

**DIVERSITY AND ASSEMBLAGES OF CANOPY AND GROUND LAYER
BEETLES IN THE FORESTS OF CHITWAN NATIONAL PARK, NEPAL**



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Science in Zoology with special paper Entomology**

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Kirtipur, Kathmandu

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DECLARATION

I hereby declare that the work presented in this thesis entitled “**Diversity and Assemblages of Canopy and Ground Layer Beetles in the Forests of Chitwan National Park, Nepal**” has been done by myself, and has not been submitted elsewhere for the award of any degree. All the sources of information have been specifically acknowledged by reference to the author (s) or institution (s).

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LIST OF ABBREVIATIONS

ABE	- Abundance Based Estimation
ACE	- Abundance-based Coverage Estimator
ANOSIM	- Analysis of Similarity
CNP	- Chitwan National Park
DBH	- Diameter at Breast Height
DC	- <i>Dalbergia</i> Canopy
DG	- <i>Dalbergia</i> Ground
GPS	- Global Positioning System
HMG	- His Majesty of Government
IBE	- Incidence-based Coverage Estimator
IBE	- Incidence Based Estimation
MSSN	- Morpho-Species Serial Number
NMDS	- Non-Metric Multidimensional scaling
PAST	- PAleontological STatistics
PERMANOVA	- Permutational Multivariate Analysis of Variance
SC	- <i>Shorea</i> Canopy
SG	- <i>Shorea</i> Ground
SIMPER	- Similarity Percenatages

ABSTRACT

Beetle assemblages of tropical forest in Nepal are still largely unexplored and the biodiversity they harbor is still poorly known. This study investigated the beetle diversity and its assemblages in canopy and ground layer of *Shorea robusta* forest and *Dalbergia sissoo* forest. Thirty trees were selected purposively from four management sectors of Chitwan National park where 4 trees of *Shorea robusta* and 4 trees of *Dalbergia sissoo* were selected from each management sector. Canopy and ground layer beetles were sampled by using flight intercept trap and pitfall trap respectively. Thirty two flight intercept traps (16 in *Shorea* forest and 16 in *Dalbergia* forest) were hanged in canopy layer and 32 pitfall traps were installed into the ground within 1 m radius of the same tree where the flight intercept traps were hanged in the branches. A total of 25258 beetles belonging to 25 families (142 morphospecies) were recorded from 6 sampling periods between April 5 and July 31, 2016. Species richness was found high in canopy layer compared to ground layer where abundance was high in ground layer in both types of forest. Scarabaeidae was the most prominent family in both ground and canopy layer. Beetle assemblages showed that the herbivore beetles dominated the canopy layer followed by predators in canopy layer in term of both species richness and abundance. However, saprophages were dominant followed by predator in the ground layer. The effects of environmental variables (soil properties, tree properties and climatic factors) had varying effects on the beetle species richness and abundance and their assemblages. Variation of beetles in different types of forest and different layer in different time suggest that the distribution of beetles is structured in time and space.

1 INTRODUCTION

1.1 Beetles

As with all insects, beetles possess a three-part body consisting of the head, thorax, and abdomen. All beetles share a select suite of physical attributes, the most conspicuous of which are hardened forewings, or elytra (singular elytron) usually meeting in a straight line down the middle of the back and covering the hind wings (Triplehorn *et al.*, 2005). Depending on the species, elytra can help stabilize beetles in flight, protect their delicate hind wings and internal organs, conserve precious bodily fluids, capture bubbles of air underwater, and insulate them from extreme temperatures (Bouchard, 2014).

Coleoptera (beetle) is found in almost all types of habitats except strictly marine environment (Kålås *et al.*, 2010). The order Coleoptera includes more species than any other orders, constituting almost 25% of all known life-forms (Rosenzweig, 1995; Hunt *et al.*, 2007; Resh and Cardé, 2009). Coleoptera are currently the most species-rich group of organisms on this planet with approximately 360,000 described species (Bouchard and Grebennikov, 2009) and many millions await discovery. Bouchard *et al.* (2011) recognized 24 super families, 211 families, 541 subfamilies, 1663 tribes and 740 sub tribes of beetles worldwide. Thapa (2015) listed 63 families from Nepal. There are 4 coleopteran suborders (Archostemata, Adephaga, Myxophaga and Polyphaga) of which Adephaga and Polyphaga are the most diverse (Triplehorn *et al.*, 2005). Family carabidae (ground beetles) and Dytiscidae (predaceous diving beetle) are common families on Adephaga while Family Hydrophilidae (water scavenger beetles), Histeridae (hister beetles), Silphidae (carrion beetles), Staphylinidae (rove beetles), Lucanidae (stag beetles), Scarabeidae (scarabs, june bugs, dung beetles etc.), Buprestidae (metallic wood boring beetles), Elateridae (click beetles), Lampyridae (fireflies), Cantharidae (soldier beetles), Dermestidae (dermestids, skin beetles), Anobiidae (deathwatch beetles), Cleridae (checkered beetles), Cucujidae (flat bark beetles), Coccinellidae (ladybird beetles), Tenebrionidae (darkling beetles), Meloidae (blister beetles), Cerambycidae (long-horned beetles), Chrysomelidae (leaf beetles), Curculionidae (weevils), Scolytidae (bark beetles) are common families on Polyphaga. Beetle have diverse forms and function, they can be forest pests (e.g. Scolytidae, Curculionidae), as well as effective predators (e.g. Carabidae, Cleridae, Coccinellidae) capable of bio-control (Reeve, 1997). Top six families of beetles are Curculionidae with 60,000 described species, Chrysomelidae (35,000 species), Staphylinidae (30,000 species), Cerambycidae (26,000 species), Carabidae (25,000 species) and Scarabaeidae (21,000 species) (Underwood, 2014).

1.2 Forests canopy layer and ground layer

The forest canopy is defined as “the top layer of a forest or wooded ecosystem consisting of overlapping leaves and branches of trees, shrubs, or both” (Art, 1993). The canopy is the main habitat for energy assimilation and primary productivity in forests (Lowman,

2009), rich in resources and primary consumers (Basset *et al.*, 2003). Although it is amongst one of the most diverse habitats of the earth, it is also one of the least studied (Lowman and Wittman, 1996; Basset *et al.*, 2003; Lowman, 2009).

Canopy biology is a relatively new discipline of forest science that incorporates the study of mobile and sessile organisms and the processes that link them into an ecological community (Lowman and Moffett, 1993; Nadkarni and Parker, 1994; Stork and Best, 1994). Tropical forests are among the most species-rich (Stork, 1988; Gaston, 2000) and most highly threatened terrestrial habitats, comprising 15 of the 25 global biodiversity hotspots (Myers *et al.*, 2000). Much still remains unknown about the diversity and biology of the most species-rich group inhabiting tropical forests, the insects, as only partial inventories has been made for a few sites around the world (Basset, 2001; Ozanne *et al.*, 2003). Until the early eighties of the last century the canopy was largely neglected in research and now the research is focused on tropical countries from the beginning (Köhler, 1992; Floren and Schmidl, 2008). Although the importance of biodiversity to the stability, resilience and productivity of forests is now widely recognized (Loreau *et al.*, 2001; Pommerening, 2009), most forest-dwelling species remain either undiscovered (May, 1988; Stork, 1988) unknown ecologically (Spence *et al.*, 2008) or of undetermined conservation status (Wilcove and Master, 2005). As a large proportion of these organisms reside in the forest canopy, canopy research is essential for acquiring the holistic perspective needed to optimize conservation and management strategies (Moffett, 2000; Didham and Fagan, 2004).

Ground layer is a terrestrial layer consisting of a mixture of soil and often, plant litter. Species associated with this layer are often ground active not often venturing into the sward/field layer above. These include a series of ground-active predators and seed hunters (such as ground beetles) and saprophages which spend a large proportion of their time on the ground or within the top most layers of leaf litter. Mostly ground layer beetles are dominated by the family Carabidae and is one of the top-10 largest animal families (Kromp, 1999). Ground-dwelling beetles have been regarded as suitable bioindicators for ecosystem conditions (Pearson, 1992; Pearson and Cassola, 1992; Dufrene *et al.*, 1997; Rodriguez *et al.*, 1998; Bohac, 1999; Rainio and Niemelä, 2003; Pearce and Venier, 2006). Darkling beetles (Coleoptera, Tenebrionidae) and ground beetles (Carabidae) are among the most conspicuous members of soil food webs across a wide range of habitats, comprising primarily generalist detritivorous and carnivorous species, respectively (Coleman *et al.*, 2004). Additionally, the use of ground beetle as indicators has frequently been incorporated into policies and regulations in order to monitor the ecological integrity of forests (Brooks *et al.*, 1998).

1.3 *Shorea robusta* and *Dalbergia sissoo*

Shorea robusta, also known as sal, is a species of the tree belonging to the Dipterocarpaceae family. It is a large, deciduous tree with a height about 18-32 m and girths of 1.5-2 m. Exceptionally its height can attain up to 50 m tall and with a Diameter

at Breast Height (DBH) of 5 m (Orwa *et al.*, 2009). It has dark brown and thick bark, with longitudinal fissures deep in poles, becoming shallow in mature trees. Sal is gregarious and dominant in its stand (Champion and Osmaston, 1962; Troup, 1986). Sal forests cover over 11 million ha in India, Nepal and Bangladesh, and these forests are conventionally managed for timber (Gautam and Devoe, 2006). In Nepal, Sal forest covers 1 million hectares (HMG, 1989). It is found mostly in Terai region from east to west in southern flat lowland (Bhardwaj, 2015), especially, in the Churia range (Shivalik Hill Churia Range) in the subtropical climate zone. There are many protected areas, such as Chitwan National Park, Bardia National Park and Shukla Phanta Wildlife Reserve, which are densely covered by huge sal trees. In wetter areas, it is evergreen; in drier areas, it is deciduous, shedding most of the leaves in between February to April (Orwa *et al.*, 2009).

Dalbergia sissoo, also known as sisam, is a species belonging to the Fabaceae family. It is a medium to large tree of about 25 m tall with grey yellow trunk, 2-3 m in diameter. Leaves are leathery, pinnately compound with alternate leaflets. They are broad, ovate, acuminate, glabrescent, petiolate with fine pointed tip (Sheikh, 1989). Native range of *Dalbergia sissoo* are Cameroon, Cyprus, Ethiopia, Indonesia, Iraq, Israel, Kenya, Mauritius, Nigeria, Sudan, Tanzania, Thailand, Togo, US, Zimbabwe whereas its exotic range are Afghanistan, Bangladesh, Bhutan, India, Malaysia, Pakistan (Bhattacharya *et al.*, 2014) and Nepal (Hawkins, 1987).

1.4 Research Objectives

1.4.1 General objective

To assess the diversity and assemblages of canopy and ground layer beetles in the forests of Chitwan National park, Nepal.

1.4.2 Specific objectives

1. To compare the taxonomic composition of beetle communities of different types of habitats investigated in Chitwan National Park.
2. To assess the community characterization of beetles in Chitwan National Park.
3. To find the relation of environment variables with beetle composition.
4. To assess the feeding guilds of beetle in Chitwan National Park.
5. To assess the indicator taxa of different types of habitats investigated.

1.5 Significance of the study

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. Beetles being highly sensitive to habitat change (Refseth, 1980) so are of great importance for conservation management (Pearce and Venier, 2006; Underwood and Fisher, 2006). Beetles are economically and environmentally important

as pest and predator species in agriculture and forestry, and have thus received major attention in biodiversity assessments of agricultural habitats, grassland habitats, tropical, boreal, and also temperate forests (Batáry *et al.*, 2007; Bos *et al.*, 2007; Botes *et al.*, 2007; Clough *et al.*, 2007; Jacobs *et al.*, 2007; Müller *et al.*, 2008).

Also the ecosystem functioning of insects reflects the collective life activities of living organisms (e.g. nutrient and carbon cycling) and the effects of these activities (e.g. feeding, moving and growing) on their environment (Naeem *et al.*, 1999). Beetles are the largest group of insects and occupy a vast array of environments and they affect local communities by various roles in food webs, litter decomposition, and nutrient flow (Lassau *et al.*, 2005). The functional significance of beetles is reflected in their diversity of foraging behavior, and they may act as saprophages (feeds on dead or decaying organic matter), xylophages (wood), herbivores (plants), fungivores (fungi) or predators (other organisms) (Lawrence and Britton, 1994). Beetles were chosen in this study to assess the indicator taxa and for the insight of feeding guilds because of their extreme diversity in form and function (Hammond, 1994).

Forest canopies contain a major portion of the diversity of organisms on earth and constitute the bulk of biomass in forest ecosystems (Preisser *et al.*, 1998). The canopy of tropical trees was called the last biotic frontier in order to emphasize that this habitat harbors the most diverse terrestrial arthropod fauna on earth (Erwin, 1983). For these reasons, canopy research has become integral to the management of forest ecosystems and to our better understanding of global change. In addition to it, canopies of tropical forests comprise a variety of habitat and resources, which are directly related to the world's insect biodiversity (Davies *et al.*, 1997; Basset *et al.*, 2003). Canopy layer beetles and ground layer beetles play an important role as nutrient recyclers' returning organic matter through multi trophic interactions which contribute to soil fertility. Also the way that beetles show preferences to particular vertical zones from the canopy to the ground within tropical forests is one of the few relatively well-studied phenomena (Nadkarni and Longino, 1990; Basset *et al.*, 2001; Tanabe, 2002; Basset *et al.*, 2003; Stork and Grimbacher, 2006; Bruhl *et al.*, 2008). So the aim of this project is to assess the diversity of beetles and to compare the beetles in the canopy of the forest with that at ground level so provide baseline data for biodiversity assessment based on coleopteran diversity.

Habitat can influence the distribution of animal species at multiple spatial scales (Wiens, 1989; Gaston, 2000) and different taxa perceive their environment at different spatial scales (Wiens *et al.*, 1997; González-Megías *et al.*, 2007). Apart from the diversity and distribution patterns for insect taxa, relationships between insect assemblages and plant communities are another key topic requiring urgent research attention (Zou, 2014). As plants provide key habitat parameters for many insect species ranging from shelter to breeding sites, insect diversity can be affected by the parameters of vegetation structure such as plant height, plant size or leave shape (Price and Wilson, 1979; Lawton, 1983; Haysom and Coulson, 1998; Axmacher *et al.*, 2004; Schuldt *et al.*, 2012). Only few current studies exist that directly compare beetle communities of different tree species (Wagner, 2000; Hulcr *et al.*, 2007). So to assess the diversity of beetles and to compare

the beetles in two types of forest, *Shorea robusta* forest and *Dalbergia sissoo* forest were chosen.

This type of study, in community level and comparison of ground and canopy layer of major taxa of canopy arthropods across a tropical forest, is conducted for the first time. First-time comprehensive data on the community structure, beetle composition and regional endemism of beetle assemblage in a tropical forest in canopy layer and ground layer from South Asia are provided.

1.6 Limitation

- Taxonomic problem for species level identification of beetles.
- In rainy season, specimens were weakly preserved despite of preservative used.

2 LITERATURE REVIEW

Since the early days of naturalists, there has been the question of how many species there were in the forests of the tropics (Erwin, 1982). Erwin and Scott (1980) provided the first hard data with regard to the Coleoptera fauna of a single species of tree in the tropical seasonal forest of Panama. Erwin (1982) estimated that canopy layer beetles 2/3rd of total beetles, since then the proportion of canopy beetles to the total beetle fauna came with different results that are 25% (Hammond, 1997), 33% (Stork, 1993), 50% (May, 1988).

Knowledge about Nepal's insects before the year 1950 was limited. After 1950 Nepal was opened to foreigners and a number of expeditions contributed to the knowledge about insect from the Nepal Himalayas. Most of the taxonomic works have been carried out on Lepidoptera, Odonata, Diptera and Coleoptera (Shrestha, 1999). Revised summary of insect collection in Nepal shows that 63 families with 6,490 species of beetles are reported from Nepal (Thapa, 2015). Different investigations have been carried out in Nepal from time to time either on one family or group of families. However, there have been few studies looking at the whole order of beetles. Also, study on a community level and comparison in canopy layer and ground layer is lacking in Nepal.

Different investigations have been carried out regarding the beetle assemblages, their feeding guilds and influence of the environmental factors in their distribution over the whole world. In a lowland forest of northern Italy, Hardersen *et al.* (2014) used 14 Malaise traps in the canopy and ground layer and worked with eleven beetle families (Buprestidae, Eucnemidae, Throscidae, Elateridae, Cantharidae, Dasytidae, Malachiidae, Tenebrionidae, Cerambycidae, Anthribidae, and Scolytidae), where 4375 beetles belonging to 88 species were identified. Species richness and similarity of assemblages were compared explaining that the beetle assemblages in the two layers were significantly different. However, species richness was found less in the canopy layer by 20% compared to the ground layer. Eight species were significantly associated with the canopy and 15 species were significantly associated with the ground layer. Similarly, 52% of species were shared between the strata, while 18% were caught exclusively in canopy compared to 30% exclusive to the ground layer. Moreover, this study showed that the distribution of beetles in the forest was structured in time and space and that season influence the capacity to distinguish between beetle assemblages sampled in the canopy and at the ground.

Few community-level entomological studies have been carried out in the canopy of temperate forests and here species composition per stratum is still poorly documented (Bouget *et al.*, 2011). Generally the composition of insect assemblages differs between the ground and canopy layers (Bouget *et al.*, 2011; Birtele and Hardersen, 2012) and, in the few forests so far investigated, habitat preferences for horizontal strata have been established for some species (Wermelinger *et al.*, 2007; Vodka *et al.*, 2009; Bouget *et al.*, 2011; Birtele and Hardersen, 2012; Stireman *et al.*, 2012).

