	0	0	0	1	0	0	0	1	0	0	0.8	0
T. championi	0.274	92.42	0	0	0	0	1	0	0	0	1	0	0	0.8	0
O. ochreatus	0.2728	92.73	0	0	0	0	0	0	0	1	0	0.8	0	0.4	0.4
S. inconspiccus	0.2728	93.04	0	0	0	0	0	0	0	1	0	0.8	0	0.4	0.4
C. rutilans	0.2728	93.35	0	0	0	0	0	0	0	1	0	0.8	0	0.4	0.4
N. andrewesi	0.2725	93.66	0	0	0	0	0	0	3	0	0	0	0	0	0
A. orichalcea	0.2725	93.98	0	0	0	0	0	0	3	0	0	0	0	0	0
O. bilobus	0.2686	94.28	0	0	0.4	0	0	0	0	0.4	0.8	0	0	1	0
C. arciferus	0.2526	94.57	0	0	0	0	0	0	0	0.4	0.8	0	0	1	0

Taxon	Contribution	Cumulative %	Mean abund 1	Mean abund 2	Mean abund 3	Mean abund 4	Mean abund 5	Mean abund 6	Mean abund 7	Mean abund 8	Mean abund 9	Mean abund 10	Mean abund 11	Mean abund 12	Mean abund 13
L. iyeri	0.2521	94.86	0.2	0.2	0.2	0.4	0.4	0	0	0.4	0.6	0	0	0	0
P. pedestris	0.2477	95.14	0	0	0.4	0	0	0.8	0.2	0.6	0	0	0.8	0	0
Lamiinae sp.2	0.2471	95.43	0	0	0	0	0	0.8	0	0.4	0.4	1.2	0	0	0
Anomophysis	0.2459	95.71	0.2	0.4	0.6	0	0	0	0	0	1	0	0	0	0
O. pseudostrigosus	0.2427	95.98	0	0	0	0.4	0.8	0.8	0	0	0.4	0	0	0	0
T. indicus	0.2384	96.26	1	0.2	0.2	0.4	0	0.2	0.4	0.2	0	0.2	0	0	0
O. dama	0.2377	96.53	0	0	0	0	0	0	0	0	1.4	0	0	0.8	0
C. downesi	0.2364	96.8	0	0	0	0	0	0	0	0.6	1.2	0.2	0.6	0	0
X. piceous	0.236	97.07	0.4	0.4	0.4	0.2	0.2	0	0	0	0.6	0	0	0	0
Micropeplus	0.2254	97.33	0.4	0.4	0.4	0.2	0.2	0	0	0	0.4	0	0	0	0.2
N. fusicatrix	0.2232	97.58	0	0	0.2	0	0	0.4	0	0.4	0.4	0	1	0	0
S. sacer	0.2188	97.83	0	0	0	0	2.4	0	0	0	0	0	0	0	0
G. opacus	0.2188	98.08	0	0	0	0	2.4	0	0	0	0	0	0	0	0
D. subfasciata	0.2109	98.32	0	0	0.2	0	0	0	0	0.6	0.6	0	0.2	0.6	0
O. ramosus	0.2089	98.56	0.6	0	1.2	0.4	0	0	0	0	0	0	0	0	0
Ropica sp.2	0.2075	98.8	0.4	0.4	0.8	0	0	0.6	0	0	0	0	0	0	0
O. anogeissi	0.1964	99.03	0	0	0	0	0	0	0	0.8	0.8	0	0.4	0	0
Adoretus sp.1	0.1796	99.23	0	0	0	0	0	0	0	2.2	0	0	0	0	0
H. uninotata	0.1796	99.44	0	0	0	0	0	0	0	2.2	0	0	0	0	0
C. bicolor	0.1796	99.64	0	0	0	0	0	0	0	2.2	0	0	0	0	0
J. crassipalpis	0.1737	99.84	0	0	0	0	1	0	0	0	1	0	0	0	0
O. beesoni	0.14	100	0	0	0	0	0	0	0	2.4	0	0	0	0	0

Appendix 3 DECORANA – Cumulative beetle (Insecta: Coleoptera) species scores

S. No.	Species	AX1	AX2	AX3	Ranked 1 EIG = 0.46904		Score	Ranked 2 EIG = 0.34707		Score
1	***A. iris***	253	130	211	152	***L. buquet***	448	48	***C. grammo***	468
2	***A. indicu***	379	75	259	79	***C. sabinu***	448	73	***C. benson***	461
3	***A. champi***	327	107	253	14	***H. longit***	444	26	***S. dubiso***	461
4	***B. campac***	-4	271	0	32	***T. babult***	440	111	***O. necrop***	461
5	***B. kara***	345	70	275	54	***H. pulche***	440	70	***C. tortri***	411
6	***B. xantha***	-15	-38	142	7	***B. xantha***	440	23	***P. ceylan***	411
7	***C. madera***	440	35	-64	117	***O. sterna***	440	108	***O. hystri***	411
8	***C. extens***	-49	273	25	61	***N. bonell***	440	173	***Ropica2***	358
9	***C. westwo***	9	227	271	64	***Adoreste***	401	92	***M. brachy***	357
10	***C. macula***	-23	-27	155	17	***N. camero***	401	76	***C. excisu***	356
11	***C. semiru***	68	0	221	2	***A. iris***	379	114	***O. pacifi***	356
12	***D. constr***	75	-63	127	49	***C. venosa***	379	29	***S. subnit***	356
13	***H. longit***	40	-33	72	107	***O. hamati***	374	184	***Cryptobi***	351
14	***H. termin***	444	44	-44	47	***C. interm***	372	103	***O. exquis***	346
15	***H. uninot***	53	50	235	69	***C. panthe***	365	162	***O. pseudo***	338
16	***N. camero***	114	35	-3	22	***P. camero***	365	142	***D. volvul***	337
17	***N. cincte***	401	26	-115	66	***A. oricha***	363	148	***H. spinic***	334
18	***N. andrew***	330	168	44	19	***N. andrew***	363	45	***C. fastid***	328
19	***N. champi***	363	-15	-179	75	***C. brahmi***	354	189	***Mitomorp***	328
20	***O. smarag***	6	-64	176	28	***S. punctu***	354	180	***X. globos***	325
21	***P. camero***	308	124	-20	113	***O. orient***	354	127	***S. neglec***	323
22	***P. ceylan***	365	-40	-92	5	***B. campac***	345	155	***M. crenat***	320
23	***P. microp***	-71	411	129	52	***C. subtil***	345	165	***P. parvic***	320
24	***S. guerin***	43	234	7	65	***Adoreste***	330	167	***P. pedest***	319

S. No.	Species	AX1	AX2	AX3	Ranked 1 EIG = 0.46904		Score	Ranked 2 EIG = 0.34707		Score
25	***S. dubiso***	223	59	41	18	***N. cincte***	330	194	***T. lunatu***	319
26	***S. incons***	-64	461	77	3	***A. indicu***	327	129	***A. rustic***	318
27	***S. punctu***	285	51	230	50	***C. bigemi***	325	144	***D. cervin***	317
28	***S. subnit***	354	71	8	43	***C. multig***	324	157	***N. tibial***	314
29	***S. pumila***	-148	356	68	181	***Belonuch***	312	185	***H. brevip***	311
30	***S. striat***	179	45	265	102	***O. expans***	309	191	***Paedurus***	310
31	***T. babult***	-19	-57	153	68	***Anomala2***	308	120	***O. varieg***	310
32	***T. cardon***	440	35	-64	21	***O. smarag***	308	132	***Anomophy***	308
33	***T. champi***	46	297	-8	106	***O. griseo***	308	153	***L. hugeli***	308
34	***T. ochria***	176	95	364	166	***P. obesus***	294	116	***O. ramosu***	308
35	***T. vagabu***	-26	-56	207	183	***C. capita***	289	146	***Exocentr***	307
36	***T. indicu***	97	8	107	139	***C. arcife***	286	96	***O. arbore***	306
37	***C. bicolo***	-55	-31	79	74	***C. rutila***	285	168	***P. ferrug***	304
38	***C. flavom***	114	35	-3	27	***S. incons***	285	187	***L. iyeri***	300
39	***C. angula***	-19	-57	153	112	***O. ochrea***	285	97	***O. atropo***	300
40	***C. chlori***	284	133	111	40	***C. angula***	284	33	***T. cardon***	297
41	***C. plumig***	-19	-57	153	94	***O. amicus***	284	138	***C. simple***	296
42	***C. multig***	91	62	-11	86	***G. miliar***	279	156	***M. unifor***	296
43	***C. erudit***	324	139	3	99	***O. circul***	274	150	***Lamiinae***	293
44	***C. fastid***	38	-61	111	178	***X. smei***	258	104	***O. fascia***	293
45	***C. vigint***	19	328	66	97	***O. atropo***	258	80	***C. sacont***	291
46	***C. interm***	180	144	-21	100	***O. dama***	258	89	***H. gigas***	288
47	***C. grammo***	372	52	-18	124	***R. glaber***	256	101	***O. dynast***	288
48	***C. venosa***	-91	468	121	182	***C. bernha***	254	163	***Ostedes1***	286
49	***C. bigemi***	379	75	259	1	***X. piceou***	253	172	***Ropica1***	281
50	***C. spinol***	325	111	259	95	***O. amplex***	243	122	***O. albopu***	280

S. No.	Species	AX1	AX2	AX3	Ranked 1 EIG = 0.46904		Score	Ranked 2 EIG = 0.34707		Score
51	***C. subtil***	-4	271	0	175	***S. tetras***	240	8	***C. madera***	273
52	***C. viduat***	345	70	275	72	***C. pithec***	236	4	***A. champi***	271
53	***H. pulche***	-19	-57	153	104	***O. fascia***	234	51	***C. spinol***	271
54	***J. chloro***	440	35	-64	143	***D. subfas***	229	55	***J. chloro***	267
55	***J. crassi***	123	267	0	25	***S. guerin***	223	131	***A. induta***	266
56	***L. striol***	80	64	302	160	***O. bilobu***	222	158	***N. fusica***	266
57	***L. parvim***	-4	-1	130	93	***M. consim***	213	121	***O. vaulog***	262
58	***M. melanc***	-19	-57	153	147	***Exocentr***	209	134	***Apomecyn***	258
59	***M. undula***	8	-68	174	110	***O. mopsus***	207	140	***C. indicu***	249
60	***N. bonell***	-6	-52	151	146	***Exocentr***	186	193	***P. bistri***	247
61	***N. saphyr***	440	35	-64	176	***S. barbat***	186	135	***A. oberth***	238
62	***Adoreste***	56	63	226	136	***C. downes***	182	188	***Micropep***	237
63	***Adoreste***	114	35	-3	156	***M. unifor***	181	24	***P. microp***	234
64	***Adoreste***	401	26	-115	134	***Apomecyn***	180	139	***C. arcife***	231
65	***A. oricha***	330	168	44	46	***C. vigint***	180	100	***O. dama***	228
66	***Anomala1***	363	-15	-179	77	***C. indicu***	179	9	***C. extens***	227
67	***Anomala2***	-1	-42	170	115	***O. pactol***	179	176	***S. barbat***	220
68	***C. panthe***	308	124	-20	30	***S. pumila***	179	190	***Pachycor***	207
69	***C. tortri***	365	-40	-92	34	***T. champi***	176	123	***P. pretio***	202
70	***C. unicor***	-71	411	129	81	***C. sarped***	176	177	***T. cribra***	189
71	***C. pithec***	82	176	3	119	***O. troglo***	176	88	***G. ruflco***	181
72	***C. benson***	236	52	102	158	***N. fusica***	173	154	***L. indicu***	180
73	***C. rutila***	-64	461	77	130	***A. holose***	171	170	***P. pyrrhu***	177
74	***C. brahmi***	285	51	230	154	***L. indicu***	170	71	***C. unicor***	176
75	***C. excisu***	354	69	13	159	***O. anogei***	170	145	***D. cinere***	174
76	***C. indicu***	-148	356	68	149	***H. indicu***	163	141	***D. demiss***	169