Stork and Grimbacher (2006) conducted a four-year beetle sampling program in lowland tropical rainforest in North Queensland, Australia by using a trap that combines Malaise and Flight interception trap functions where each pairs of this trap were suspended on the ground and 15-20 m above in the canopy at five sites, with tree spaced 50 m or more apart and these traps produced 29,986 beetles of 1,473 species and 77 families with similar numbers of individuals (canopy 14,473; ground 15,513) and species (canopy 1,158; ground 895) in each stratum, but significantly more rare species in the canopy (canopy 509; ground 283) showing that the canopy and the ground strata both provide important contributions to rainforest biodiversity. Moreover, seventy two percent of the species, excluding rare species, were found in both strata and by using IndVal, they found 24% and 27% of the abundant species ($n \geq 20$ individuals) to be specialized to the canopy and the ground strata respectively, and equivalent analyses at the family level showed Figs of 30% and 22%, respectively.

Grimbacher and Stork (2007) concluded with herbivores (35.6% of species, 31.3% of individuals), predators (24.3% of species, 12.6% individuals), xylophages (14.1% of species, 25.7% of individuals), and fungivores (20.5% of species and 24.1% of individuals) in lowland tropical forest of Australia. Guild proportions between the canopy and the ground were remarkably similar for the number of species, but showed a few differences when a number of individuals were considered (more herbivores in canopy and more saprophages and fungivores in ground).

Ulyshen and Hanula (2007) compared the beetle fauna captured in a temperate deciduous forest of the southeastern United States with the help of 12 pairs of flight intercept traps, suspended at two different heights above the ground (≥ 15 m and 0.5 m) where they reported a total of 15,012 beetle specimens representing 73 families and 558 morphospecies where three families (Cerambycidae, Cleridae and Coccinellidae) were more abundant and speciose in the canopy. Four other groups Carabidae, Pselaphinae (Staphylinidae), Scolytinae (Curculionidae) and Staphylinidae were more abundant and speciose near the ground and witnessed that Shannon's diversity and evenness were both higher near the ground than in the canopy, but showed no differences in total abundance or species richness between the two layers. Before Ulyshen and Hanula (2007), only two previous studies compared the overall numbers of beetles in the canopy and near the ground in temperate deciduous forests. Unfortunately, study was not replicated and they produced somewhat conflicting results. Nielsen (1987) collected nearly seven times more beetles near the ground than in the canopy in Denmark, whereas in the northeastern United States, Preisser *et al.* (1998) reported no clear difference in abundance between the two heights. Data of Ulyshen and Hanula (2007) were more similar to Preisser *et al.* (1998) in that they did not see a difference in overall beetle abundance between the two trapping locations.

Chung *et al.* (2000) studied the diversity of beetle assemblages in primary forest, logged forest, acacia plantation and oil palm plantation in Malaysia by winkler sampling, flight interception trapping and mist-blowing. They measured floristic (plant species, sapling

and tree densities, canopy and ground cover), leaf litter and soil condition (pH and soil compaction) to investigate their relationships with the beetle assemblages. They collected 1711 species among 8028 individuals and 81 families (115 family and subfamily groups). In terms of beetle species composition, the acacia fauna showed much similarity with the logged forest fauna, and the oil palm fauna were very different from the rest. Staphylinidae and Pselaphidae were the two most prominent families sampled throughout the study. Predators were the most speciose and abundant group, representing more than 40% of the trophic assemblage. Saprophages and fungivores represented more than 15%, herbivores 10–13%, both xylomycetophages and xylophages about 5%. Environmental changes affected the trophic structure with proportionally more herbivores (abundance) but fewer predators (species richness and abundance).

Chung (2004) investigated the beetle assemblages, using flight intercept traps set up at different levels (ground, 6m, 12m) of an aluminium-alloy tower in a lowland dipterocarp forest in Sabah where 215 morphospecies belonging to 48 families were collected. Staphylinidae and Scarabaeidae were the most prominent families. Species richness and abundance of beetles were significantly lower in both 6 m and 12 m levels compared to the ground level.

In the study by Chung *et al.* (2001) in Sabah Malaysia, using mist-blowing, Chrysomelidae was the most prominent family sampled, followed by Curculionidae, Coccinellidae, Mordellidae and Phalacridae.

Sobek (2008) across a tree diversity gradient in a Central European deciduous forest sampled beetles using 12 cross-window flight interception traps. A total of 10,360 individuals belonging to 60 families and 422 species were collected. Feeding guilds suggested that more than one third of the species was denoted as predators (36.7 %), followed by 119 herbivores (28.2 %) and 54 fungivores species (12.8 %). In terms of abundance, herbivorous species were most common (3,194 individuals, 30.8 %), whereas one quarter of all individuals was fungivores (2,782 individuals, 26.9 %) and one quarter predatory (2,588 individuals, 25 %).

Arias *et al.* (2008) collected 25,497 beetle specimens sorted to 485 morphospecies from the canopy of 29 trees (*Nothofagus dombeyi*, *Nothofagus obliqua* and *Araucaria araucana*) in Chilean temperate rain forests by canopy fogging. The canopy beetle fauna found in the canopies of three Chilean temperate rain forest tree species were estimated to be large (600+ species). *Nothofagus obliqua* also yielded the greatest diversity of beetle species: 60% of all the species were found on *N. obliqua*. Guild structure showed the dominant of predator (36.1%) followed by xylophages (24.3%), mycetophages (16.9%), phytophages (13.8%) and saprophages (7.2%). Davies *et al.* (1997), in Venezuelan rain forests, collected 978 species from canopy of trees of 6 species where phytophages (29.7%) was dominant followed by mycetophages (22.2%), predators (21.9%), xylophages (13.3%), and saprophages (12.9%). In Australia, Hammond *et al.* (1996) collected 454 species from the tree crown of Australian subtropical forest where

predators (27.3%) dominated, followed by mycetophages (23.1%), xylophages (21.1%), phytophages (19.8%) and saprophages (8.4%).

Heyborne *et al.* (2003) studied ground dwelling beetles and forest vegetation change in Oregon, USA for a period of 17 years. From the study, they found specifically defined plant communities were associated with unique beetle communities also they found that different ages of forest had significantly different beetle communities.

Ulyshen (2011) studied the vertical distribution patterns of arthropods in temperate deciduous forests and concluded that they were unevenly vertically distributed communities where these patterns were determined by time (forest age, season, time of day), forest structure (height, vertical foliage complexity, plant surface textures, tree cavities), plant community composition (plant diversity, invasive species), climatic gradients (light exposure, temperature, wind speed, humidity), resource availability (foliage, sugars, wood, epiphytes, carrion, dung, prey, hosts, mates), inter-specific interactions (predation, interference, competition) and logistics (dispersal abilities, proximity to emergence sites, open flight zones). Protecting large diameter trees and snags was also important, especially for a wide variety of canopy arthropod taxa associated with standing or suspended dead wood, tree cavities and epiphytes.

Lassau *et al.* (2005) with the help of pitfall trap and flight interception traps compared the beetle assemblages difference on habitat complexity where they found that the composition and species richness of flight-intercept-trapped beetles were similar in high and low complexity sites whereas pitfall trapped beetles were more species rich and of different composition in high complexity sites, compared with low complexity sites. Eight hundred and thirty-five beetles belonging to 126 species of 29 families were collected in pitfall traps and 979 individuals of 271 species of 47 families in flight-intercept traps. The Staphylinidae contributed the greatest proportion of species richness (32%, 24%) and abundance (43%, 31%) in both pitfalls and flight-intercept traps, respectively. The composition of beetle species trapped in pitfalls differed substantially from that trapped in flight-intercept traps.

Antvogel and Bonn (2001) studied the ground beetles in a pristine alluvial *Quercus-Ulmus* forest along the river Elbe (North Germany) using 152 pitfall traps over a study period of 28 days. They concluded that composition of the ground beetle was strongly influenced by microclimatic parameters and vegetation structure within a few meters: specifically soil moisture, light intensity, pH as well as cover of leaf litter and herbs.

Baker *et al.* (2007) studied the ground dwelling beetles in wet Eucalypt forest with an overstorey dominated by *Eucalyptus obliqua* in Tasmania by using 96 pitfall traps in three seasons (spring, winter, summer/autumn). They found that the beetle assemblage composition varied between the three seasonal trapping periods.

Liberal *et al.* (2011) studied on dung beetle diversity in Caatinga, a Brazilian semi-arid ecosystem in dry and wet season where they collected a total of 1021 individuals representing 13 species in the wet season and 76 individuals representing six species in

the dry season. Significant differences were found in abundance between seasons. Moreover, a significant difference was found in diversity index values between seasons, whereas no statistically significant seasonal differences were found with regard to species richness.

Charles and Basset (2005) studied the vertical stratification of leaf beetle fauna in dry tropical forest and wet tropical forest. A total of 4615 leaf beetles were collected, and they were significantly more abundant at the dry site. They were also significantly more abundant in the canopy than in the understorey at the wet tropical forest.

Hammond *et al.* (1990) recorded Staphylinoidae (the superfamily consisting of Staphylinidae, Pselaphidae and other smaller groups) as the most species rich superfamily, representing 26.6% of the beetle species sampled in Sulawesi. Mawdsley (1994), however, recorded a different set of dominant families. The most abundant families or subfamilies in his study were the plant-associated Mordellidae, the wood-feeding Scolytidae and the plant-associated chrysomelid subfamily, Galerucinae. The Galerucinae (Chrysomelidae), Scolytidae and Curculionidae were the most speciose taxa in the investigation.

To facilitate monitoring of Coleopteran diversity and indicators at the family level that adequately represent the beetle diversity, Ohsawa (2010) placed one malaise trap in each of 52 forest stands and distance between the trap ranged from 0.2 km to 14.5 km in the central mountainous region of Japan where 12,099 beetle individuals belonging to 869 species and 76 families were captured. The relationship between the species composition of each family and the overall composition of all families was examined using Mantel tests where families with high correlation coefficients for species richness included Cerambycidae, Cleridae, Curculionidae, Lycidae and Elateridae. Families exhibiting strong similarity in composition were Scolytidae, Elateridae, Curculionidae, Cerambycidae, and Staphylinidae. Cerambycidae, Curculionidae, and Elateridae were determined to be useful surrogates for Coleopteran diversity.

Daniel *et al.* (2014) collected dung beetles in different vegetation types in the Brazilian Shield-Chacoan Depression border where they collected 96 species of dung beetles.

Preisser *et al.* (1998) with the help two types of traps, light traps and malaise traps trapped the insects at two heights, 0 and 20 meters above the ground in a temperate forest. They reported 78 individuals of beetles in 20 m height, whereas 384 individuals of beetles in 0 m temperate forest. Cantharidae was the most prominent family followed by Elateridae, Lycidae and Scarabaeidae.

Banerjee (2014) reported 9 distinct families of beetles (Scarabaeidae, Carabidae, Chrysomelidae, Coccinellidae, Borydae, Lycidae, Curculionidae, Hydrophilidae, and Derodontidae) from the three sites over a long one-year survey at Durgapur, West Bengal, India.

Ødegaard (2006) studied species diversity, host specificity and species turnover among phytophagous beetles in the canopy of two tropical lowland forests (drier forest and wetter forest) in Panama with the use of canopy cranes. Species richness was found low in drier forest (1165 species) compared to wetter forest (1603 species). He collected 2462 species, of which 306 species (8.04%) were shared between the two sites.

3 MATERIALS AND METHODS

3.1 Study area

Chitwan National Park (CNP), established in 1973 AD, is the first National park in Nepal. The park is situated in south-central Nepal in the Terai region covering an area of 932 sq km. Recognizing its unique ecosystems of international significance, UNESCO declared the national park, a world heritage site in 1984 AD, which comprises of a complex ecosystem of Churia hills, ox-bow lakes and flood plains of Rapti, Reu and Narayani rivers. Geographically the CNP lies at 27° 16' 56" to 27° 42' 14" North latitude and 83° 50' 23" to 84° 46' 25" East longitude. The altitude ranges 110 m to 850 m above sea level. The shape of the park is irregular and elongated east to west.

In 1996, an area of 750 km² surrounding the park was declared a buffer zone, which consists of forests and private lands including cultivated lands. The buffer zone contains a Ramsar Site– Beeshazari Tal.

Vegetation of CNP is tropical type. Vegetation of CNP can be divided into following types

- A) Sal forest: Sal forest is considered as the climax vegetation of the Terai region of Nepal. Sal forest covers about 70% of the park area. The sal is sparsely associated with trees like *Terminalia bellerica*, *Garuga pinnata*, *Dillenia pentagyna*, *Bridelia retusa*, *Anogeissus latifolius* and creepers such as *Bauhinia vahlii* and *Spatholobus parviflorus*. The ground vegetation is poor with bushes of *Woodfordia fruticosa*.
- B) Riverine forest: This type of vegetation occurs along the river banks, water courses and islands in the Narayani and Rapti river (Nepal and Weber, 1993) and occupies about 7% of the park (Mishra, 1982). Four types of riverine forests have been distinguished.
 - a) Khair- Sisham forest
 - b) Simal-Bhellar forest
 - c) Tropical Evergreen forest
 - d) Eugenia wood land
- C) Grassland: The grasslands comprise of diverse and complex communities of several species and occupy about 20% of the park area.

The study area had covered all four management sectors of the Chitwan National Park (Fig 1) (CNP, 2015).

- a) Eastern (Sauraha sector)
- b) Central (Kasara sector)
- c) Southern (Bagai/Madi sector)
- d) Western (Amalatari sector)

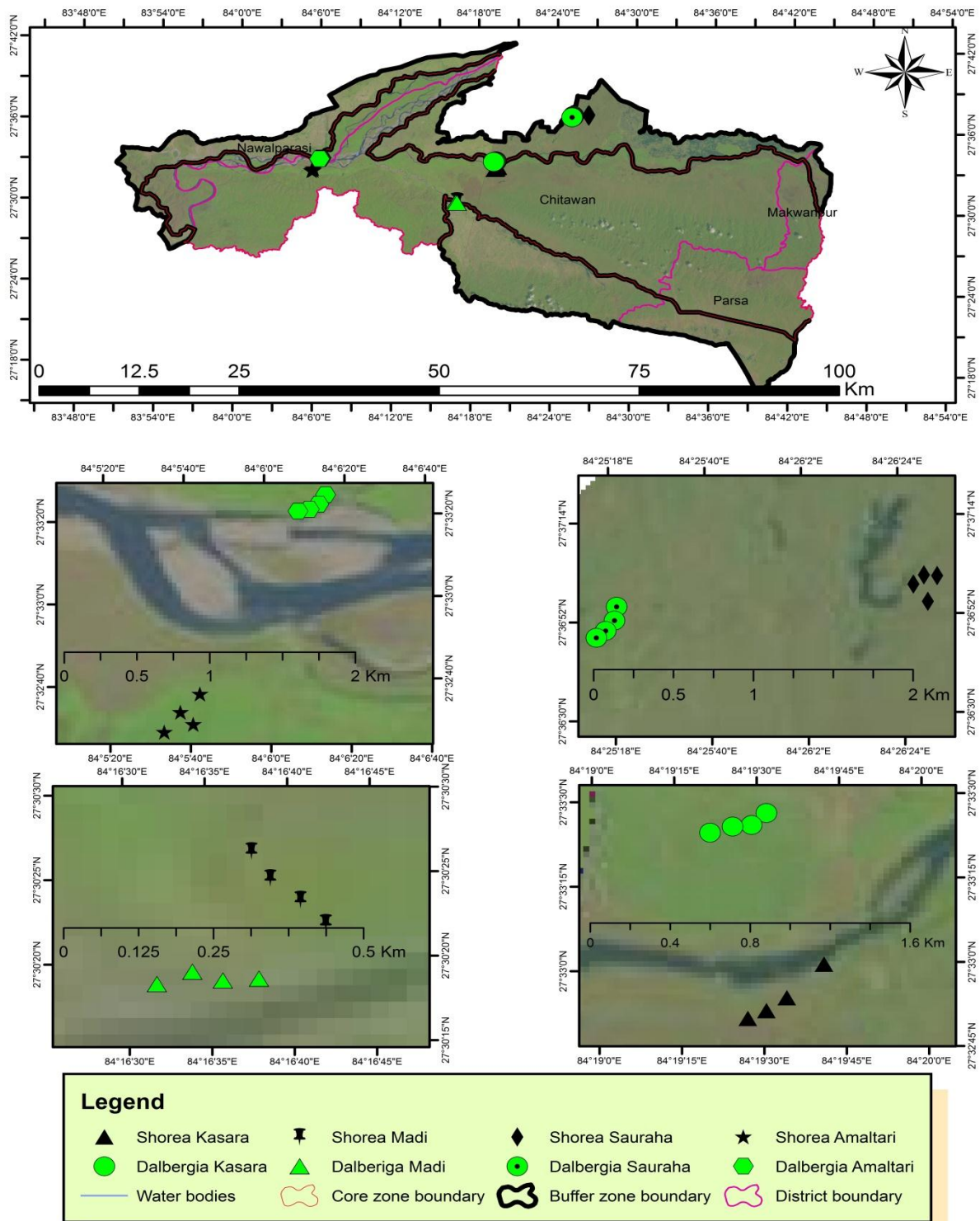


Fig 1. Location of study area (Geographic location is given in Annex 9)

3.1.1 Climate

The climate of the Chitwan National park is humid and warm for much of the year. According to climatic data of 2006-2015 of the nearest station (Rampur), the mean monthly maximum temperature ranged from 21.9⁰C in January to 35.7⁰C in May.

Similarly, the mean monthly minimum temperature ranged from 7.6°C in January to 25.4°C in August (Fig. 2).

The average monthly relative humidity of morning (8:45 am) ranged from 67.1% in April to 97.5% in January. Similarly average monthly relative humidity of evening (5:45 pm) ranged from 52.9% in April to 86.5% in October. The average annual rainfall was high in August (451.7 mm) whereas November is the month for least rainfall (0.8 mm) (Fig. 3).