S. No.	Species	AX1	AX2	AX3	Ranked 1 EIG = 0.46904		Score	Ranked 2 EIG = 0.34707		Score
77	***C. punjab***	179	45	265	168	***P. ferrug***	163	65	***Adoreste***	168
78	***C. sabinu***	-19	-57	153	80	***C. sacont***	162	18	***N. cincte***	168
79	***C. sacont***	448	52	-23	140	***C. indicu***	155	109	***O. luridr***	167
80	***C. sarped***	162	291	-15	172	***Ropica1***	153	178	***X. smei***	162
81	***C. surdus***	176	95	364	144	***D. cervin***	149	183	***C. capita***	159
82	***E. indica***	-19	-57	153	167	***P. pedest***	148	133	***A. histri***	157
83	***G. cyaneu***	-19	-57	153	174	***Sophroni***	143	94	***O. amicus***	157
84	***G. maculo***	-19	-57	153	120	***O. varieg***	142	128	***X. gideon***	151
85	***G. miliar***	72	107	-25	151	***Lamiinae***	140	102	***O. expans***	147
86	***G. opacus***	279	49	3	131	***A. induta***	136	46	***C. vigint***	144
87	***G. ruflco***	-8	66	286	185	***H. brevip***	136	161	***O. indian***	142
88	***H. gigas***	105	181	137	118	***O. tarand***	136	159	***O. anogei***	141
89	***H. mutabi***	-155	288	100	165	***P. parvic***	132	43	***C. multig***	139
90	***H. nigrit***	-19	-57	153	193	***P. bistri***	131	118	***O. tarand***	137
91	***M. brachy***	94	123	-30	179	***X. subscu***	125	40	***C. angula***	133
92	***M. consim***	36	357	106	55	***J. chloro***	123	126	***S. devotu***	133
93	***O. amicus***	213	66	16	164	***Ostedes2***	121	143	***D. subfas***	132
94	***O. amplex***	284	157	413	105	***O. furcil***	118	149	***H. indicu***	131
95	***O. arbore***	243	97	420	16	***H. uninot***	114	1	***X. piceou***	130
96	***O. atropo***	107	306	62	38	***C. bicolo***	114	186	***L. beeson***	128
97	***O. beeson***	258	300	-62	63	***Adoreste***	114	68	***Anomala2***	124
98	***O. circul***	57	-27	96	141	***D. demiss***	113	21	***O. smarag***	124
99	***O. dama***	274	13	299	163	***Ostedes1***	111	106	***O. griseo***	124
100	***O. dynast***	258	228	431	96	***O. arbore***	107	151	***Lamiinae***	123
101	***O. expans***	-79	288	84	88	***G. ruflco***	105	91	***H. nigrit***	123
102	***O. exquis***	309	147	-28	171	***Rondibil***	104	50	***C. bigemi***	111

S. No.	Species	AX1	AX2	AX3	Ranked 1 EIG = 0.46904		Score	Ranked 2 EIG = 0.34707		Score
103	***O. fascia***	-127	346	-1	137	***C. scabra***	102	147	***Exocentr***	109
104	***O. furcil***	234	293	406	133	***A. histri***	101	85	***G. maculo***	107
105	***O. griseo***	118	65	24	109	***O. luridr***	99	3	***A. indicu***	107
106	***O. hamati***	308	124	-20	153	***L. hugeli***	98	160	***O. bilobu***	106
107	***O. hystri***	374	-11	-56	150	***Lamiinae***	98	137	***C. scabra***	100
108	***O. luridr***	-71	411	129	36	***T. vagabu***	97	171	***Rondibil***	99
109	***O. mopsus***	99	167	1	91	***H. nigrit***	94	179	***X. subscu***	98
110	***O. necrop***	207	59	-2	42	***C. plumig***	91	174	***Sophroni***	98
111	***O. ochrea***	-64	461	77	192	***Pinophil***	85	95	***O. amplex***	97
112	***O. orient***	285	51	230	187	***L. iyeri***	84	34	***T. champi***	95
113	***O. pacifi***	354	71	8	122	***O. albopu***	84	81	***C. sarped***	95
114	***O. pactol***	-148	356	68	71	***C. unicor***	82	119	***O. troglo***	95
115	***O. ramosu***	179	45	265	190	***Pachycor***	81	130	***A. holose***	89
116	***O. sterna***	-135	308	47	56	***J. crassi***	80	166	***P. obesus***	89
117	***O. tarand***	440	35	-64	180	***X. globos***	77	192	***Pinophil***	89
118	***O. troglo***	136	137	-13	12	***C. semiru***	75	181	***Belonuch***	83
119	***O. varieg***	176	95	364	85	***G. maculo***	72	49	***C. venosa***	75
120	***O. vaulog***	142	310	153	11	***C. macula***	68	2	***A. iris***	75
121	***O. albopu***	62	262	-14	121	***O. vaulog***	62	175	***S. tetras***	73
122	***P. pretio***	84	280	153	98	***O. beeson***	57	164	***Ostedes2***	71
123	***R. glaber***	-4	202	182	62	***N. saphyr***	56	136	***C. downes***	71
124	***S. sacer***	256	57	-12	177	***T. cribra***	55	113	***O. orient***	71
125	***S. devotu***	-8	66	286	128	***X. gideon***	53	28	***S. punctu***	71
126	***S. neglec***	-76	133	169	15	***H. termin***	53	5	***B. campac***	70
127	***X. gideon***	-179	323	111	132	***Anomophy***	51	52	***C. subtil***	70
128	***A. rustic***	53	151	102	188	***Micropep***	48	75	***C. brahmi***	69

S. No.	Species	AX1	AX2	AX3	Ranked 1 EIG = 0.46904		Score	Ranked 2 EIG = 0.34707		Score
129	***A. holose***	32	318	43	33	***T. cardon***	46	169	***Pothyne***	67
130	***A. induta***	171	89	186	162	***O. pseudo***	46	93	***M. consim***	66
131	***Anomophy***	136	266	45	24	***P. microp***	43	87	***G. opacus***	66
132	***A. histri***	51	308	159	138	***C. simple***	41	125	***S. sacer***	66
133	***Apomecyn***	101	157	221	13	***D. constr***	40	105	***O. furcil***	65
134	***A. oberth***	180	258	101	44	***C. erudit***	38	56	***J. crassi***	64
135	***C. downes***	35	238	40	92	***M. brachy***	36	62	***N. saphyr***	63
136	***C. scabra***	182	71	183	135	***A. oberth***	35	42	***C. plumig***	62
137	***C. simple***	102	100	58	184	***Cryptobi***	33	182	***C. bernha***	60
138	***C. arcife***	41	296	65	129	***A. rustic***	32	25	***S. guerin***	59
139	***C. indicu***	286	231	372	191	***Paedurus***	29	110	***O. mopsus***	59
140	***D. demiss***	155	249	216	142	***D. volvul***	28	124	***R. glaber***	57
141	***D. volvul***	113	169	-24	45	***C. fastid***	19	72	***C. pithec***	52
142	***D. subfas***	28	337	172	194	***T. lunatu***	19	79	***C. sabinu***	52
143	***D. cervin***	229	132	324	170	***P. pyrrhu***	15	47	***C. interm***	52
144	***D. cinere***	149	317	180	9	***C. extens***	9	152	***L. buquet***	52
145	***Exocentr***	-39	174	65	186	***L. beeson***	9	112	***O. ochrea***	51
146	***Exocentr***	186	307	233	59	***M. melanc***	8	74	***C. rutila***	51
147	***H. spinic***	209	109	306	20	***N. champi***	6	27	***S. incons***	51
148	***H. indicu***	-35	334	179	67	***Anomala1***	-1	15	***H. termin***	50
149	***Lamiinae***	163	131	20	155	***M. crenat***	-1	86	***G. miliar***	49
150	***Lamiinae***	98	293	135	123	***P. pretio***	-4	115	***O. pactol***	45
151	***L. buquet***	140	123	203	4	***A. champi***	-4	77	***C. indicu***	45
152	***L. hugeli***	448	52	-23	51	***C. spinol***	-4	30	***S. pumila***	45
153	***L. indicu***	98	308	82	57	***L. striol***	-4	14	***H. longit***	44
154	***M. crenat***	170	180	176	60	***M. undula***	-6	16	***H. uninot***	35

S. No.	Species	AX1	AX2	AX3	Ranked 1 EIG = 0.46904		Score	Ranked 2 EIG = 0.34707		Score
155	***M. unifor***	-1	320	178	87	***G. opacus***	-8	32	***T. babult***	35
156	***N. tibial***	181	296	185	125	***S. sacer***	-8	63	***Adoreste***	35
157	***N. fusica***	-66	314	113	6	***B. kara***	-15	61	***N. bonell***	35
158	***O. anogei***	173	266	123	84	***G. cyaneu***	-19	54	***H. pulche***	35
159	***O. bilobu***	170	141	156	82	***C. surdus***	-19	38	***C. bicolo***	35
160	***O. indian***	222	106	354	39	***C. flavom***	-19	7	***B. xantha***	35
161	***O. pseudo***	-93	142	-15	31	***S. striat***	-19	117	***O. sterna***	35
162	***Ostedes1***	46	338	267	83	***E. indica***	-19	17	***N. camero***	26
163	***Ostedes2***	111	286	204	78	***C. punjab***	-19	64	***Adoreste***	26
164	***P. parvic***	121	71	137	90	***H. mutabi***	-19	99	***O. circul***	13
165	***P. obesus***	132	320	76	53	***C. viduat***	-19	36	***T. vagabu***	8
166	***P. pedest***	294	89	324	41	***C. chlori***	-19	11	***C. macula***	0
167	***P. ferrug***	148	319	-14	58	***L. parvim***	-19	57	***L. striol***	-1
168	***Pothyne***	163	304	244	10	***C. westwo***	-23	107	***O. hamati***	-11
169	***P. pyrrhu***	-43	67	81	35	***T. ochria***	-26	19	***N. andrew***	-15
170	***Rondibil***	15	177	160	148	***H. spinic***	-35	66	***A. oricha***	-15
171	***Ropica1***	104	99	215	145	***D. cinere***	-39	10	***C. westwo***	-27
172	***Ropica2***	153	281	149	169	***Pothyne***	-43	98	***O. beeson***	-27
173	***Sophroni***	-101	358	60	8	***C. madera***	-49	37	***T. indicu***	-31
174	***S. tetras***	143	98	249	37	***T. indicu***	-55	13	***D. constr***	-33
175	***S. barbat***	240	73	-17	73	***C. benson***	-64	6	***B. kara***	-38
176	***T. cribra***	186	220	152	111	***O. necrop***	-64	69	***C. panthe***	-40
177	***X. smei***	55	189	256	26	***S. dubiso***	-64	22	***P. camero***	-40
178	***X. subscu***	258	162	330	157	***N. tibial***	-66	67	***Anomala1***	-42
179	***X. globos***	125	98	151	70	***C. tortri***	-71	60	***M. undula***	-52
180	***Belonuch***	77	325	114	23	***P. ceylan***	-71	35	***T. ochria***	-56

S. No.	Species	AX1	AX2	AX3	Ranked 1 EIG = 0.46904		Score	Ranked 2 EIG = 0.34707		Score
181	***C. bernha***	312	83	330	108	***O. hystri***	-71	90	***H. mutabi***	-57
182	***C. capita***	254	60	252	126	***S. devotu***	-76	84	***G. cyaneu***	-57
183	***Cryptobi***	289	159	290	101	***O. dynast***	-79	39	***C. flavom***	-57
184	***H. brevip***	33	351	244	189	***Mitomorp***	-85	58	***L. parvim***	-57
185	***L. beeson***	136	311	74	48	***C. grammo***	-91	53	***C. viduat***	-57
186	***L. iyeri***	9	128	191	161	***O. indian***	-93	78	***C. punjab***	-57
187	***Micropep***	84	300	191	173	***Ropica2***	-101	82	***C. surdus***	-57
188	***Mitomorp***	48	237	233	103	***O. exquis***	-127	41	***C. chlori***	-57
189	***Pachycor***	-85	328	70	116	***O. ramosu***	-135	31	***S. striat***	-57
190	***Paedurus***	81	207	6	114	***O. pacifi***	-148	83	***E. indica***	-57
191	***Pinophil***	29	310	181	76	***C. excisu***	-148	44	***C. erudit***	-61
192	***P. bistri***	85	89	67	29	***S. subnit***	-148	12	***C. semiru***	-63
193	***T. lunatu***	131	247	24	89	***H. gigas***	-155	20	***N. champi***	-64
194	***X. piceou***	19	319	191	127	***S. neglec***	-179	59	***M. melanc***	-68

Appendix 4 Habitat breadth (H') of beetle species (Insecta: Coleoptera) recorded from Simbalbara Wildlife Sanctuary, Himachal Pradesh

S.No.	Species	Habitat Breadth (H')[1] Min. 0 - Max. 13	S.No.	Species	Habitat Breadth (H')[1] Min. 0 - Max. 13
CARABIDAE (GROUND BEETLES)					
1	*Agonotrechus iris*	5.08	19	*Neoblemus championi*	6.03
2	*Asaphidion indicum*	4.79	20	*Omophron smaragdus*	7.16
3	*Axonya championi*	7.55	21	*Perileptus cameroni*	7.28
4	*Bembidion compactum*	6.79	22	*Perileptus ceylanicus*	7.14
5	*Bembidion kara*	7.09	23	*Perileptus microps*	5.72
6	*Bembidion xanthacrum*	7.18	24	*Scapterus guerini*	5.52
7	*Calosoma maderae*	7.14	25	*Scarites dubisosus*	5.11
8	*Clivina extensicollis*	7.55	26	*Scarites inconspicuus*	6.12
9	*Clivina westwoodi*	6.25	27	*Scarites punctum*	5.43
10	*Coryza maculata*	5.5	28	*Scarites subnitens*	7.23
11	*Coryza semirubra*	5.25	29	*Siagona pumila*	6.54
12	*Dyschirius constrictus*	5.08	30	*Sparostes striatulus*	7.13
13	*Hexagonia longithorax*	7.55	31	*Tachys babulti*	7.83
14	*Hexagonia terminata*	6.79	32	*Tachys cardoni*	7.31
15	*Hexagonia uninotata*	7.09	33	*Tachys championi*	7.13
16	*Nebria cameroni*	7.18	34	*Tachys ochrias*	7.13
17	*Nebria cinctella*	7.14	35	*Tachys vagabundus*	7.13
18	*Neoblemus andrewesi*	6.78	36	*Trechus indicus*	7.31
CICINDELIDAE (TIGER BEETLES)					
1	*Calochroa bicolor*	3.33	3	*Calochroa flavomaculata*	5.67
2	*Cosmodela intermedia*	4.91	4	*Calomera angulata*	2.51