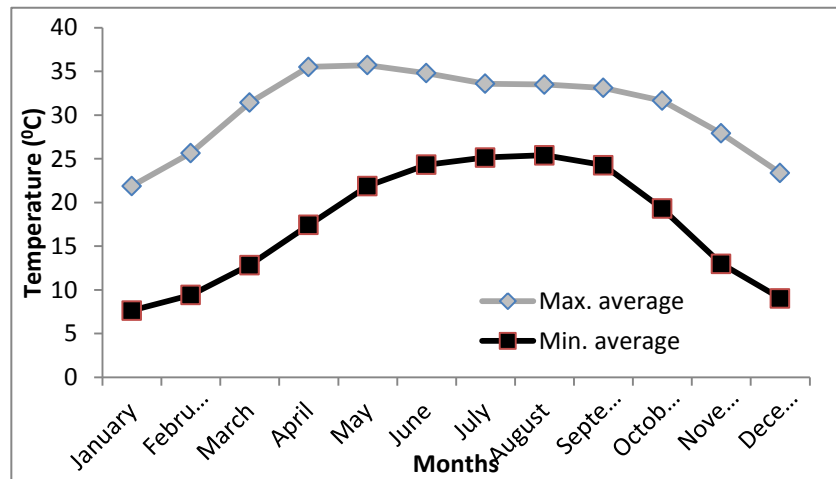


Fig 2. Monthly average (ten yearly, 2006-2015) maximum and minimum temperature

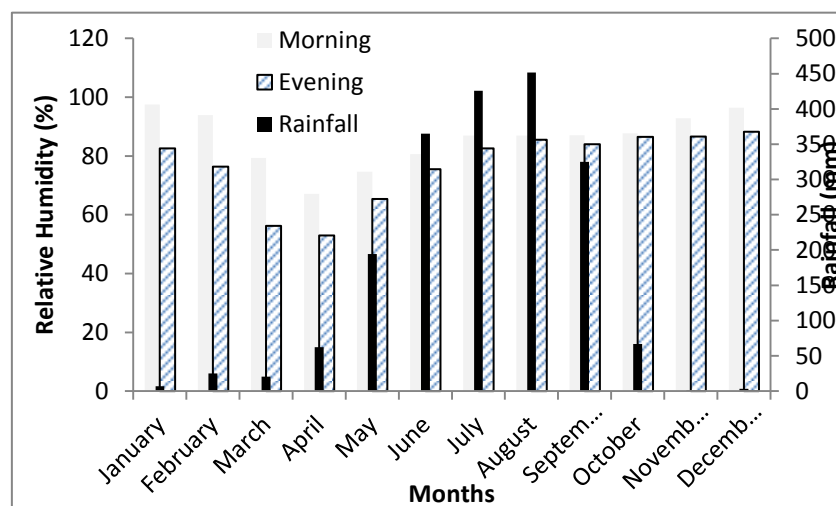


Fig 3. Monthly average (ten yearly, 2006-2015) relative humidity (morning at 8:45 and Evening at 17:45) and rainfall

3.2 Materials used

3.2.1 Canopy trap

Canopy trap is composite interception traps consists of two pieces of transparent plastic plates (each 60 x 40 cm, height x width) which are arranged crosswise and fixed upon a red plastic bowl of 40 cm in diameter from upper surface and a collecting jar filled with ethylene-glycol as a preservative liquid at the bottom to collect canopy beetles (Sobek *et al.*, 2009; Meng *et al.*, 2013). The advantages of this form of interception trap include: continuous trapping, day and night; localised interception of the arthropods, whether flying or crawling within the tree crown or flying across the crown; a wide range of arthropods is trapped; the traps are inexpensive and, once in place, they require little attention (Basset, 1988).

3.2.2 Pitfall trap

Pitfall traps of plastic cups (18 cm depth, 14 cm diameter at the mouth and 12 cm at the bottom) were used in the study. An exclusion barrier (roof top) made up of plastic sheet was used to exclude unwanted fauna (predators, non-target species) and to protect it from rainwater.

3.2.3 Ethylene glycol, unscented detergent and ethanol

Ethylene glycol with added unscented detergent was used as preservatives to preserve the collected specimen during the collection period whereas 70% ethanol was used to preserve the collected specimens during transportation and storing in laboratory.

3.2.4 Global Positioning System (GPS)

Garmin eTrex 10 GPS was used for acquiring the location of trees.

3.2.5 Measuring tape

Measuring tape was used to measure DBH of tree, crown size, trap height and tree height.

3.2.6 Rope

The rope was used to hold canopy traps high in the tree canopy branches.

3.2.7 Collection jars

Transparent plastic bottles were used to collect the samples from study sites.

3.2.8 Magnifying glass and microscope

Magnifying glass (10x and 20x) and simple microscope were used to explore the morphological characters of beetles during the course of identification.

3.2.9 Camera

Fujifilm FinePix F800EXR was used to photograph the specimens in laboratory as well as in field.

3.3 Study design

Data was collected from each management sector of Chitwan National Park. Four trees of *Shorea robusta* and four trees of *Dalbergia sissoo* were selected purposively from each management sector. Tree were selected in such a manner that minimum distance between each sample were at least 50 m. Thirty two trees were chosen from all management sectors, each type of trees with sixteen trees. Canopy traps and pitfall traps were used in chosen trees and preservative to preserve the collected specimen during the collection period.

Canopy traps were hanged at height of 7.5 m - 16.5 m in branches of tree with the help of crossbow.

Pitfall traps were placed within 1 m radius around the sampled trees. Litter was repositioned around the edge of the trap to simulate natural conditions. Ethylene glycol was used as preservatives in addition to it some amount of unscented detergent will be added to reduce surface tension. An exclusion barrier (roof top) was used to exclude unwanted fauna (predators, non-target species) and to protect it from rainwater.

Both the sampling techniques are passive form which neither attracts nor repel insects, so that it allows unbiased estimates of insect population.

3.4 Data collection

3.4.1 Specimens collection

Samples were collected at interval of about 18 days from April 5 to July 31 for a total six sampling periods. During the sample collection the flight interception traps were lowered down by pulling the lower rope and the collection jar was replaced by another collection jar with preservatives. Similarly, specimens from the pitfall traps were collected at interval of 15 days. Specimens from each flight interception traps and each pitfall traps were collected in separate container in each sampling periods. In a sampling period, 16 samples from canopy layer of *Shorea* forest and 16 samples from canopy layer of *Dalbergia* forest, and 16 samples from ground layer of *Shorea* forest and 16 samples from ground layer of *Dalbergia* forest were sampled. Altogether, 384 sample collections were made in six sampling periods from the study. Following collection, samples were poured through a fine mesh strainer to filter them from the ethylene glycol and dirt particles. They were then rinsed with 70% ethyl alcohol to remove all remaining ethylene

glycol. Specimens were separated from leaves, twigs, and placed in a vial of 70% ethyl alcohol labeled inside and outside of the vial with the collection date, site, and sample number.

The collected specimens were taken to the laboratory of Central Department of Zoology, Entomology section, Kirtipur for sorting, identification, and preservation.

3.4.2 Environmental variables

3.4.2.1 Tree properties

Crown spread, Height and DBH are the three key measurements that characterize the size of a tree (Blozan, 2006).

Crown size was measured by average crown spread method given by Blozan (2006) which was obtained by measuring the longest and shortest extent of the crown and averaging the Figures (Fig. 4). Crown spread is taken independent of trunk position.

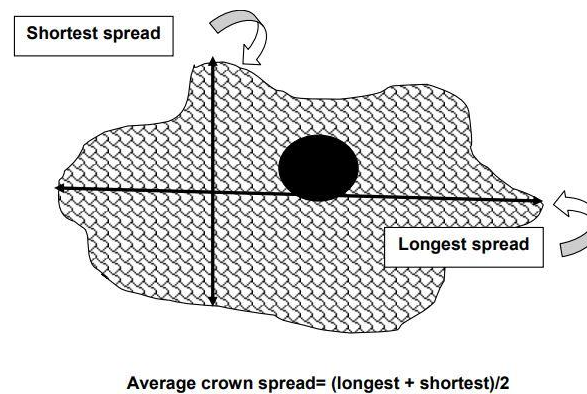


Fig 4. Average crown spread measurement technique to measure crown size of individual tree

Tree height was measured by stick measurement technique which is the best approximating tree heights (Walker, n.d.). To eliminate the greatest potential for error, trees were viewed from several different angles to see where the actual top of the tree is located. The point from where the actual top of the tree can be located was used for the measurement. For this, a stick of 0.7 m meter was holding in straight up position making 90° angles to outstretched arm. Distance between eye and arm was maintained to be 0.7 m (length of the stick above hand equals the distance from hand to eye). While moving backward or forward, When the tip of the stick line up with the top of the tree, distance from the tree base was measured up to eye which is the approximate height of the tree (Fig. 5).

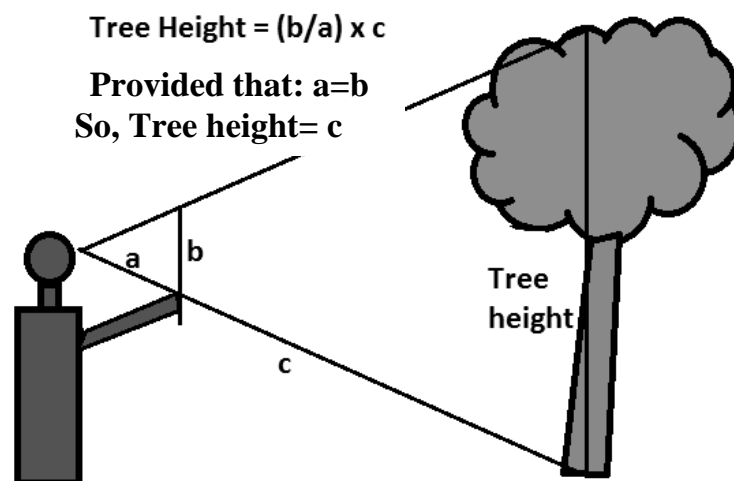


Fig 5. Stick measurement technique to measure the tree height

Diameter at breast height was measured by using measuring tape.

3.4.2.2 Soil parameters

Soil samples under the plant canopy were collected from each study site in each sampling period. Altogether 48 soil samples were examined for pH, organic matter, nitrogen and phosphorus content in soil at the laboratory of Agricultural Technology Centre, Pulchowk, Lalitpur.

3.4.2.3 Climatic factors

Temperature, maximum temperature, minimum temperature($^{\circ}\text{C}$) and morning relative humidity (8:45 am) and evening relative humidity (5:45 pm) and rainfall (mm) of six sampling periods were gathered from Meteorological and Hydrological Station at Rampur.

3.5 Insect Identification

Specimens collected were sorted out into different orders and beetles were sorted out for study purpose from the collection. Identification was performed by all six ways provided by Johnson *et al.* (2004) using standard analytical keys, author or experts studying the different taxonomic groups, comparing with labeled specimens in collection, comparing with pictures, comparing with descriptions and by combination of two or more procedures. Beetles were identified up to family using keys from Johnson and Triplehorn (2004) and Lawrence *et al.* (2000).. Nomenclature of beetle families and subfamilies followed Bouchard *et al.* (2011). Further confirmation of family was done by expert Enrico Ruzzier (Natural History Museum, London) who had worked in Palearctic regions' canopy beetles, Dr. Arthur V. Evans (Entomologist of Virginia) who has become public Fig in insects' field and Azaz Ahmed, University of Agriculture, Peshawar. After family level identification, subfamily, tribe and genus level identification of beetles were done with the help of experts across the world. Taxonomic level above family were identified by the specialists indicated in brackets: Carabidae (Riccardo Skiaky, University

of Milan, entomologist), Scarabaeidae and Hybosoridae (Seena Narayanan, Senior Research Associate, Assistant Museum Curator, EOL Rubenstein Fellow and Stefano Ziani, University of Nebraska State Museum), Coccinellidae (Poorani Janakiraman, Indian Council of Agricultural Research, National Research Centre for Banana New Delhi, India), Curculionidae (Jennifer Cristina Girón Duque, Doctoral aspirant), Chrysomelidae (Dr Michael Geiser, Natural History Museum, London), Trogossitidae (Harald schillhammer, Natural History Museum Vienna), Cerambycidae (Westerdujin Rob and Antonio Santos-Silva, University of São Paulo), Elateridae (Robert L. Otto, University of Wisconsin–Madison, Madison, Wisconsin, United States and Wataru Suzuki), Zopheridae (Rudolf Schuh, Natural History Museum Vienna), Salpingidae, Melyridae and Tenebrionidae (Enrico Ruzzier). Comparison of specimens were done with labeled specimens collection of Natural History Museum, Swoyambhu Nepal and Entomology division of Nepal Agricultural Research Council, Khumaltar, Nepal. Pictures were compared from Thapa (2015) for the identification purposes.

3.6 Specimens deposition

All of the Specimens collected in this research are deposited in Entomological lab of Central Department of Zoology, Tribhuvan University.

3.7 Data processing and statistical analysis

Specimens were sorted in ‘morphospecies’ which describes the taxonomic unit putatively regarded as a species in a collection where species identities are not known (Hammond, 1994), hereafter referred to as species. Beetle specimens after sorting into morphospecies, were identified to family or subfamily according to Johnson and Triplehorn (2004) and Lawrence *et al.* (2000). Beetle families and subfamilies were allocated to five feeding guilds (predators, herbivores, xylophages, fungivores and saprophages) based on information from Hammond (1990) and Lawrence *et al.*(2000). Parasitoids were included within the predators. Xylophages were used in a broad sense to include xylomycetophages (Lawrence *et al.*, 2000). Assigning species/families to trophic guilds is a complex issue (Moran and Southwood, 1982; Stork, 1987). Some beetle families were unable to be assigned to feeding guilds because information about their feeding biology is unknown. These were placed in an ‘unknown’ group. The task of assigning beetle species and groups of species to feeding guilds is difficult, mainly due to the poor level of knowledge of feeding behavior of individual species (Hammond, 1990; Stork, 1987). The resolution and number of trophic groups recognized are somewhat arbitrary and differ between studies. Thus, to avoid confusion, the trophic classification in this study explicitly follows (Hammond, 1990) and (Lawrence *et al.*, 2000).

Any attempt to describe and compare a complex community structure by one single attribute, such as richness or evenness, can be criticized because valuable information about community structure will be lost (Begon *et al.*, 2006). So here performed Non-metric Multidimensional Scaling (NMDS) followed by Adonis, ANOSIM and SIMPER,

Diversity indices, Rarefaction curve and species rank abundance curve so that it can better describe and compare the beetle community of CNP.

3.7.1 NMDS

Non-metric Multi-Dimensional Scaling is often the method of choice for graphical representation of community relationships (Everitt, 1978; Kenkel and Orloci, 1986).

Beetle community compositions of different habitats and different seasons were analyzed by two- dimensional Non-metric Multidimensional Scaling (NMDS) of the abundance data (Jari Oksanen, Personal Communication) employing the function metaMDS, which is incorporated in the statistical package vegan (Oksanen *et al.*, 2008). Beetle abundance data were square root transformed to reduce the influence of extreme values. In the resulting plot trap groups were connected to the cluster centroids by a line using the function ‘ordispider’ present in the same package. For statistical test for differences in species composition between habitats and seasons, following statistical measurement was carried out:

a) PERMANOVA/Adonis (Permutational Multivariate Analysis of Variance):

Permanova was carried out following NMDS to measure if the community differs between groups. Adonis creates a set by first identifying the relevant centroids of the data and then calculating the squared deviations from these points. After that, significance tests are performed using F-tests based on sequential sums of squares from permutations of the raw data. It produces a p-value to determine the statistical significance.

b) ANOSIM (Analysis of Similarities):

The statistical significance of differences among locations was assessed using analysis of similarities (ANOSIM, a non-parametric method based on randomization of rank-similarities among all samples (Clarke, 1993).

As Both Adonis and ANOSIM are nonparametric, statistical significance is determined through permutations. P values of Permanova and ANOSIM is sensitive to the number of permutations so that the number of permutations was taken in high number (999).

c) SIMPER (Similarity percentage analysis):

Where Adonis and ANOSIM revealed significant differences between groups, SIMPER analyses were used to identify those species that contributed most to the observed assemblage differences (Clarke and Gorley, 2001).

NMDS and all of the three procedures (Adonis, ANOSIM, and SIMPER) were carried out using software R 3.4.2 (R core team, 2017) using “vegan” package (Oksanen *et al.*, 2017).

3.7.2 Community Characterization

3.7.2.1 Species diversity, shared species and turnover

In this study, four different species diversity indices (Shannon-Wiener, Simpson's, Fisher's alpha and Margalef) were used for comparative estimating. In this study, diversity of ecological communities was assessed within habitat diversity and compared between habitats or landscapes (Magurran, 2004; Begon *et al.*, 2006; Stireman, 2008).

PAST. PAleontological STatistics. (Hammer *et al.*, 2001) Version 3.17 computed the diversity indices. Random matrices with two samples are generated, each with the same row and column totals as in the original data matrix which provided the significance of diversity between α groups.

3.7.2.1.1 Chao's Sorensen index

For similarity between tested habitats groups Chao's Sorensen index for both observed and estimated species was used. To calculate community similarity for raw abundance data, we used Chao's Sørensen index (an improved version of the classical Sørensen index), which takes different sample sizes and the relative abundance of each species into account (Chao *et al.*, 2005).

Beta-diversity is central to concepts about what controls diversity in ecological communities. Species turnover was calculated by using software PAST. PAleontological STatistics.(Hammer *et al.*, 2001) Version 3.17 and habitats similarity indices were calculated by using EstimateS software (Colwell, 2013) version 9.0 .