S.No.	Species	Habitat Breadth (H')[1] Min. 0 - Max. 13	S.No.	Species	Habitat Breadth (H')[1] Min. 0 - Max. 13
5	*Calomera chloris*	2.22	16	*Cylindera (Eugrapha) venosa*	5.50
6	*Calomera plumigera*	5.88	17	*Cylindera (Ifasina) bigemina*	5.71
7	*Cicindela (Spilodia) multiguttata*	1.31	18	*Cylindera (Ifasina) spinolae*	1.77
8	*Cicindela erudita*	3.60	19	*Cylindera (Ifasina) subtilesignata*	6.60
9	*Cicindela fastidiosa*	1.20	20	*Cylindera (Ifasina) viduata*	1.90
10	*Cicindela vigintiguttata*	3.11	21	*Heptodonta pulchella*	4.78
11	*Jansenia crassipalpis*	1.13	22	*Jansenia chloropleura*	2.06
12	*Lophyra (Spilodia) striolata*	0.00	23	*Myriochile (Myriochile) undulata*	1.11
13	*Lophyra parvimaculata*	1.54	24	*Neocollyris (Neocollyris) bonellii*	1.67
14	*Myriochile (Myriochile) melancholica*	0.00	25	*Neocollyris (Neocollyris) saphyrina*	1.43
15	*Cylindera (Eugrapha) grammophora*	6.66			
SCARABAEIDAE (DUNG BEETLES)					
1	*Adoretus sp.1*	8.08	14	*Copris excisus*	9.79
2	*Adoretus sp.2*	7.79	15	*Copris indicus*	10.09
3	*Adoretus sp.3*	10.55	16	*Copris punjabensis*	10.18
4	*Agerstrata orichalcea*	9.79	17	*Copris sabinus*	10.14
5	*Anomala sp.1*	10.09	18	*Copris sacontala*	9.78
6	*Anomala sp.2*	10.18	19	*Copris sarpedon*	9.03
7	*Caccobius pantherinus*	10.14	20	*Copris surdus*	10.16
8	*Caccobius tortricornis*	10.55	21	*Episcapha indica*	10.28
9	*Caccobius unicornis*	9.25	22	*Gymnopleurus cyaneus*	10.14
10	*Catharsius pithecius*	8.5	23	*Gymnopleurus maculosus*	8.72
11	*Cetonia bensoni*	8.25	24	*Gymnopleurus miliaris*	8.52
12	*Cetonia rutilans*	8.08	25	*Gymnopleurus opacus*	8.11
13	*Copris brahminus*	10.55	26	*Gymnopleurus ruflcornis*	9.12

S.No.	Species	Habitat Breadth (H')[1] Min. 0 - Max. 13	S.No.	Species	Habitat Breadth (H')[1] Min. 0 - Max. 13
27	*Heliocopris gigas*	8.43	47	*Onthophagus luridripennis*	12.23
28	*Heterorrhina mutabilis*	10.23	48	*Onthophagus mopsus*	11.54
29	*Heterorrhina nigritarsis*	9.54	49	*Onthophagus necrophagus*	12.13
30	*Megalodacne brachycera*	10.13	50	*Onthophagus ochreatus*	12.83
31	*Megalodacne consimilis*	10.83	51	*Onthophagus orientalis*	12.31
32	*Onthophagus amicus*	10.31	52	*Onthophagus pacificus*	12.13
33	*Onthophagus amplexus*	10.13	53	*Onthophagus pactolus*	12.13
34	*Onthophagus arboreus*	12.09	54	*Onthophagus ramosus*	12.13
35	*Onthophagus atropolitus*	12.18	55	*Onthophagus sternalis*	12.31
36	*Onthophagus beesoni*	12.14	56	*Onthophagus tarandus*	12.62
37	*Onthophagus circulifer*	11.78	57	*Onthophagus troglodyta*	10.71
38	*Onthophagus dama*	11.03	58	*Onthophagus variegatus*	11.49
39	*Onthophagus dynastoides*	12.16	59	*Onthophagus vaulogeri*	12.31
40	*Onthophagus expansicornis*	12.28	60	*Oxycetonia albopunctata*	12.13
41	*Onthophagus exquisitus*	12.14	61	*Protaetia pretiosa*	12.62
42	*Onthophagus fasciatus*	10.72	62	*Rhomborrhina glaberrima*	8.74
43	*Onthophagus furcillifer*	10.52	63	*Scarabreus sacer*	12.41
44	*Onthophagus griseosotosus*	10.11	64	*Scarabus devotus*	10.15
45	*Onthophagus hamaticeps*	11.12	65	*Sisyphus neglectus*	10.65
46	*Onthophagus hystrix*	10.43	66	*Xylotrupes gideon*	9.8
STAPHYLINIDAE (ROVE BEETLES)					
1	*Belonuchus sp.*	6.71	5	*Holosus brevipennis*	8.62
2	*Cryptobium bernhaueri*	7.49	6	*Lisipinus beesoni*	4.74
3	*Cryptobium capitale*	8.31	7	*Lisipinus iyeri*	8.41
4	*Cryptobium sp.*	8.13	8	*Micropeplus sp.*	6.15

S.No.	Species	Habitat Breadth (H')[1] Min. 0 - Max. 13	S.No.	Species	Habitat Breadth (H')[1] Min. 0 - Max. 13
9	*Mitomorphus sp.*	6.65	13	*Pseudolispinoides bistriatus*	7.05
10	*Pachycorynus sp.*	5.8	14	*Trogophloeus (Thinodromus) lunatus*	6.94
11	*Paedurus sp.*	5.21	15	*Xantholineus piceous*	6.94
12	*Pinophilus sp.*	5.21			
CERAMBYCIDAE (BORERS)					
1	*Acalolepta rusticatrix*	7.08	20	*Hoplocerambyx spinicornis*	9.16
2	*Aeolesthes holosericea*	6.79	21	*Hypoeschrus indicus*	9.28
3	*Aeolesthes induta*	9.55	22	*Lamiinae sp.1*	9.14
4	*Anomophysis sp.*	8.79	23	*Lamiinae sp.2*	7.72
5	*Apomecyna histrio*	9.09	24	*Lophosternus buqueti*	7.52
6	*Apomecynini*	9.18	25	*Lophosternus hugelii*	7.11
7	*Arhopalus oberthueri*	9.14	26	*Lophosternus indicus*	8.12
8	*Cantharocnemis downesi*	9.55	27	*Macrotoma crenata*	7.08
9	*Celosterna scabrator*	8.25	28	*Metamecyna uniformis*	11.62
10	*Ceresium simplex*	7.5	29	*Niphona (Nothopeus) tibialis*	7.74
11	*Chlorophorus (Caloclytus) arciferus*	7.25	30	*Niphona fusicatrix*	11.41
12	*Clyzomedus indicus*	7.08	31	*Olenecamptus anogeissi*	9.15
13	*Derolus demissus*	9.55	32	*Olenecamptus bilobus*	9.65
14	*Derolus volvulus*	8.79	33	*Olenecamptus indianus*	8.8
15	*Desisa subfasciata*	9.09	34	*Olenecamptus pseudostrigosus*	8.21
16	*Dihammus cervinus*	9.18	35	*Ostedes sp.1*	8.21
17	*Diorthus cinereus*	9.14	36	*Ostedes sp.2*	10.05
18	*Exocentrus sp.1*	8.78	37	*Pachydissus parvicollis*	9.94
19	*Exocentrus sp.2*	8.03	38	*Plocaederus obesus*	9.94
39	*Plocaederus pedestris*	9.94	46	*Sophronica sp.*	11.78

S.No.	Species	Habitat Breadth (H')[1] Min. 0 - Max. 13	S.No.	Species	Habitat Breadth (H')[1] Min. 0 - Max. 13
40	*Plocederus ferrugineus*	9.94	47	*Stibara (Polyzonus) tetraspilota*	11.51
41	*Pothyne sp.*	9.94	48	*Stromatium barbatum*	9.39
42	*Pyrestes pyrrhus*	11.46	49	*Trinophylum cribratum*	9.31
43	*Rondibilis sp.*	11.51	50	*Xylotrechus smei*	10.34
44	*Ropica sp.1*	10.27	51	*Xylotrechus subscutellatus*	10.72
45	*Ropica sp.2*	8.13	52	*Xystrocera globosa*	9.53

[1] **H'- Habitat breadth is the function of quantification of Bulla's diversity index**

Appendix 5 Indicator values (IndVal) for the beetle species recorded from Simbalbara Wildlife Sanctuary, Himachal Pradesh

S.No.	Species	Observed Indicator value (IV)	IV* from randomized groups		P**
			Mean	S. Dev	
CARABIDAE (GROUND BEETLES)					
1.	*Agonotrechus iris*	14.3	11.8	5.65	0.1401
2.	*Asaphidion indicum*	20	12.5	4.92	0.0991
3.	*Axonya championi*	44.4	11.9	5.08	**0.001**
4.	*Bembidion compactum*	24	12.7	6.35	0.0831
5.	*Bembidion kara*	11.8	12.7	5.24	0.5425
6.	*Bembidion xanthacrum*	60	12.1	7.13	**0.003**
7.	*Calosoma maderae*	39.7	13.4	4.79	**0.001**
8.	*Clivina extensicollis*	21.2	12.3	6.02	0.0991
9.	*Clivina westwoodi*	6.3	12.2	5.28	0.9129
10.	*Coryza maculata*	8.7	12.1	4.41	0.7828
11.	*Coryza semirubra*	10.4	12.2	5.71	0.5646
12.	*Dyschirius constrictus*	7.7	11.9	5.2	0.7467
13.	*Hexagonia longithorax*	60	10.5	7.83	**0.003**
14.	*Hexagonia terminata*	25.3	12.5	7.14	0.0841
15.	*Hexagonia uninotata*	100	12.9	7.55	**0.001**
16.	*Nebria cameroni*	100	11.4	6.79	**0.001**
17.	*Nebria cinctella*	35	11.8	5.94	0.007
18.	*Neoblemus andrewesi*	80	12.2	7.09	**0.001**
19.	*Neoblemus championi*	6.9	12.5	5.72	0.951
20.	*Omophron smaragdus*	30	11.4	6.44	0.042
21.	*Perileptus cameroni*	100	13.2	7.18	**0.001**
22.	*Perileptus ceylanicus*	100	11.6	7.14	**0.001**
23.	*Perileptus microps*	26.8	12.6	3.74	**0.004**
24.	*Scapterus guerini*	52.1	13.3	6.12	**0.002**
25.	*Scarites dubisosus*	48.8	13.1	7.31	**0.003**
26.	*Scarites inconspicuus*	15.4	11.3	6.15	0.2853
27.	*Scarites punctum*	27.1	12.7	4.21	0.006
28.	*Scarites subnitens*	36	12.3	5.94	0.007
29.	*Siagona pumila*	24	12.7	6.47	0.0861
30.	*Sparostes striatulus*	5.9	12.4	5.56	0.994
31.	*Tachys babulti*	60	12.1	7.13	**0.003**
32.	*Tachys cardoni*	22.2	12.2	4.36	**0.033**
33.	*Tachys championi*	14.3	11.5	7.24	0.3473
34.	*Tachys ochrias*	9.1	12.1	5.59	0.7728
35.	*Tachys vagabundus*	12.5	12.9	6.34	0.5816
36.	*Trechus indicus*	14.3	12.2	6.16	0.2883
CICINDELIDAE (TIGER BEETLES)					
37.	*Calochroa bicolor*	100	12.9	7.55	**0.001**
38.	*Calochroa flavomaculata*	5.9	12.4	5.56	0.994
39.	*Calomera angulata*	100	12.9	7.55	**0.001**