3.7.2.2 Species richness estimation, sampling effort, and rarefaction curves

Three nonparametric abundance-based estimators ABE of species richness (abundance-based coverage estimator ACE, Chao 1, and Jackknife 1) and three nonparametric incidence-based estimators of species richness IBE (incidence-based coverage estimator ICE, Chao 2, and Jackknife 2), which are considered accurate and not sensitive to statistical problems (Hortal *et al.*, 2006) were used to estimate the potential number of species. Completeness of the sample (sampling effort) was calculated in relation to these richness estimators.

Rarefaction curve also known as species accumulation curve is a technique to assess species richness from the results of sampling. Rarefaction allows the calculation of species richness for a given number of individual/samples, based on the construction of rarefaction curves. Rarefaction curves estimate species richness for a sub-sample of the pooled total species richness, based on all species actually discovered. These curves are based on the assumption that beyond a certain amount of effort, the species versus effort curve should reach an asymptote (Magurran, 2004; Chao *et al.*, 2005). That asymptote provides a reasonable estimate of the number of species present. Both sample based and individual based rarefaction curve were generated for the same types of traps in two forests.

3.7.2.3 Species rank abundance curve

The changes in community structure during different seasons were compared based on the number of individuals per species with dominance-diversity (rank abundance) curves. A rank abundance plot (or Whittaker plot) was used to visualize species abundance distributions. In this plot, the number of individuals of each species was sorted in descending order and the proportion of the total number of individuals for each species for different habitats and season was 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. The combination of species richness estimation and rarefaction curves were generated with 50 randomizations, using EstimateS software (Colwell, 2013) version 9.0, and the observed species richness allowed evaluation of the sampling effort in each locality.

3.7.3 Indicator taxa

Package *indicspecies* (Cáceres and Legendre, 2009) for R was used to study the association of the beetle caught in habitat types. *Indicspecies* package provides a set of functions to assess the strength and statistical significance of the relationship between species occurrence/abundance and groups of sites (Cáceres and Legendre, 2009). Two data elements (community data matrix and traps were classified in group of particular sites) were prepared for an indicator species analysis. Function *multipatt* was used to allow in determining lists of species that are associated to particular groups of sites (Cáceres and Legendre, 2009).

3.7.4 Chi-square

To test the significant difference in abundance and morphospecies between different pairs of habitats and season chi-square test were performed in software R 3.4.2.

3.7.5 Environmental

To quantify the impact of known environmental conditions on the species composition, the unconstrained NMDS ordination graph was overlaid with environmental variables. Environmental variables were fitted onto the NMDS ordination with maximum correlation to the NMDS pattern using the *envfit* function (package *vegan*). A permutation test (with 10,000 repetitions) was calculated to test the hypothesis of a relationship among environmental variables and species composition. To examine how environmental factors affected the species richness and abundance, we plotted the number of species collected and the number of beetles collected as a function of different environmental variable.

4 RESULTS

4.1 Beetles in Chitwan National Park

A total of 25,228 sample specimens belonging to 25 families were collected during the study period. They represented 142 different morphospecies (Annex 1) which was assigned to family, subfamily, tribe and genus taxonomic level. All of the morphospecies were identified up to family level. Out of 142 morphospecies 115, 100 and 91 morphospecies belonging to 25 subfamilies, 50 tribes and 60 genera level respectively were identified from the collected beetles of Chitwan National park (Table 1).

Table 1. Classification Details of the Collected Beetles in Chitwan National Park, 2016

MSSN	Family	Subfamily	Tribe	Genus
1	Anthribidae Billberg, 1820	-	-	-
2	Attelabidae Billberg, 1820	Rhynchitinae Gistel, 1848	-	-
3	Attelabidae	-	-	-
4	Bostrichidae Latreille, 1802	Bostrichinae Latreille, 1802	-	-
5	Byturidae Gistel, 1848	Byturinae Gistel, 1848	-	-
6	Carabidae Latreille, 1802	Carabinae Latreille, 1802	Carabini Latreille, 1802	<i>Calosoma</i> Weber, 1801
7	Carabidae	Cicindelinae Latreille, 1802	Cicindelini Latreille, 1802	<i>Cicindela</i> Linnaeus, 1758
8	Carabidae	Harpalinae Bonelli, 1810	Chlaeniini Brullé, 1834	<i>Chalaenius</i> Bonelli, 1810
9	Carabidae	Harpalinae	Chlaeniini	<i>Chalaenius</i>
10	Carabidae	Harpalinae	Harpalini Bonelli, 1810	<i>Harpalus</i> Latreille, 1802
11	Carabidae	Harpalinae	Helluonini Hope, 1838	<i>Omphra</i> Dejean, 1825

Table 1 contd.

MSSN	Family	Subfamily	Tribe	Genus
12	Carabidae	Harpalinae	Lebiini Bonelli, 1810	<i>Microlestes</i> Schmidt-Goebel, 1846
13	Carabidae	Harpalinae	Lebiini	-
14	Carabidae	Harpalinae	Lebiini	<i>Anomotarus</i> Chaudoir, 1875
15	Carabidae	Harpalinae	Lebiini	<i>Calleida</i> Dejean, 1824
16	Carabidae	Harpalinae	Lebiini	<i>Dromius</i> Bonelli, 1810
17	Carabidae	Harpalinae	Lebiini	<i>Paraphaea</i> Bates, 1873
18	Carabidae	Harpalinae	Lebiini	<i>Holcoderus</i> Chaudoir, 1869
19	Carabidae	Harpalinae	Oodini LaFerté- Sénectère, 1851	-
20	Carabidae	Harpalinae	Orthogoniini Schaum, 1857	<i>Orthogonius</i> MacLeay, 1825
21	Carabidae	Harpalinae	Pterostichini Bonelli, 1810	<i>Trigonotoma</i> Dejean, 1828
22	Carabidae	Harpalinae	Sphodrini Laporte, 1834	<i>Calathus</i> Bonelli, 1810
23	Carabidae	Scaritinae Bonelli, 1810	Scaratini Bonelli, 1810	<i>Scarites</i> Fabricius, 1775
24	Carabidae	Scaritinae	Clivinini Rafinesque, 1815	<i>Clivina</i> Latreille, 1802
25	Cerambycidae Latreille, 1802	Cerambycinae Latreille, 1802	-	-
26	Cerambycidae	Cerambycinae	Clytini Mulsant, 1839	<i>Xylotrechus</i> Chevrolat, 1825

Table 1 contd.

MSSN	Family	Subfamily	Tribe	Genus
27	Cerambycidae	Cerambycinae	Cerambycini Latreille, 1802	-
28	Cerambycidae	Cerambycinae	Cerambycini	<i>Derolus</i> Gahan, 1891
29	Cerambycidae	Cerambycinae	Pyrestini Lacordaire, 1868	<i>Pyrestes</i> Pascoe, 1857
30	Cerambycidae	Lamiinae Latreille, 1825	Mesosini Muslant, 1839	<i>Coptops</i> Audinet-Serville, 1832
31	Chelonariidae Blanchard, 1845	--	--	<i>Chelonarium</i> Fabricicius, 1801
32	Chrysomelidae Latreille, 1802	Bruchinae Latreille, 1802	Bruchini Latreille, 1802	<i>Callosobruchus</i> Pic, 1902
33	Chrysomelidae	Cryptocephalinae Gyllenhal, 1813	Cryptocephalini Gyllenhal, 1813	<i>Cryptocephalus</i> Geoffroy, 1762
34	Chrysomelidae	Cryptocephalinae	Cryptocephalini	<i>Cryptocephalus</i>
35	Chrysomelidae	Eumolpinae Hope, 1840	Typophorini Baly, 1865	<i>Basilepta</i> Baly, 1860
36	Chrysomelidae	Eumolpinae	-	-
37	Chrysomelidae	Galerucinae Latreille, 1802	Hylaspini Chapuis, 1875	<i>Dercetina</i> Gressitt- Kimoto, 1963
38	Chrysomelidae	Galerucinae	Alticini Newman, 1834	-
39	Cleridae Latreille, 1802	-	-	-
40	Cleridae	-	-	-
41	Coccinellidae Latreille, 1807	Coccinellinae Latreille, 1807	Chilocorini Muslant, 1846	<i>Brumoides</i> Chapin, 1965
42	Coccinellidae	Coccinellinae	Chilocorini	<i>Chilocorus</i> Leach, 1815

Table 1 contd.

MSSN	Family	Subfamily	Tribe	Genus
43	Coccinellidae	Coccinellinae	Chnoodini Muslant, 1850	<i>Sumnius</i> Weise, 1892
44	Coccinellidae	Coccinellinae	Chnoodini	<i>Sumnius</i>
45	Coccinellidae	Coccinellinae	Chnoodini	<i>Sumnius</i>
46	Coccinellidae	Coccinellinae	Coccinellini Latreille, 1807	<i>Menochilus</i> Timberlake, 1943
47	Coccinellidae	Coccinellinae	Coccinellini	<i>Coccinella</i> Linnaeus, 1758
48	Coccinellidae	Coccinellinae	Coccinellini	<i>Phrynocaria</i> Timberlake, 1943
49	Coccinellidae	Coccinellinae	Noviini Muslant, 1846	<i>Rodolia</i> Muslant, 1850
50	Coccinellidae	Coccinellinae	Noviini	<i>Rodolia</i>
51	Coccinellidae	Coccinellinae	Noviini	<i>Rodolia</i>
52	Coccinellidae	Coccinellinae	Noviini	<i>Rodolia</i>
53	Coccinellidae	Coccinellinae	Noviini	<i>Rodolia</i>
54	Coccinellidae	Coccinellinae	Noviini	<i>Rodolia</i>
55	Coccinellidae	Coccinellinae	Ortaliini Muslant, 1850	<i>Ortalia</i> Muslant, 1850
56	Coccinellidae	Coccinellinae	Ortaliini	<i>Ortalia</i>
57	Curculionidae Latreille, 1802	Entiminae Schönherr, 1823	-	-
58	Curculionidae	Entiminae	-	-
59	Curculionidae	Entiminae	-	-
60	Curculionidae	Entiminae	-	-
61	Curculionidae	-	-	-

Table 1 contd.

MSSN	Family	Subfamily	Tribe	Genus
62	Curculionidae	Scolytinae Latreille, 1804	-	-
63	Curculionidae	-	-	-
64	Curculionidae	-	-	-
65	Curculionidae	-	-	-
66	Curculionidae	-	-	-
67	Dryophthoridae Schönherr, 1825	-	-	-
68	Elateridae Leach, 1815	Agrypninae Candèze, 1857	Agrypnini Candèze, 1857	<i>Agrypnus</i> Eschscholtz, 1829
69	Elateridae	Agrypninae	Agrypnini	<i>Adelocera</i> Latreille, 1829.
70	Elateridae	Cardiophorinae Candèze 1859	-	<i>Paracardiophorus</i> Schwarz, 1895
71	Elateridae	Elaterinae Leach, 1815	Megapenthini Gurjeva, 1973	<i>Melanoxanthus</i> Eschscholtz, 1829
72	Elateridae	Elaterinae	Melanotini Candèze, 1859	<i>Melanotus</i> Eschscholtz, 1829
73	Elateridae	Elaterinae	-	<i>Melanotus</i>
74	Histeridae Gyllenhal, 1808	-	-	-
75	Histeridae	-	-	-
76	Hybosoridae Erichson, 1847	Hybosorinae Erichson, 1847	-	<i>Hybosorus</i> MacLeay, 1819
77	Lucanidae Latreille, 1804	Lucaninae Latreille, 1804	Lucanini Latreille, 1804	<i>Figulus</i> MacLeay, 1819
78	Melyridae Leach, 1815	-	-	-

Table 1 contd.

MSSN	Family	Subfamily	Tribe	Genus
79	Melyridae	Malachiinae Fleming, 1821	-	-
80	Nitidulidae Latreille, 1802	-	-	-
81	Nitidulidae	-	-	-
82	Nitidulidae	-	-	-
83	Nitidulidae	-	-	-
84	Nitidulidae	-	-	-
85	Prionoceridae Latreille, 1802	-	-	-
86	Prionoceridae	-	Prionocerini Majer, 1987	<i>Idgia</i> Laporte, 1836
87	Salpingidae Leach, 1815	Othniinae LeConte, 1861	--	<i>Elacatis</i> Pascoe, 1860
88	Scarabaeidae Latreille, 1802	Melolonthinae Leach, 1819	Diplotaxini Kirby, 1837	<i>Apogonia</i> Kirby, 1819
89	Scarabaeidae	Melolonthinae	Melolonthini	-
90	Scarabaeidae	Melolonthinae	Melolonthini	-
91	Scarabaeidae	Melolonthinae	Melolonthini	<i>Holotrichia</i> Hope, 1837
92	Scarabaeidae	Melolonthinae	Sericini Kirby, 1837	<i>Maladera</i> Muslant, 1842
93	Scarabaeidae	Melolonthinae	Sericini	<i>Maladera</i>
94	Scarabaeidae	Melolonthinae	Sericini	-
95	Scarabaeidae	Melolonthinae	Sericini	-
96	Scarabaeidae	Melolonthinae	Sericini	-
97	Scarabaeidae	Melolonthinae	Sericini	-

Table 1 contd.

98	Scarabaeidae	Rutelinae MacLeay, 1819	Adoretini Burmeister, 1844	<i>Adoretus</i> Dejean, 1833
99	Scarabaeidae	Rutelinae	Adoretini	<i>Adoretus</i>
100	Scarabaeidae	Rutelinae	Adoretini	<i>Adoretus</i>
101	Scarabaeidae	Rutelinae	Adoretini	<i>Adoretus</i>
102	Scarabaeidae	Rutelinae	Anomalini Streubel, 1839	<i>Anomala</i> Samouelle, 1819
103	Scarabaeidae	Rutelinae	Anomalini	-
104	Scarabaeidae	Scarabaeinae Latreille, 1802	-	-
105	Scarabaeidae	Scarabaeinae	Coprini Leach, 1815	<i>Catharsius</i> Hope, 1837
106	Scarabaeidae	Scarabaeinae	Coprini	<i>Catharsius</i>
107	Scarabaeidae	Scarabaeinae	Coprini	<i>Catharsius</i>
108	Scarabaeidae	Scarabaeinae	Coprini	<i>Copris</i> Geoffroy, 1762
109	Scarabaeidae	Scarabaeinae	Coprini	<i>Copris</i>
110	Scarabaeidae	Scarabaeinae	Gymnopleurini Lacordaire, 1856	<i>Paragymnopleurus</i> Shipp, 1897
111	Scarabaeidae	Scarabaeinae	Onthophagini Burmeister, 1846	<i>Onthophagus</i> Latreille, 1802
112	Scarabaeidae	Scarabaeinae	Onthophagini	<i>Onthophagus</i>
113	Scarabaeidae	Scarabaeinae	Onthophagini	<i>Onthophagus</i>
114	Scarabaeidae	Scarabaeinae	Onthophagini	<i>Onthophagus</i>
115	Scarabaeidae	Scarabaeinae	Onthophagini	<i>Onthophagus</i>
116	Scarabaeidae	Scarabaeinae	Onthophagini	<i>Onthophagus</i>
117	Scarabaeidae	Scarabaeinae	Onthophagini	<i>Onthophagus</i>

Table 1 contd.

MSSN	Family	Subfamily	Tribe	Genus
118	Scarabaeidae	Scarabaeinae	Onthophagini	<i>Onthophagus</i>
119	Scarabaeidae	Scarabaeinae	Onthophagini	<i>Onthophagus</i>
120	Scarabaeidae	Scarabaeinae	Onthophagini	<i>Onthophagus</i>
121	Scarabaeidae	Scarabaeinae	Onthophagini	<i>Onthophagus</i>
122	Scarabaeidae	Scarabaeinae	Sisyphini Muslant, 1842	<i>Sisyphus</i> Latreille, 1807
123	Silvanidae Kirby, 1837	-	-	-
124	Tenebrionidae Latreille, 1802	-	-	-
125	Tenebrionidae	-	-	-
126	Tenebrionidae	Diaperinae Latreille, 1802	Leiochrini Lewis, 1894	-
127	Tenebrionidae	Lagriinae Latreille, 1825	Lupropini Ardoin, 1958	<i>Luprops</i> Hope, 1833
128	Tenebrionidae	Lagriinae	Lagriini Latreille, 1825	<i>Cerogria</i> Borchmann, 1909
129	Tenebrionidae	Stenochiinae Kirby, 1837	Stenochiini Kirby, 1837	<i>Strongylium</i> Kirby, 1819
130	Tenebrionidae	Stenochiinae	Cnodalonini Oken, 1843	<i>Hemicera</i> Laporte & Brulle, 1831
131	Tenebrionidae	Tenebrioninae Latreille, 1802	Amarygmini Gistel, 1848	-
132	Tenebrionidae	Tenebrioninae	Triboliini Gistel, 1848	<i>Tribolium</i> MacLeay, 1825
133	Tenebrionidae	Tenebrioninae	Opatrini Brullé, 1832	<i>Gonocephalum</i> Solier, 1834
134	Tenebrionidae	Tenebrioninae	Opatrini	<i>Gonocephalum</i>

Table 1 contd.

MSSN	Family	Subfamily	Tribe	Genus
135	Tenebrionidae	Tenebrioninae	Opatrini	<i>Gonocephalum</i>
136	Trogossitidae Latreille, 1802	Peltinae Latreille, 1806	Ancyronini Kolibáč, 2006	-
137	Trogossitidae	-	-	-
138	Trogossitidae	-	-	-
139	Trogossitidae	-	-	-
140	Zopheridae Solier, 1834	Colydiinae Billberg, 1820	Gempylodini Sharp, 1893	<i>Gempylodes</i> Pascoe, 1863
141	Zopheridae	Zopherinae Solier, 1834	Monommatini Blanchard, 1845	<i>Monomma</i> Klug, 1833
142	Zopheridae	Zopherinae	Monommatini	<i>Monomma</i>

MSSN; Morpho-species serial number, -; Unidentified, --; Not applicable

Abundance of each morphospecies collected in each traps and total is given in Annex 3, 4, 5, 6 and 7.