S.No.	Species	Observed Indicator value (IV)	IV* from randomized groups		P**
			Mean	S. Dev	
40.	*Calomera chloris*	5.9	12.4	5.56	0.994
41.	*Calomera plumigera*	72.2	12.4	6.25	**0.001**
42.	*Cicindela (Spilodia) multiguttata*	26.1	11.7	5.95	0.0641
43.	*Cicindela erudita*	8.3	12.7	6.33	0.8879
44.	*Cicindela fastidiosa*	56.9	12.3	5.5	**0.001**
45.	*Cicindela vigintiguttata*	18.5	12.8	4.08	0.0961
46.	*Cosmodela intermedia*	48.1	13.1	5.25	**0.001**
47.	*Cylindera (Eugrapha) grammophora*	50.3	12.6	7.41	**0.004**
48.	*Cylindera (Eugrapha) venosa*	14.3	11.8	5.65	0.1401
49.	*Cylindera (Ifasina) bigemina*	19.6	12.6	4.77	0.1071
50.	*Cylindera (Ifasina) spinolae*	44.4	11.9	5.08	**0.001**
51.	*Cylindera (Ifasina) subtilesignata*	24	12.7	6.35	0.0831
52.	*Cylindera (Ifasina) viduata*	5.9	12.4	5.56	0.994
53.	*Heptodonta pulchella*	60	12.1	7.13	**0.003**
54.	*Jansenia chloropleura*	15	13.6	5.26	0.3994
55.	*Jansenia crassipalpis*	20	12.3	7.39	0.2332
56.	*Lophyra (Spilodia) striolata*	10.8	12.7	4.79	0.6647
57.	*Lophyra parvimaculata*	100	13.2	7.18	**0.001**
58.	*Myriochile (Myriochile) melancholica*	6.9	12.4	5.68	0.9489
59.	*Myriochile (Myriochile) undulata*	9.4	12.6	5.4	0.7077
60.	*Neocollyris (Neocollyris) bonellii*	60	12.1	7.13	**0.003**
61.	*Neocollyris (Neocollyris) saphyrina*	100	11.4	6.79	**0.001**
SCARABAEIDAE (DUNG BEETLES)					
62.	*Adoretus sp.1*	20.7	12.5	5.58	0.0741
63.	*Adoretus sp.2*	22.9	13.1	6.93	0.0851
64.	*Adoretus sp.3*	35	11.8	5.94	0.007
65.	*Agerstrata orichalcea*	80	12.2	7.09	**0.001**
66.	*Anomala sp.1*	6.5	12.8	5.55	0.985
67.	*Anomala sp.2*	30	11.4	6.44	0.042
68.	*Caccobius pantherinus*	5.9	12.4	5.56	0.994
69.	*Caccobius tortricornis*	100	11.6	7.14	**0.001**
70.	*Caccobius unicornis*	18.5	12.9	3.9	0.0851
71.	*Catharsius pithecius*	43.9	12.6	5.43	**0.002**
72.	*Cetonia bensoni*	23.1	11.4	6.13	0.0641
73.	*Cetonia rutilans*	15.4	11.3	6.15	0.2853
74.	*Copris brahminus*	32	11.1	5.39	0.015
75.	*Copris excisus*	36	12.3	5.94	0.007
76.	*Copris indicus*	24	12.7	6.47	0.0861
77.	*Copris punjabensis*	5.9	12.4	5.56	0.994
78.	*Copris sabinus*	60	11.4	7.62	**0.003**
79.	*Copris sacontala*	10.5	13.8	5.75	0.6777
80.	*Copris sarpedon*	14.3	11.5	7.24	0.3473
81.	*Copris surdus*	5.9	12.4	5.56	0.994
82.	*Episcapha indica*	5.9	12.4	5.56	0.994

S.No.	Species	Observed Indicator value (IV)	IV* from randomized groups		P**
			Mean	S. Dev	
83.	*Gymnopleurus cyaneus*	5.9	12.4	5.56	0.994
84.	*Gymnopleurus maculosus*	17.5	12	4.58	0.1151
85.	*Gymnopleurus miliaris*	45	11.7	7.46	0.008
86.	*Gymnopleurus opacus*	40	13.9	7.66	0.0801
87.	*Gymnopleurus ruflcornis*	17.1	12.5	5.31	0.1892
88.	*Heliocopris gigas*	40.7	11.7	7.78	0.013
89.	*Heterorrhina mutabilis*	5.9	12.4	5.56	0.994
90.	*Heterorrhina nigritarsis*	16.6	12	4.67	0.1562
91.	*Megalodacne brachycera*	14.4	12.1	5.68	0.3213
92.	*Megalodacne consimilis*	48.8	12.4	5.71	**0.003**
93.	*Onthophagus amicus*	29.2	11.7	6.34	0.029
94.	*Onthophagus amplexus*	23.1	10.9	7.69	0.1652
95.	*Onthophagus arboreus*	17.1	12.2	5.07	0.1892
96.	*Onthophagus atropolitus*	26.7	12.7	5.53	0.032
97.	*Onthophagus beesoni*	40	18.2	5.87	0.0681
98.	*Onthophagus circulifer*	20	11.2	7.71	0.3203
99.	*Onthophagus dama*	50.9	12	6.78	**0.001**
100.	*Onthophagus dynastoides*	13.3	12.6	6.33	0.4454
101.	*Onthophagus expansicornis*	13.3	12	3.53	0.3814
102.	*Onthophagus exquisitus*	19.4	12	4.97	0.1081
103.	*Onthophagus fasciatus*	9.1	10.8	5.1	0.6312
104.	*Onthophagus furcillifer*	8.9	12.8	5.64	0.7968
105.	*Onthophagus griseosotosus*	30	11.4	6.44	0.042
106.	*Onthophagus hamaticeps*	100	13.1	7.28	**0.001**
107.	*Onthophagus hystrix*	16	11.8	5.26	0.1582
108.	*Onthophagus luridripennis*	25.5	13.1	4.13	0.011
109.	*Onthophagus mopsus*	58.1	13.6	6.54	**0.002**
110.	*Onthophagus necrophagus*	23.1	12.1	6.27	0.0621
111.	*Onthophagus ochreatus*	15.4	11.3	6.15	0.2853
112.	*Onthophagus orientalis*	27.1	12.7	4.21	0.006
113.	*Onthophagus pacificus*	36	12.3	5.94	0.007
114.	*Onthophagus pactolus*	24	12.7	6.47	0.0861
115.	*Onthophagus ramosus*	32.7	12	6.72	0.029
116.	*Onthophagus sternalis*	10	12.1	5.21	0.5475
117.	*Onthophagus tarandus*	9.3	12.7	5.41	0.6897
118.	*Onthophagus troglodyta*	14.3	11.5	7.24	0.3473
119.	*Onthophagus variegatus*	7.1	12.4	4.91	0.8849
120.	*Onthophagus vaulogeri*	19.2	12.5	5.42	0.1471
121.	*Oxycetonia albopunctata*	12.6	11.8	4.65	0.5485
122.	*Protaetia pretiosa*	34.3	11.8	5.15	**0.004**
123.	*Rhomborrhina glaberrima*	47.6	12.6	7.51	0.008
124.	*Scarabreus sacer*	40	13.9	7.66	0.0801
125.	*Scarabus devotus*	12.7	12.2	5.93	0.4214
126.	*Sisyphus neglectus*	42	12.2	7.51	0.014