Scarabaeidae was the most speciose family with 35 morphospecies which accounted 24.5% of the total collected species, followed by Carabidae (19), Coccinellidae (16), Tenebrionidae (13) and Curculionidae (10) with 13.3%, 11.2%, 9.1% and 7 % of the total collected species respectively (Table 1, Fig 6). Hybosoridae was the most abundant family with 10092 individuals which is 40% of the total specimens, followed by Scarabaeidae (9781) and Coccinellidae (2512) which are 38.78% and 9.96 % of the total specimens collected respectively (Fig 6). Collectively these three families represent 88.7% of collected specimens.

Subfamily Scarabaeinae belonging to Scarabaeidae family was found to be most speciose subfamily with 19 morphospecies, followed by Coccilinae belonging to Coccinellidae family with 16 morphospecies and Harpalinae belonging to Carabidae with 14 morphospecies (Table 1).

Similarly, tribe Onthophagini belonging to Scarabaeidae family was found to be most speciose tribe with 11 morphospecies followed by Lebiini belonging to Carabidae family with 7 morphospecies (Table 1).

Genus *Onthophagus* belonging to Scarabaeidae family was found to be most speciose genus with 11 morphospecies followed by *Rodolia* and *Sericini* of Coccinellidae and Scarabaeidae family, respectively, with 6 morphospecies in each genus (Table 1).

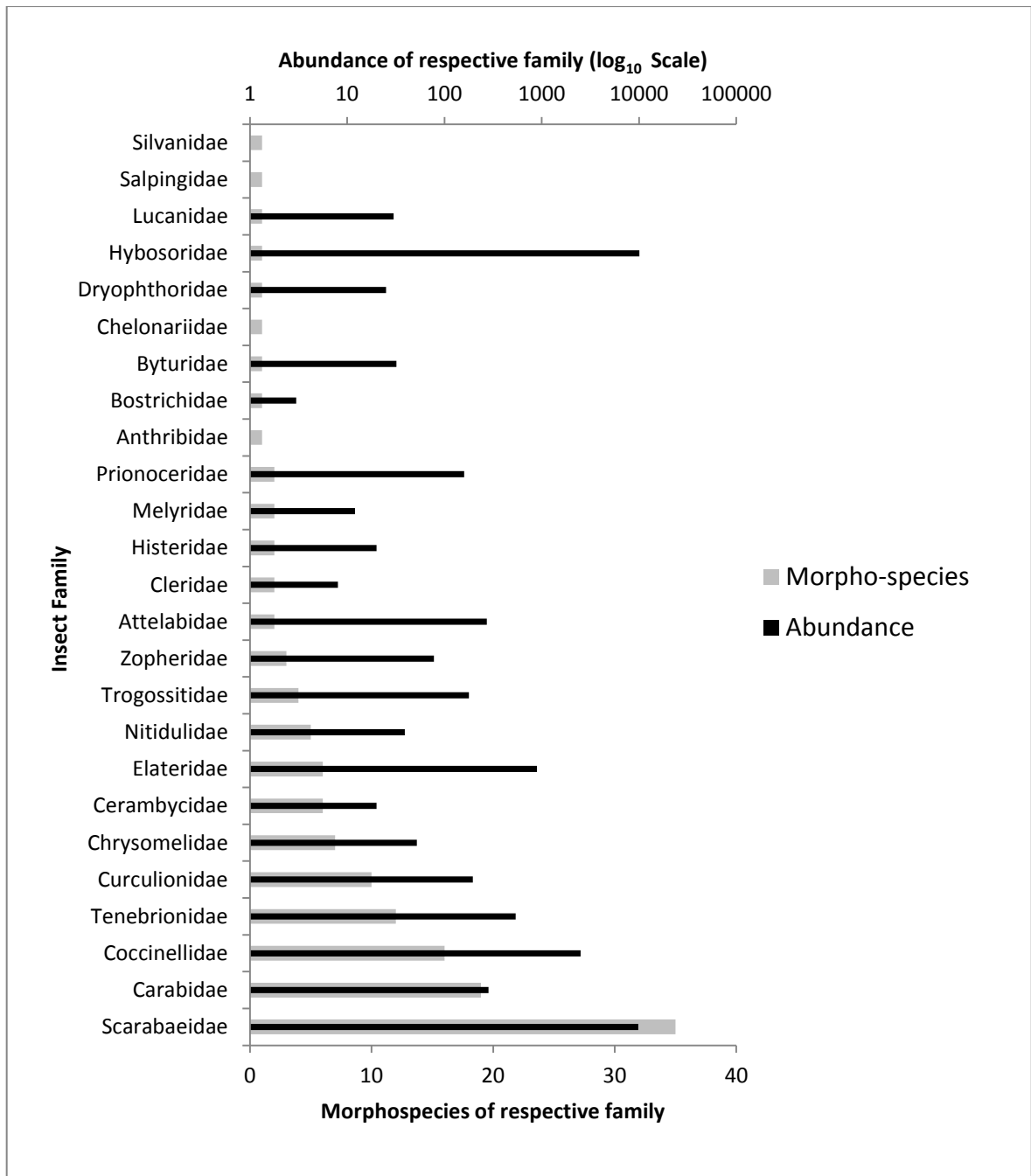
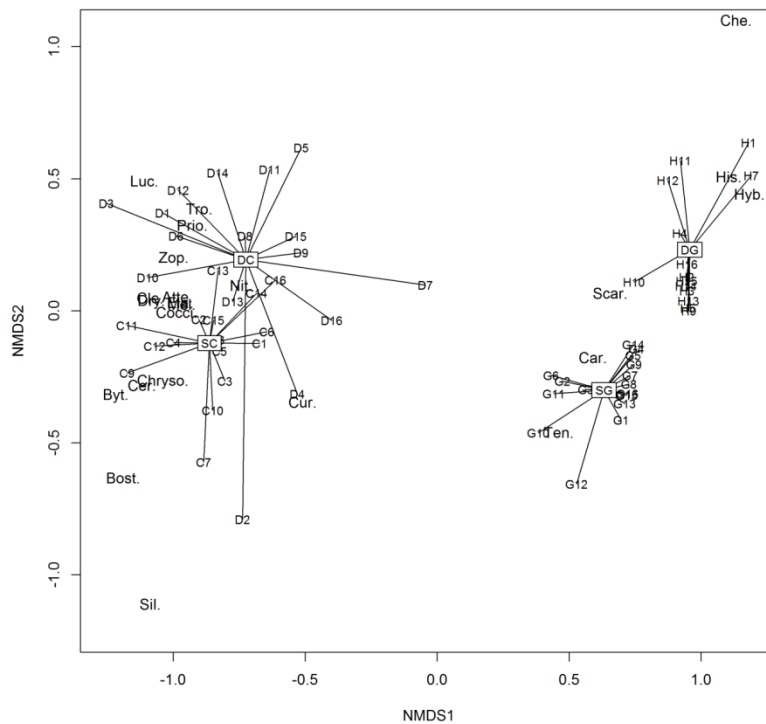


Fig 6. Morphospecies and abundance of respective family of beetles in Chitwan National Park.

NMDS analysis (Stress =0.102) showed that the global assemblages (*Shorea* canopy, *Shorea* ground, *Dalbergia* canopy and *Dalbergia* ground) were well separated (Fig 7) from each other.



A global test with two non-parametric multivariate statistical tests (Adonis and ANOSIM) showed significant differences ($P < 0.05$) in beetle community structure among all habitats (Table 5). SIMPER test showed that the cumulative contributions of Coccinellidae, Scarabaeidae and Elateridae were the most influential families to make this significant difference (Table 6).

Fig 7. NMDS of the abundance data in Chitwan National Park, using Bray-Curtis similarity as the pair wise distances among samples (SC: *Shorea* canopy, DC: *Dalbergia* canopy, SG: *Shorea* ground, DG: *Dalbergia* ground, C: canopy trap in *Shorea*, G: ground trap in *Shorea*, D: canopy trap in *Dalbergia*, H: ground trap in *Dalbergia*, numbers indicate trap numbers)

4.2 Taxonomic composition of beetle communities

4.2.1 *Shorea robusta* forest and *Dalbergia sissoo* forest

Of the total collected beetles, 111 morphospecies with 9743 individuals belonging to 22 families were collected in *Shorea* forest compared to 84 morphospecies with 15485 individuals belonging to 22 families in *Dalbergia* forest (Table 2).

Morphospecies of Tenebrionidae are found to be significantly different between *Shorea* forest and *Dalbergia* forest whereas abundance of Attelabidae, Byturidae, Carabidae, Cerambycidae, Chrysomelidae, Coccinellidae, Curculionidae, Dryophthoridae, Elateridae, Histeridae, Hybosoridae, Prionoceridae, Scarabaeidae, Tenebrionidae, Trogossitidae and Zopheridae family was found to be significantly different between *Shorea* forest and *Dalbergia* forest (Table 2).

Numbers of total morphospecies were found to be statistically similar; however, numbers of total individuals were found to be significantly different in two types of forest (Table 2).

Table 2. Morphospecies and abundance of beetles in canopy layer, ground layer, *Shorea* forest and *Dalbergia* forest

Family	Morphospecies		Abundance		Morphospecies		Abundance	
	C	G	C	G	S	D	S	D
Anthribidae	1	0	1	0	0	1	0	1
Attelabidae	2	0	272	0	1	1	260	12
Bostrichidae	1	0	3	0	1	0	3	0
Byturidae	1	0	32	0	1	0	32	0
Carabidae	9	10	101	183	16	10	196	88
Cerambycidae	6	0	20	0	5	1	19	1
Chelonariidae	0	1	0	1	0	1	0	1
Chrysomelidae	7	0	52	0	4	3	42	10
Cleridae	2	0	8	0	1	1	6	2
Coccinellidae	16	0	2512	0	14	6	2342	170
Curculionidae	10	1	162	34	8	7	159	37
Dryophthoridae	1	0	25	0	1	1	16	9
Elateridae	6	0	891	0	6	4	799	92
Histeridae	0	2	0	20	1	2	1	19
Hybosoridae	0	1	0	10092	0	1	0	10092
Lucanidae	1	0	30	0	1	1	14	16
Melyridae	2	0	12	0	1	2	6	6
Nitidulidae	4	1	38	1	4	2	25	14
Prionoceridae	2	0	159	0	2	1	127	32
Salpingidae	1	0	1	0	0	1	0	1
Scarabaeidae	16	19	2773	7008	28	31	5085	4696
Silvanidae	1	0	1	0	1	0	1	0
Tenebrionidae	7	5	116	424	10	2	488	52
Trogossitidae	4	0	178	0	3	3	59	119
Zopheridae	3	0	78	0	2	2	63	15
Total	103	40	7465	17763	111	84	9743	15485

C: Canopy layer, G: Ground layer, S: *Shorea* forest, D: *Dalbergia* forest (Bold numbers within a bordered box indicates significant difference ($p < 0.05$)).

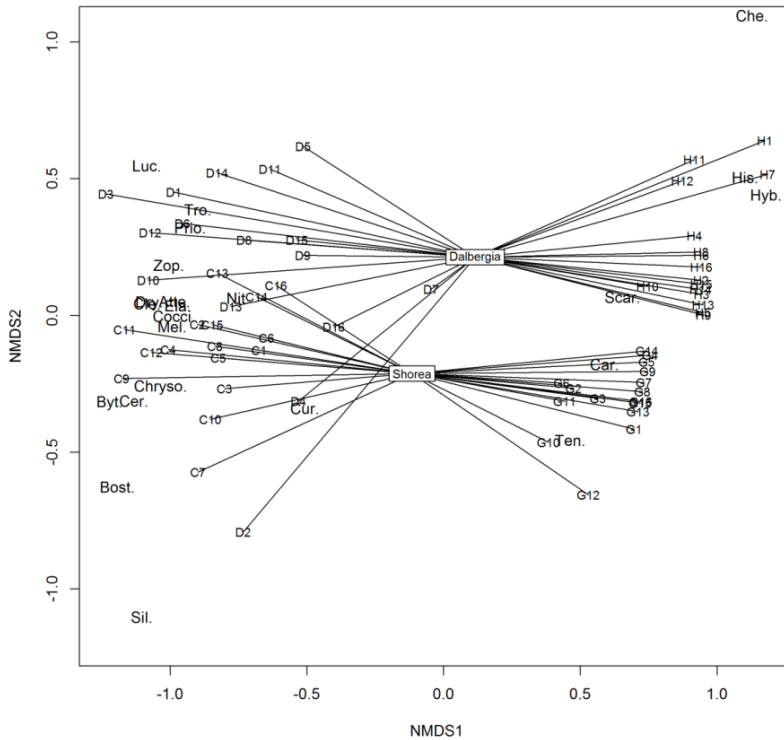


Fig 8. NMDS of the abundance data in Chitwan National park, using Bray-Curtis similarity as the pair wise distances among sample of *Shorea* forest and *Dalbergia* forest (C: canopy trap in *Shorea*, G: ground trap in *Shorea*, D: canopy trap in *Dalbergia*, H: ground trap in *Dalbergia*, numbers indicate trap numbers)

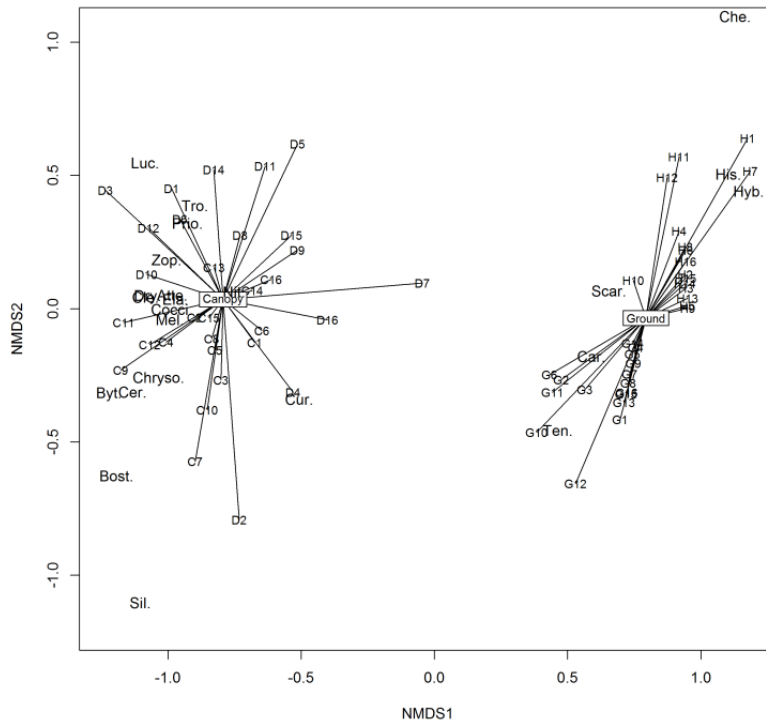
NMDS analysis (Stress =0.0321) showed that the two assemblages (*Shorea* forest and *Dalbergia* forest) were well separated (Fig 8) from each other.

Non-parametric multivariate statistical tests (Adonis, ANOSIM) showed significant differences ($P < 0.05$) in beetle community structure in *Shorea* forest and *Dalbergia* forest (Table 5). SIMPER test showed that the cumulative contributions of Scarabaeidae, Hybosoridae and Coccinellidae are the most influential family to make this significant difference (Table 6).

4.2.2 Canopy layer and ground layer

Similarly, 103 morphospecies with 7465 individuals belonging to 22 families were collected from canopy layer in the study area compared to 40 morphospecies belonging to 8 families in ground layer (Table 2). Numbers of morphospecies belonging to Cerambycidae, Chrysomelidae, Coccinellidae, Elateridae, Trogossitidae families were found to be significantly different in canopy layer and ground layer, and abundance of all of the family except Anthribidae, Bostrichidae, Chelonariidae, Salpingidae and Silvanidae are significantly different in canopy and ground layer (Table 2). Both number of morphospecies and number of individuals were found to be significantly different in canopy layer and ground layer (Table 2).

NMDS analysis (Stress = 0.071) showed that the two assemblages (Canopy and Ground) were well separated (Fig 9).



Non-parametric multivariate statistical tests (Adonis, ANOSIM) showed significant differences ($P < 0.05$) in beetle community structure in canopy and ground layers (Table 5). SIMPER test showed that the cumulative contributions of Scarabaeidae, Hybosoridae and Coccinellidae were the most influential family to make this significant difference (Table 6).

Fig 9. NMDS of the abundance data in Chitwan National park, using Bray-Curtis similarity as the pair wise distances among sample of canopy layer and ground layer (C: canopy trap in *Shorea*, G: ground trap in *Shorea*, D: canopy trap in *Dalbergia*, H: ground trap in *Dalbergia*, numbers indicate trap numbers)

4.2.2.1 Canopy layer of two different forest

Altogether, 80 morphospecies with 6126 individuals belonging to 20 families were collected from Canopy layer of *Shorea* forest compared to 56 morphospecies with 1339 individuals belonging to 19 families in *Dalbergia* forest (Table 3). Both number of morphospecies and number of individuals were found to be significantly different in canopy layer of *Shorea* forest and *Dalbergia* forest (Table 3).

NMDS analysis (Stress = 0.113) showed that the two assemblages (*Shorea* canopy and *Dalbergia* Canopy) were well separated (Fig 10, Fig 7) from each other.