S.No.	Species	Observed Indicator value (IV)	IV* from randomized groups		P**
			Mean	S. Dev	
127.	*Xylotrupes gideon*	19.1	13	5.64	0.1942
STAPHYLINIDAE (ROVE BEETLES)					
128.	*Belonuchus sp.*	48.8	13.1	7.31	**0.003**
129.	*Cryptobium bernhaueri*	15	12	5.32	0.3253
130.	*Cryptobium capitale*	100	11.6	7.14	**0.001**
131.	*Cryptobium sp.*	24	11.7	5.44	0.038
132.	*Holosus brevipennis*	8	11.7	5.3	0.8709
133.	*Lisipinus beesoni*	16	11.8	5.17	0.1421
134.	*Lisipinus iyeri*	10	11.8	5.75	0.7518
135.	*Micropeplus sp.*	7.3	11.7	5.53	0.988
136.	*Mitomorphus sp.*	31.6	13.1	4.8	**0.005**
137.	*Pachycorynus sp.*	12	12.1	5.06	0.4965
138.	*Paedurus sp.*	43.1	12.6	6.49	**0.003**
139.	*Pinophilus sp.*	8	11.6	5	0.8899
140.	*Pseudolispinoides bistriatus*	10.4	12.1	4.35	0.6036
141.	*Trogophloeus (Thinodromus)*	15.4	12	3.96	0.1742
142.	*Xantholineus piceous*	59.4	11.2	7.23	**0.002**
CERAMBYCIDAE (BORERS)					
143.	*Acalolepta rusticatrix*	18	12.5	4.89	0.1391
144.	*Aeolesthes holosericea*	17.1	12.7	4.82	0.1912
145.	*Aeolesthes induta*	12.3	12.9	3.38	0.5866
146.	*Anomophysis sp.*	27.3	12.1	6.32	0.043
147.	*Apomecyna histrio*	10.3	12.2	4.12	0.5756
148.	*Apomecynini*	14.3	12.2	4.33	0.2513
149.	*Arhopalus oberthueri*	20	12.5	4.97	0.0961
150.	*Cantharocnemis downesi*	36.9	11.9	5.65	**0.004**
151.	*Celosterna scabrator*	8.6	11.9	4.41	0.8869
152.	*Ceresium simplex*	11.9	13	5.28	0.5025
153.	*Chlorophorus (Caloclytus) arciferus*	36.4	12.1	6.05	0.006
154.	*Clyzomedus indicus*	8	11.6	5.35	0.8128
155.	*Derolus demissus*	5	12.3	5.73	0.995
156.	*Derolus volvulus*	17.1	11.5	5.28	0.1832
157.	*Desisa subfasciata*	16.4	12	5.75	0.2222
158.	*Dihammus cervinus*	8.6	12.3	4.86	0.7497
159.	*Diorthus cinereus*	20	11.8	5.67	0.1411
160.	*Exocentrus sp.1*	7.7	12	4.03	0.8839
161.	*Exocentrus sp.2*	24.3	12.3	4.95	0.042
162.	*Hoplocerambyx spinicornis*	18	12.5	4.88	0.1391
163.	*Hypoeschrus indicus*	11.4	11.2	5.3	0.4224
164.	*Lamiinae sp.1*	15.5	12.5	4.52	0.2232
165.	*Lamiinae sp.2*	25.7	12.1	5.98	0.0801
166.	*Lophosternus buqueti*	60	11.4	7.62	**0.003**
167.	*Lophosternus hugelii*	20.4	12.8	3.61	0.0541

S.No.	Species	Observed Indicator value (IV)	IV* from randomized groups		P**
			Mean	S. Dev	
168.	*Lophosternus indicus*	21.8	13.1	4.51	0.0561
169.	*Macrotoma crenata*	13.8	12.5	5.86	0.3253
170.	*Metamecyna uniformis*	16	11.8	5.65	0.2002
171.	*Niphona (Nothopeus) tibialis*	13.3	12.3	5.88	0.4464
172.	*Niphona fusicatrix*	33.3	12.2	6.27	0.009
173.	*Olenecamptus anogeissi*	17.1	12	5.58	0.2633
174.	*Olenecamptus bilobus*	48.8	13.1	7.31	**0.003**
175.	*Olenecamptus indianus*	18.7	12	6.37	0.1071
176.	*Olenecamptus pseudostrigosus*	48.6	12.3	6.03	**0.001**
177.	*Ostedes sp.1*	11.5	12.3	4.73	0.5185
178.	*Ostedes sp.2*	5.9	12.1	4.58	0.995
179.	*Pachydissus parvicollis*	6.3	12.2	5.64	0.979
180.	*Plocaederus obesus*	43.1	11.8	5.72	0.001
181.	*Plocaederus pedestris*	17.1	12	5.56	0.1512
182.	*Plocederus ferrugineus*	14.9	12.4	3.67	0.2412
183.	*Pothyne sp.*	15	11.4	5.04	0.3303
184.	*Pyrestes pyrrhus*	60	12.1	7.13	**0.003**
185.	*Rondibilis sp.*	29.6	12.4	5.31	0.02
186.	*Ropica sp.1*	15	11.6	5.02	0.2192
187.	*Ropica sp.2*	21.8	11.8	6.24	0.0961
188.	*Sophronica sp.*	15.2	12.4	4.37	0.2202
189.	*Stibara (Polyzonus) tetraspilota*	13	12	4.43	0.4064
190.	*Stromatium barbatum*	15.6	11.9	4.61	0.1592
191.	*Trinophylum cribratum*	42.4	12.9	5.52	**0.001**
192.	*Xylotrechus smei*	40.9	11.6	5.11	**0.001**
193.	*Xylotrechus subscutellatus*	8.9	12	4.8	0.7628
194.	*Xystrocera globosa*	73.3	13.1	7.16	**0.001**

p*- proportion of randomized trials with indicator value equal to or exceeding the observed indicator value. p = (1 + number of runs ≥ observed)/ (1 + number of randomized runs)
****Monte Carlo test of significance of observed maximum indicator value for species at 999 permutations**

Appendix 6 List of publications from the present research work

A. Research papers

- **Bhargav V**, Uniyal VP, Sivakumar K (In press) Distinctive patterns in habitat association and distribution of tiger beetles in the Shivalik landscape of north western India. Journal of Insect Conservation (DOI 10.1007/s10841-008-9193-y, Published online: 18 November 2008).

- Bhardwaj M, **Bhargav VK,** Uniyal VP (2008) Occurrence of tiger beetles (Cicindelidae: Coleoptera) in Chilla Wildlife Sanctuary, Rajaji National Park, Uttarakhand. Indian Forester 134(12): 1636-1645.

- **Bhargav VK**, Uniyal VP (2008) Communal roosting of tiger beetles (Cicindelidae: Coleoptera) in the Shivalik Hills, Himachal Pradesh, India. Cicindela 40(1-2): 1-12.

- Uniyal VP, **Bhargava V** (2007) Assessment of butterflies in Bir Shikargah Wildlife Sanctuary, Haryana. Tiger Paper 34(3) 13-15.

- **Bhargava VK**, Uniyal VP, Kittur S, Sivakumar K (2007) Bird records from Simbalbara Wildlife Sanctuary, Himachal Pradesh. Indian Forester 133(10): 1411- 1418.

B. Field guide

- Uniyal VP, **Bhargava V** (2007) Tiger Beetles: A field study in the Shivaliks of Himachal Pradesh. Wildlife Institute of India, Dehradun.