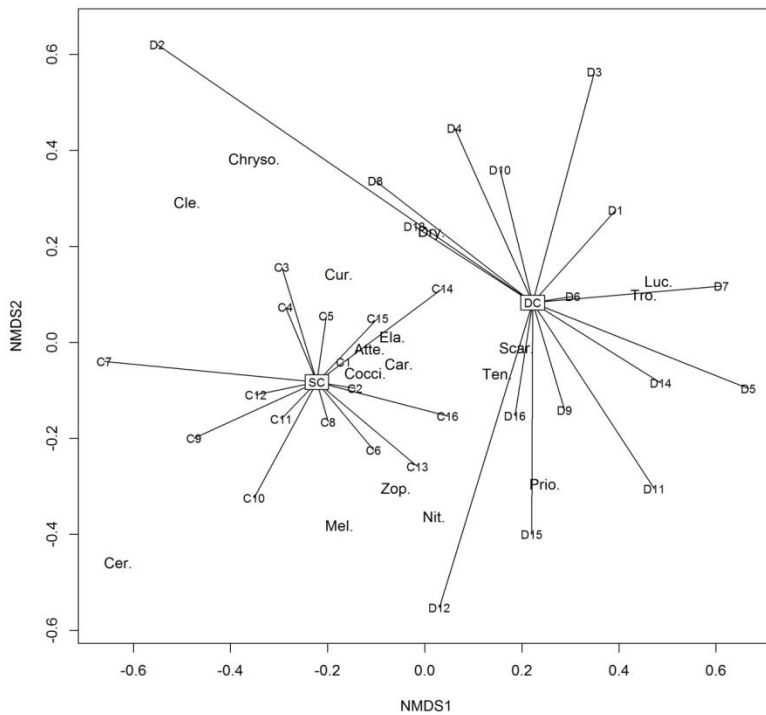


Fig 10. NMDS of the abundance data in Chitwan National Park, using Bray-Curtis similarity as the pair wise distances among sample of canopy layer of *Shorea* forest and canopy layer of *Dalbergia* forest (C: canopy trap in *Shorea*, D: canopy trap in *Dalbergia*, numbers indicate trap numbers) (Table 6).

Non-parametric multivariate statistical tests (adonis, ANOSIM) showed significant differences ($P < 0.05$) in beetle community structure in canopy layer of *Shorea* forest and canopy layer of *Dalbergia* forest (Table 5). SIMPER test showed that the cumulative contributions of Coccinellidae, Scarabaeidae and Elateridae were the most influential family to make this significant difference

4.2.2.2 Ground layer of two different types of forest

Similarly, 32 morphospecies with 3617 specimens belonging to 6 families were collected from ground layer of sal forest compared to 56 morphospecies with 1339 specimens belonging to 6 families in Sisham forest (Table 3). Morphospecies numbers were found to be statistically similar. However, numbers of individuals were found to be significantly different in ground layers of two types of forest.

Table 3. Morphospecies and abundance of beetle family in canopy layer and ground layer of *Shorea* forest and *Dalbergia* forest

Family	C morphospecies		C abundance		G morphospecies		G abundance	
	S	D	S	D	S	D	S	D
Anthribidae	0	1	0	1	0	0	0	0
Attelabidae	1	1	260	12	0	0	0	0
Bostrichidae	1	0	3	0	0	0	0	0
Byturidae	1	0	32	0	0	0	0	0
Carabidae	7	5	78	23	9	5	118	65
Cerambycidae	5	1	19	1	0	0	0	0
Chelonariidae	0	0	0	0	0	1	0	1
Chrysomelidae	4	3	42	10	0	0	0	0
Cleridae	1	1	6	2	0	0	0	0
Coccinellidae	14	6	2342	170	0	0	0	0
Curculionidae	8	7	125	37	1	0	34	0
Dryophthoridae	1	1	16	9	0	0	0	0
Elateridae	6	4	799	92	0	0	0	0
Histeridae	0	0	0	0	1	2	1	19
Hybosoridae	0	0	0	0	0	1	0	10092
Lucanidae	1	1	14	16	0	0	0	0
Melyridae	1	2	6	6	0	0	0	0
Nitidulidae	3	2	24	14	1	0	1	0
Prionoceridae	2	1	127	32	0	0	0	0
Salpingidae	0	1	0	1	0	0	0	0
Scarabaeidae	12	13	2045	728	16	18	3040	3968
Silvanidae	1	0	1	0	0	0	0	0
Tenebrionidae	6	1	65	51	4	1	423	1
Trogossitidae	3	3	59	119	0	0	0	0
Zopheridae	2	2	63	15	0	0	0	0
	80	56	6126	1339	32	28	3617	14146

C: Canopy layer, G: Ground layer, S: *Shorea* forest, D: *Dalbergia* forest (Bold numbers within bordered line indicates significant difference ($p < 0.05$))

NMDS analysis (Stress =0.105) showed that the two assemblages (Ground layer of *Shorea* and Ground layer of *Dalbergia*) were well separated (Fig 7, Fig 11) from each other.

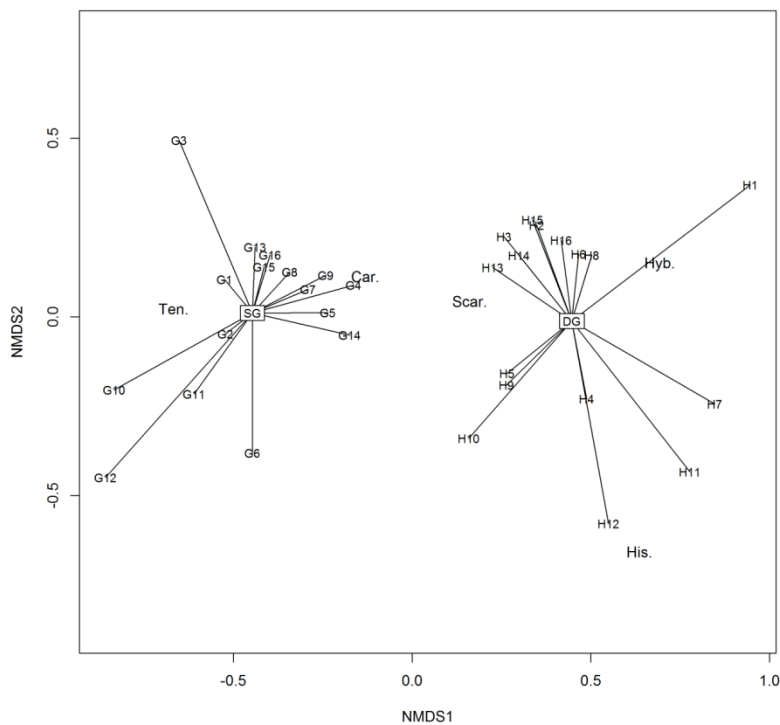


Fig 11. NMDS of the abundance data in Chitwan National park, using Bray-Curtis similarity as the pair wise distances among sample of ground layer of *Shorea* forest and ground layer of *Dalbergia* forest (G: ground trap in *Shorea*, H: ground trap in *Dalbergia*, numbers indicate trap numbers)

Non-parametric multivariate statistical tests (Adonis, ANOSIM) showed significant differences ($P < 0.05$) in beetle community structure in ground layer of *Shorea* forest and ground layer of *Dalbergia* forest (Table 5). SIMPER test showed that the cumulative contributions of Hybosoridae and Scarabaeidae are the most influential family to make this significant difference (Table 6).

4.2.3 Three different seasons

In spring season 95 morphospecies with 6953 specimens belonging to 19 families were collected whereas 106 morphospecies with 13418 specimens belonging to 22 families in summer season and 71 morphospecies with 4857 specimens belonging to 17 families were collected in rainy season (Table 4, Annex 8).

Table 4. Species and abundance of beetles in three different seasons

Family	Species			Abundance		
	Sp	Su	Ra	Sp	Su	Ra
Anthribidae	1	0	0	1	0	0
Attelabidae	2	2	0	203	69	0
Bostrichidae	0	0	1	0	0	3
Byturidae	0	1	1	0	1	31
Carabidae	11	13	8	130	120	34
Cerambycidae	4	3	1	15	4	1
Chelonariidae	0	1	0	0	1	0
Chrysomelidae	6	5	0	27	25	0
Cleridae	0	1	1	0	6	2

Coccinellidae	12	11	9	1711	619	182
Curculionidae	7	6	4	50	84	62
Dryophthoridae	1	1	1	7	7	11
Elateridae	4	5	5	231	567	93
Histeridae	1	2	1	3	8	9
Hybosoridae	1	1	1	145	7405	2542
Lucanidae	0	1	1	0	23	7
Melyridae	1	2	0	7	5	0
Nitidulidae	3	3	0	36	3	0
Prionoceridae	2	1	1	86	43	30
Salpingidae	1	0	0	1	0	0
Scarabaeidae	26	32	24	3903	4142	1736
Silvanidae	0	1	0	0	1	0
Tenebrionidae	9	8	7	296	186	58
Trogossitidae	2	4	2	90	68	20
Zopheridae	1	2	2	11	31	36
Total	95	106	71	6953	13418	4857

Sp; spring, Su; summer, Ra; rainy (Bold numbers within bordered line indicates significant difference ($p < 0.05$))

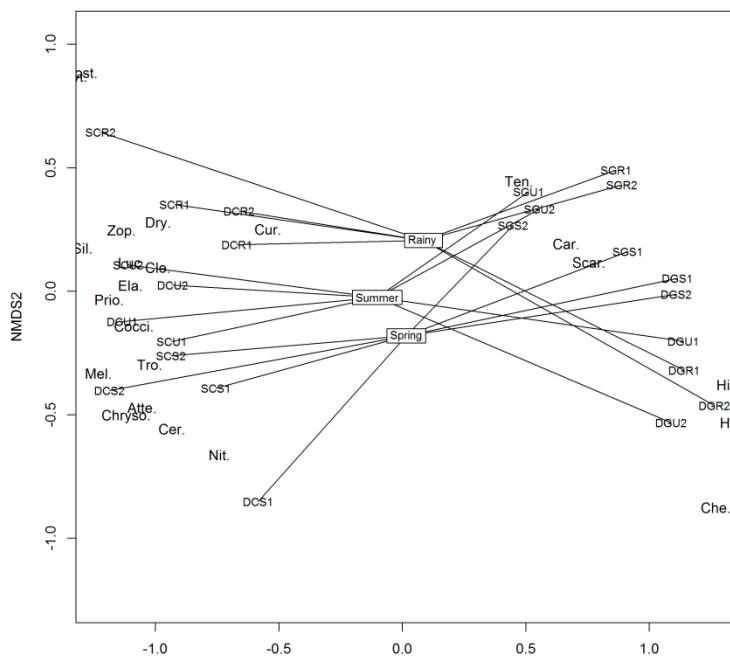


Fig 12. NMDS of the abundance data in Chitwan National park, using Bray-Curtis similarity as the pair wise distances among sample of Spring, Summer and Rainy season (SC: *Shorea* canopy, DC: Dalbergia canopy, SG: *Shorea* ground, DG: Dalbergia ground, S: Spring, U: Summer, R: Rainy, numbers indicate sampling numbers)

NMDS analysis (Stress =0.09) showed that the seasonal assemblages (spring season, summer season and rainy season) were not well separated with overlapping of assemblages of traps with each other (Fig 12).

Non-parametric multivariate statistical tests (adonis, ANOSIM) showed no significant differences ($P < 0.05$) in beetle community structure in spring season, summer season and rainy season (Table 5).

Table 5. Significance tests of the beetle assemblages with two non-parametric statistical approaches

Compared Groups	adonis ^a		ANOSIM ^b	
	F	P	R	P
Global test	33.58	0.001***	0.81	0.001***
S vs. D	10.58	0.001***	0.28	0.001***
C vs. G	21.96	0.001***	0.49	0.001***
SC vs. DC	41.99	0.001***	0.96	0.001***
SG vs. DG	21.24	0.001***	0.61	0.001***
SC vs SG	34.18	0.001***	0.85	0.001***
DC vs DG	41.44	0.001***	0.95	0.001***
Global season	1.032	0.395	0.01	0.376
Spring vs Summer	0.62	0.700	-0.04	0.706
Spring vs Rainy	1.80	0.099.	0.11	0.090
Summer vs Rainy	0.71	0.562	-0.03	0.562

S: *Shorea* forest, D: *Dalbergia* forest, C: canopy layer, G: ground layer, SC: *Shorea* canopy, SG: *Shorea* ground, DC: *Dalbergia* canopy

^aPermutational multivariate analysis of variance using bray Curtis distance matrices. Significance tests were performed using F-tests based on sequential sums of squares from 999 permutations of the raw data.

^bAnalysis of similarities. Statistic R is carried out based on the difference of the mean ranks between groups and within groups. The statistical significance of the observed R is assessed by permuting the grouping vector to obtain the empirical distribution of R under the null mode

Table 6. Most influential families for significant differences in assemblages of compared communities

Compared Group	Most influential Family	Cumulative Contributions
S vs D	Scarabaeidae	0.31
	Hybosoridae	0.63
	Coccinellidae	0.80
C vs G	Scarabaeidae	0.33
	Hybosoridae	0.65
	Coccinellidae	0.81
SC vs DC	Coccinellidae	0.42
	Scarabaeidae	0.69
	Elateridae	0.82
SG vs DG	Hybosoridae	0.69
	Scarabaeidae	0.94
SC vs SG	Coccinellidae	0.40
	Scarabaeidae	0.67
	Elateridae	0.79
DC vs DG	Hybosoridae	0.60
	Scarabaeidae	0.93
SC vs DG	Hybosoridae	0.52
	Coccinellidae	0.71
SG vs DC	Scarabaeidae	0.63
	Tenebrionidae	0.76

S: *Shorea* forest, D: *Dalbergia* forest, C: canopy layer, G: ground layer, SC: *Shorea* canopy, SG: *Shorea* ground, DC: *Dalbergia* canopy DG; *Dalbergia* ground

4.3 Community Characterisation

4.3.1 Species diversity, shared species and turnover

The highest species richness value was obtained in *Shorea* canopy with 80 species recorded, followed by *Dalbergia* canopy (56), *Shorea* ground (32) and *Dalbergia* ground (28) (Table 7). For the Margalef index values, there was no significant variation of diversity between canopy layer of *Shorea* and *Dalbergia*, whereas ground layer of *Shorea* and *Dalbergia* was found to be significant different (Table 7). The Shannon and Simpson indexes both ranked the beetle community of *Dalbergia* canopy as the most diverse followed by *Shorea* canopy, however; Fisher's and Margalef's index ranked the *Shorea* canopy as the most diverse followed by *Dalbergia* canopy (Table 7). The values of the evenness index showed a non-significant difference in abundance distribution between *Shorea* ground and *Dalbergia* canopy (Table 7). All alpha diversity index shows that ground of *Dalbergia* is the least diverse community (Table 7).

Spring season was found to be most diverse in term of Shannon and Simpson index which was not same with the Fisher's and Margalef's index which values ranked the summer season as the most diverse community (Table 7).

Table 7. Diversity indices of beetle in Chitwan National park, 2016

Group		S	H	1-D	F	M	J	D
	CNP (γ)	142	2.86	0.82	19.87	13.91	0.58	0.18
Layer	C (α)	103 ^a	3.20 ^a	0.93 ^a	16.91 ^a	11.44 ^a	0.69 ^a	0.07 ^a
	G (α)	40 ^b	1.85 ^b	0.66 ^b	4.88 ^b	3.99 ^b	0.50 ^b	0.34 ^b
Forest	S (α)	111 ^a	3.55 ^a	0.95 ^a	17.56 ^a	11.98 ^a	0.75 ^a	0.05 ^a
	D (α)	84 ^b	1.75 ^b	0.57 ^b	11.68 ^b	8.60 ^b	0.39 ^b	0.43 ^b
Different layer of different forest	SC (α)	80 ^a	2.98 ^a	0.91 ^a	12.99 ^a	9.06 ^a	0.68 ^a	0.09 ^a
	SG (α)	32 ^b	2.74 ^b	0.90 ^a	4.83 ^b	3.78 ^b	0.79 ^b	0.10 ^a
	DC (α)	56 ^{a*}	3.16 ^c	0.94 ^b	11.82 ^a	7.64 ^a	0.79 ^b	0.06 ^b
	DG (α)	28 ^{b*}	1.29 ^d	0.48 ^c	3.35 ^c	2.83 ^c	0.39 ^c	0.52 ^c
Season	Spring (α)	95 ^a	3.38 ^a	0.95 ^a	15.56 ^a	10.63 ^a	0.74 ^a	0.05 ^a
	Summer (α)	106 ^a	2.26 ^b	0.68 ^b	15.70 ^a	11.05 ^a	0.52 ^b	0.32 ^b
	Rainy (α)	71 ^b	2.22 ^b	0.71 ^b	11.79 ^b	8.25 ^b	0.48 ^c	0.29 ^b

S; Species richness, H; Shannon-Weiner, 1-D; Simpson, F; Fisher's alpha, M; Margalef, J; Pielou's evenness, D: Dominance, C; Canopy layer, G; Ground layer, S; *Shorea* forest, D; *Dalbergia* forest, SC; *Shorea* canopy, SG; *Shorea* ground, DC; *Dalbergia* canopy, DG; *Dalbergia* ground. γ denotes Gamma diversity, α denotes alpha diversity. On a given column, values followed by the same letter are not significantly different among group at $P < 0.05$ by the t-test comparing diversity in PAST software. Two values in a group with * denoted that they are not significantly different regardless of different alphabet.

Pearson correlation value shows that the species richness observed was highly correlated with the number of traps sample and number of individuals collected in *Shorea* canopy ($r=0.92$), *Dalbergia* canopy ($r=0.94$), *Shorea* ground ($r=0.87$), *Dalbergia* ground ($r=0.84$). This is the significant positive correlation ($p < 0.001$) (Fig 13,14).

Shorea and *Dalbergia* forest had shared 53 species whereas canopy and ground layer had shared only 1 species (Table 8).

Canopy layer had high number of shared species where *Shorea* canopy and *Dalbergia* canopy had shared 33 species whereas ground layer of two different types of forest had shared 20 species (Table 8). Chao's Sørensen value for unseen species is given by Chao's Sørensen index estimation (Table 8). Chao's Sørensen index (both observed and estimated for unseen species) was high among canopy layer of two forests than ground layer of two forests (Table 8). Season wise, Chao's Sørensen index was high between summer and rainy season followed by the spring and summer season's pairing (Table 8). Overall, Whittaker species turnover was 0.887, where turnover of canopy and ground layer was found to be nearly 1 (Table 8). Seasonwise, high species turnover was recorded between spring and rainy season followed by turnover of species on summer from that of rainy season (Table 8).

Table 8. Shared species index and turnover of beetles community in Chitwan National Park, 2016

Compared Groups			Total species	Shared species	Chao's Sørensen index obs.	Chao's Sørensen index est.	Whittaker (Beta diversity)
Global test	-	-	142	-	-	-	0.887
S vs. D	111	84	142	53	0.447	0.468	0.451 (βs)
C vs. G	103	40	142	1	0.002	0.002	0.986 (βs)
SC vs. DC	80	56	103	33	0.710	0.817	0.515(βs)
SG vs. DG	32	28	40	20	0.420	0.420	0.333(βs)
SC vs. SG	80	32	111	1	0.003	0.003	0.982(βs)
DC vs. DG	56	28	84	0	0.000	0.000	1.000(βs)
Global season	-	-	142	-	-	-	0.567
Spring vs. Summer	95	106	129	72	0.947	0.948	0.286(βt)
Spring vs. Rainy	95	71	126	40	0.837	0.839	0.521 βt)
Summer vs. Rainy	106	71	120	57	0.971	0.974	0.356 βt)

C; Canopy layer, G; Ground layer, S; *Shorea* forest, D; *Dalbergia* forest, SC; *Shorea* canopy, SG; *Shorea* ground, DC; *Dalbergia* canopy, DG; *Dalbergia* ground. βs; Beta spatial diversity, βt; Beta temporal diversity

4.3.2 Species richness estimation, sampling effort, and rarefaction curves

Computing the mean values obtained from the three abundance based species richness estimators, ABE mean in *Shorea* Canopy, *Shorea* ground, *Dalbergia* canopy and *Dalbergia* ground (94.99, 39.47, 70.68, 29.34), and the observed species richness generated by Mao tau (Table 9), estimated sampling effort was, respectively, 84.22, 81.08, 79.23 and 95.42% (Table 9).

Computing the mean values obtained from the three incidence based species richness estimators, IBE mean in *Shorea* canopy, *Shorea* ground, *Dalbergia* canopy and *Dalbergia* ground (93.69, 39.12, 78.81, 29.80), and the observed species richness

generated by Mao tau (Table 10), estimated sampling effort was, respectively, 85.38, 81.79, 71.06 and 93.97% (Table 10).

Overall Sampling effort of Chitwan National park was found to be 76.75 % (ABE) and 74.77% (IBE). Ground layer was found to be sampled better compared to the Canopy layer in both terms of ABE and IBE (Table 9, Table 10). *Dalbergia* forest with 85.78% sampling effort was sampled comparatively well than *Shorea* forest with 82.04% in terms of species abundance (Table 9), however; this is opposite in incidence based data (Table 10).

ABE Sampling effort was found to be good in rainy season (84.50%) followed by summer (83.33%) where spring stands for 79.63% sampling effort (Table 9).

Sample based rarefaction curve (Fig 14) showed that Mao tau species observed per addition traps in canopy layer was significantly higher ($p < 0.001$, anova) in *Shorea* forest than in *Dalbergia* forest. Similarly Mao tau species observed in ground layer was significantly higher in *Shorea* forest ($p < 0.05$, anova) than in *Dalbergia* forest.

Incidence based estimator curve (Fig 14) showed that 14 species in *Shorea* canopy and 23 species in *Dalbergia* canopy, which were collectable by canopy traps, were not caught. Similarly, 7 and 2 species in *Shorea* ground and *Dalbergia* ground, which were collectable by pitfall traps, were not caught.

Individual based rarefaction curve (Fig 13) showed that the Mao tau species observed per individual in canopy layer was high in *Dalbergia* canopy layer (both observed and estimation) than *Shorea* canopy which was just opposite in ground layer.

Abundance based estimator curve (Fig 13) shows that 15 species in *Shorea* canopy, which are collectable by canopy traps, were not caught which is also similar in case of *Dalbergia* canopy. Similarly, 7 species and 1 species in *Shorea* ground and *Dalbergia* ground, which are collectable by pitfall traps, were not caught.

Table 9. Abundance based estimation of species richness

	S_{obs} (Mao Tau)	Singletons	Doubletons	ACE mean	Chao1 mean	Jack1 mean	Mean ABE	SE%
CNP	142	31	10	188.54	190.05	176.45	185.01	76.75
C	103	25	10	138.57	134.25	131.09	134.64	76.50
G	40	6	0	48.83	55.00	45.81	49.88	80.19
S	111	19	5	128.44	147.1	130.38	135.31	82.04
D	84	15	5	96.91	95.43	101.44	97.93	85.78
SC	80	14	5	91.31	99.60	94.06	94.99	84.22
SG	32	5	0	39.71	42.00	36.69	39.47	81.08
DC	56	13	5	68.14	72.89	71.00	70.68	79.23
DG	28	2	0	29.15	29	29.88	29.34	95.42
Spring	95	18	8	111.78	115.25	130.88	119.30	79.63
Summer	106	16	6	117.64	127.33	136.63	127.2	83.33
Rainy	71	10	6	78.1	79.33	94.63	84.02	84.50

C; Canopy layer, G; Ground layer, S; *Shorea* forest, D; Dalbergia forest, SC; *Shorea* canopy, DC; Dalbergia canopy, SG; *Shorea* ground, DG; Dalbergia ground, ABE; Abundance based estimators, SE; Sampling effort, obs; Observed

Table 10. Incidence based estimation of species richness

	S_{obs} (Mao Tau)	Unique	Duplicates	ICE mean	Chao2 mean	Jack2 mean	Mean IBE	SE%
CNP	142	35	11	173.10	196.81	199.87	189.93	74.77
C	103	29	11	131.46	140.03	148.30	139.93	73.61
G	40	6	0	43.39	54.43	51.44	49.75	80.40
S.r.	111	20	0	122.98	132.53	140.96	132.16	83.99
D.r	84	18	4	95.43	123.23	114.68	111.11	75.60
SC	80	15	9	89.52	91.72	99.84	93.69	85.38
SG	32	5	0	34.93	41.38	41.06	39.12	81.79
DC	56	16	4	68.69	86.00	81.73	78.81	71.06
DG	28	2	7	28.82	28.94	31.63	29.80	93.97

C; Canopy layer, G; Ground layer, S; *Shorea* forest, D; Dalbergia forest, SC; *Shorea* canopy, DC; Dalbergia canopy, SG; *Shorea* ground, DG; Dalbergia ground, ICE; Incidence based estimators, SE; Sampling effort, obs; Observed

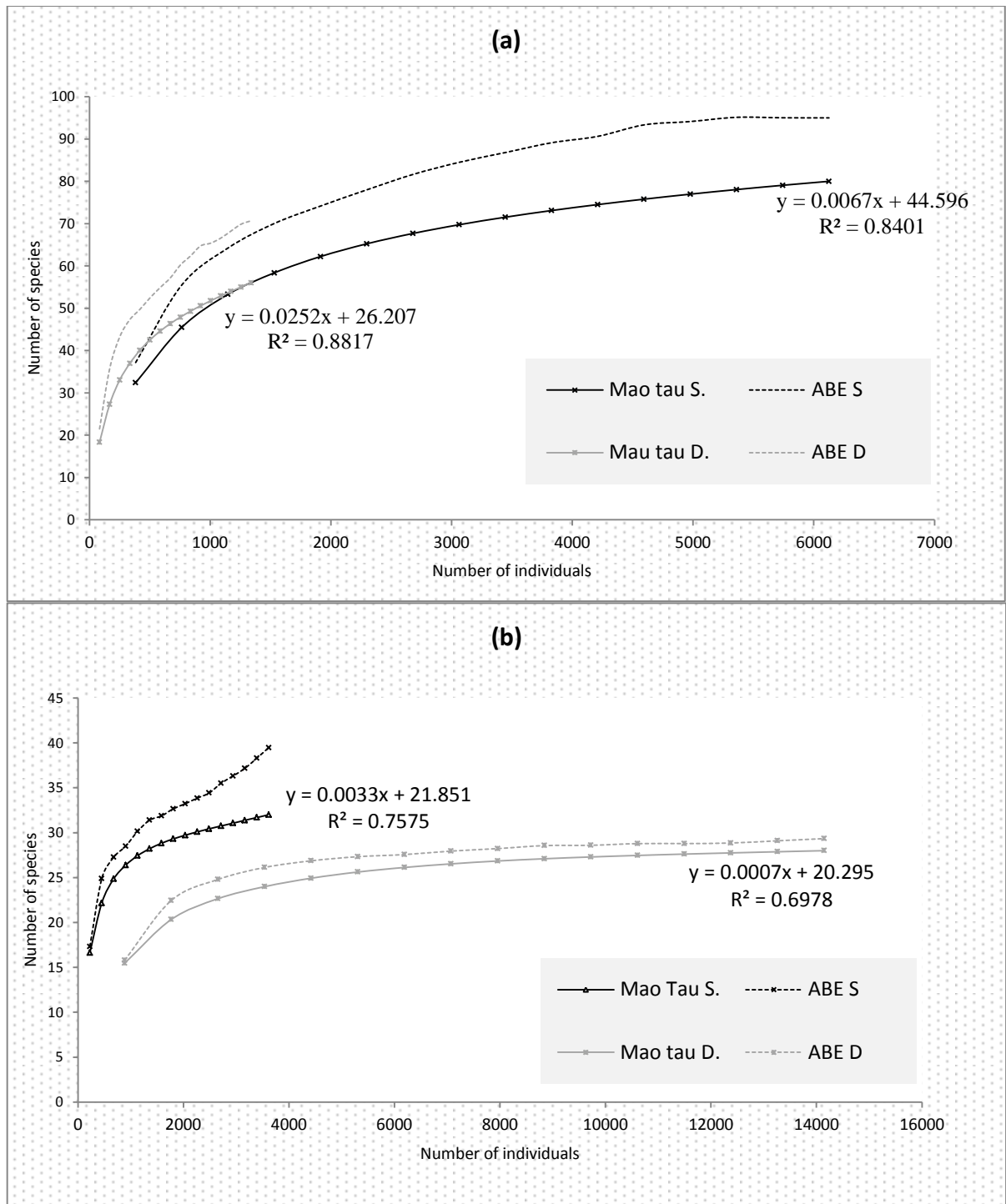


Fig 13. Individual based rarefaction curve of canopy and ground layer of two types of forest, a: *Shorea* Canopy and *Dalbergia* Canopy (S: *Shorea*, D: *Dalbergia*, ABE: Abundance Based Estimation), b: *Shorea* Ground and *Dalbergia* Ground (S:*Shorea*, D: *Dalbergia*, ABE: Abundance Based Estimation)

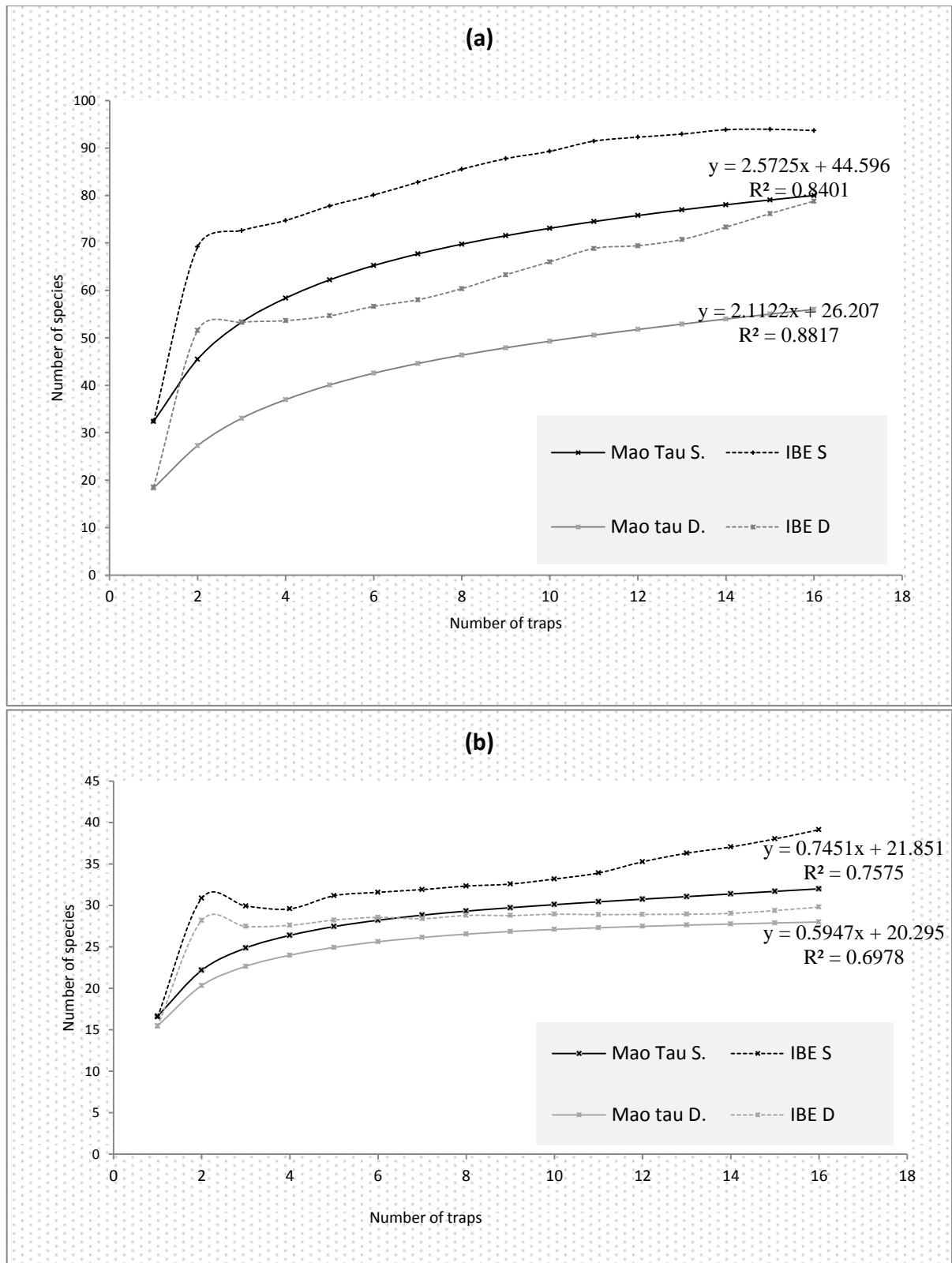


Fig 14. Traps (sample) based rarefaction curve of canopy and ground layer of two types of forest, a: *Shorea* Canopy and *Dalbergia* Canopy (S: *Shorea*, D: *Dalbergia*, IBE: Incidence Based Estimation), b: *Shorea* Ground and *Dalbergia* Ground (S:*Shorea*, D: *Dalbergia*, IBE: Incidence Based Estimation)

4.3.3 Species rank-abundance curve

Rank abundance curve is presented in 2D chart with species abundance on the Y axis and abundance rank on the X-axis. Curve is compared to distribution models given by Magurran (1988) which is depicted in Fig 15 (Inset). The species rank-abundance curves (Fig 15) shows that the ground layer of *Dalbergia* has the steepest curve, followed by ground layer of *Shorea* forest, canopy layer of *Dalbergia* and canopy layer of *Shorea* (Fig 15d). The ground layer of *Dalbergia* curve resembles the geometric series distribution. Species abundance patterns portrayed by the ground layer of *Shorea* curve grade into the log series distribution. The shallower but protracted curves of canopy layer of both *Shorea* and *Dalbergia* followed the log normal distribution. Ground layer of Chitwan National park resembles geometric series distribution, unlike it; Canopy layer of Chitwan National park curve depicts the log normal distribution (Fig 15c).

Shorea forest follows log normal distribution whereas *Dalbergia* forest follows the log series distribution (Fig 15b).

Overall the species abundance curve of Chitwan National park has shallower curve which fits with the log series distribution (Fig 15a).

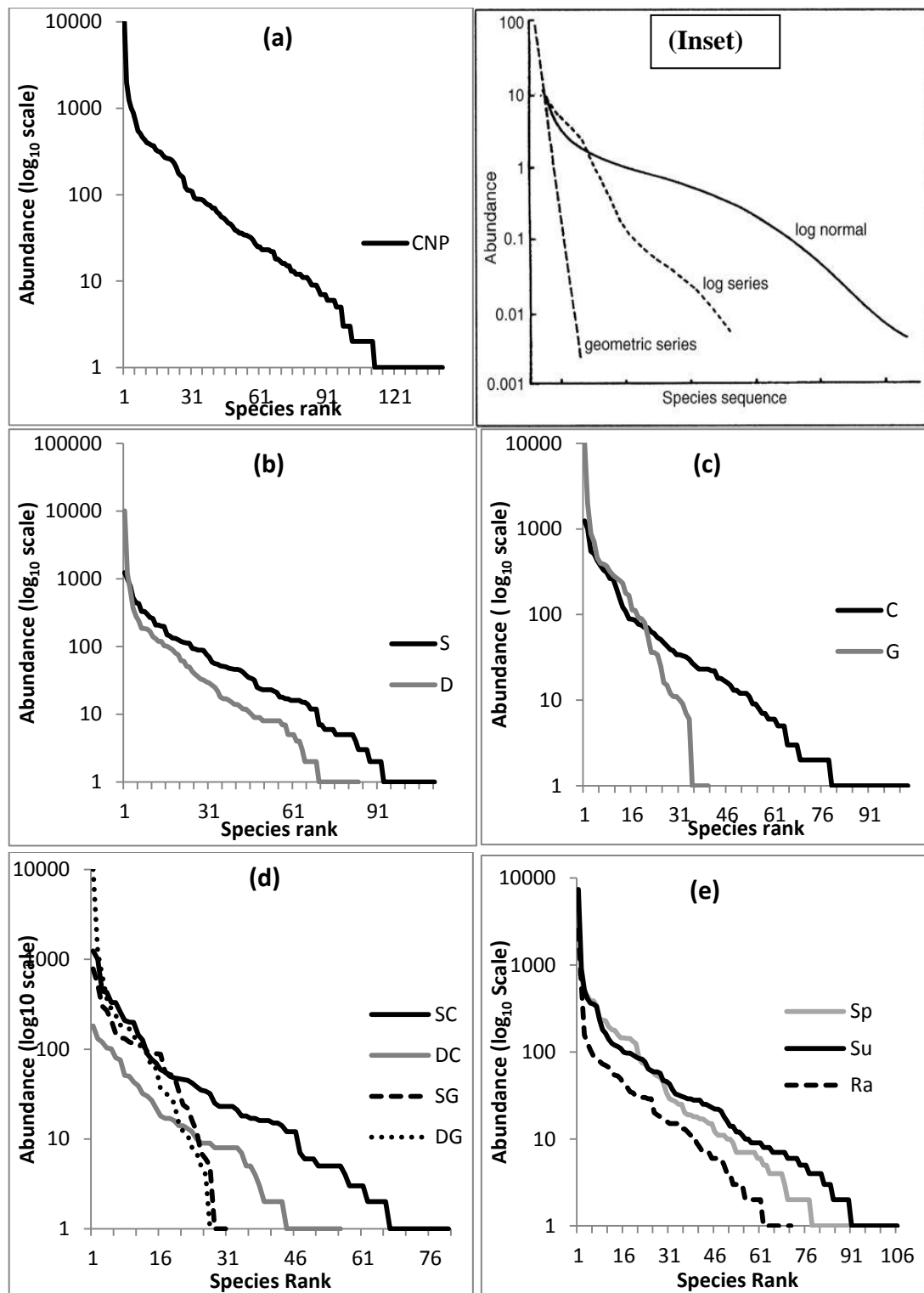


Fig 15. Species rank-abundance curves for the total beetle samples: (a); Chitwan National park, (b); S and D (*Shorea* forest and *Dalbergia* forest), (c); C and G (Canopy layer and Ground layer), (d); SC, DC, SG, DG (*Shorea* canopy, *Dalbergia* Canopy, *Shorea* ground, *Dalbergia* ground), (e); Sp, Su, Ra (Spring season, Summer season and Rainy season), Inset: hypothetical distribution models from Magurran (1988).

4.4 Beetle composition relation with environmental variables

4.4.1 Ground layer beetles and Soil properties

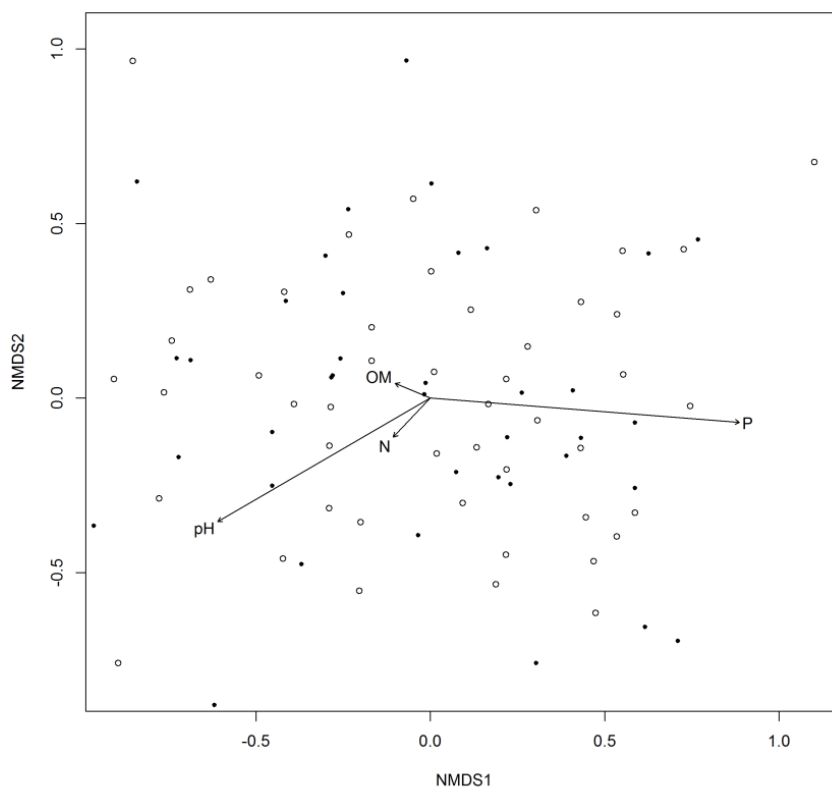


Fig 16. NMDS of the abundance data in Chitwan National park, using Bray-Curtis similarity as the pair wise distances among ground layer sample and their envfit correlations for abiotic environmental factor (OM: Organic Matter, N: Nitrogen, P: Phosphorus) (Annex 10)

NMDS analysis (Stress =0.198) showed that the pH value and phosphorus amount of the soil show a statistical significant relationship with the composition of ground layer beetles whereas Nitrogen and Organic matter present in the soil matter was not found to have a significant relationship with the ground layer beetles (Table 14, Fig 17).

Table 11. NMDS value of soil properties with ground layer beetles of Chitwan National Park, 2016

	NMDS1	NMDS2	r2	Pr(>r)
pH	-0.864	-0.502	0.378	0.001 ***
OM	-0.923	0.382	0.009	0.819
N	-0.689	-0.724	0.018	0.660
P	0.996	-0.078	0.602	0.001 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

OM: Organic matter, N: Nitrogen, P: Phosphorus

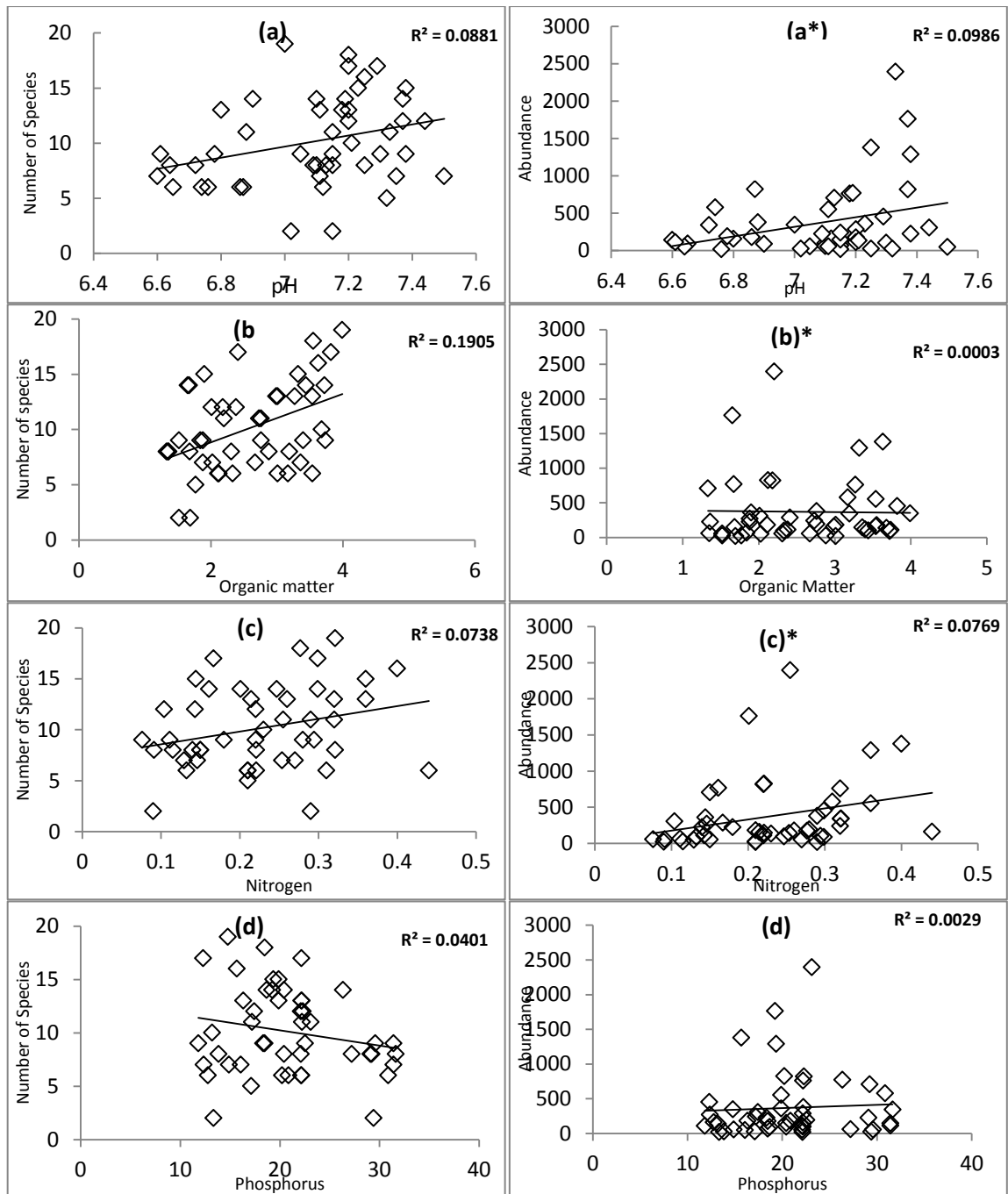


Fig 17. Linear relationship in scatterplot plotted against number of species and abundance with soil properties (a: pH, b: Organic matter, c: Nitrogen, d: Phosphorus). On a given row, alphabet denotes relationship with number with species and asterisk in alphabet denotes relationship with abundance. R^2 ; coefficient of determination fitting the given line.

4.4.2 Canopy layer and tree properties

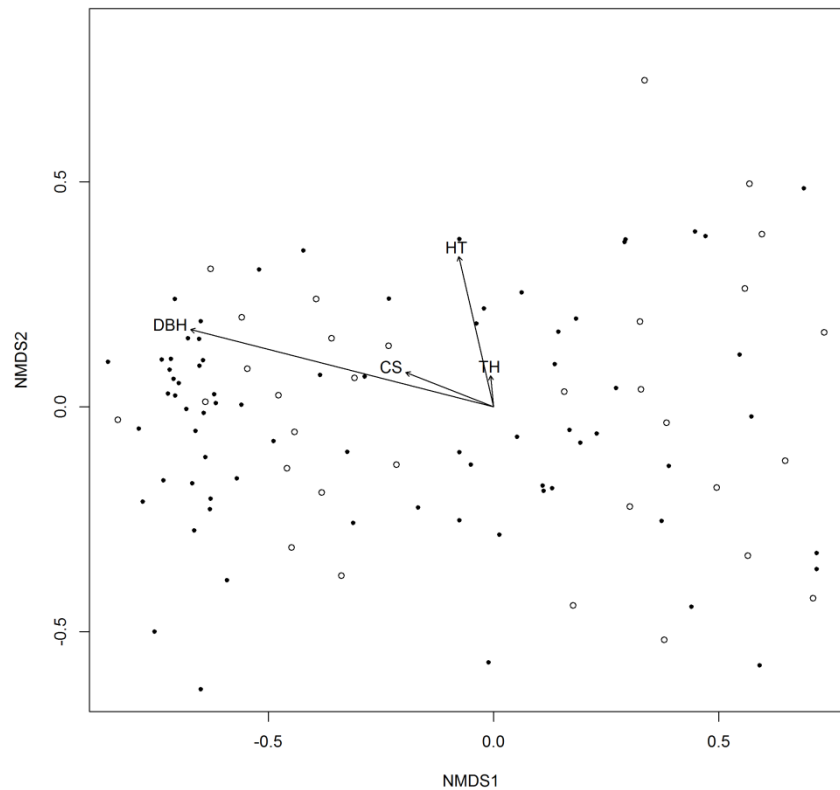


Fig 18. NMDS of the abundance data in Chitwan National park, using Bray-Curtis similarity as the pair wise distances among canopy layer sample and their envfit correlations for biotic environmental factor (DBH; Diameter at Breast height, CS; Crown size, TH: Trap Height, HT: Height of Tree) (Annex 9)

NMDS analysis (Stress =0.195) showed that thy DBH shows the relationship with the beetle composition ($p < 0.1$) whereas Crown size, Tree height and variation of Trap height in canopy layer was not found to have significant relationship with canopy layer beetles composition (Table 12). Beetle species were found to be significantly positively correlated with DBH (Table 14, Fig 19).

Table 12. NMDS value of tree properties with canopy layer beetles of Chitwan National park

	NMDS1	NMDS2	r2	Pr(>r)
DBH	-0.969	0.247	0.139	0.081 .
CS	-0.931	0.364	0.013	0.833
TH	-0.097	0.995	0.001	0.983
HT	-0.225	0.974	0.033	0.600

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1, CS; Crown size, TH; Trap height, HT; Tree height

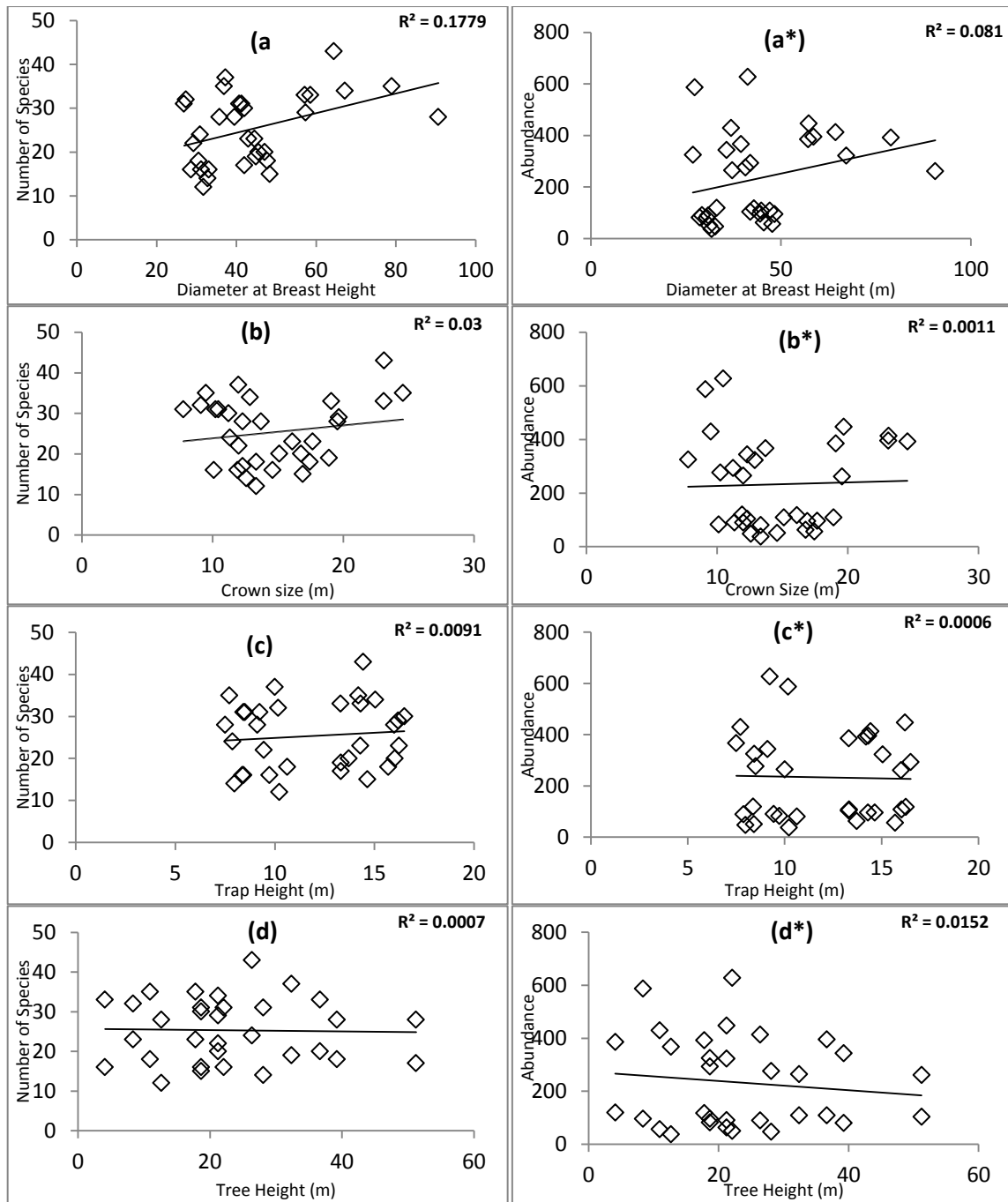


Fig 19. Linear relationship in scatterplot plotted against number of species and abundance with tree properties (a; DBH, b; Crown size, c; Trap height, d; Tree height). On a given row, alphabet denotes relationship with number with species and asterisk in alphabet denotes relationship with abundance. R^2 ; coefficient of determination fitting the given line.

4.4.3 Beetles and climatic factors

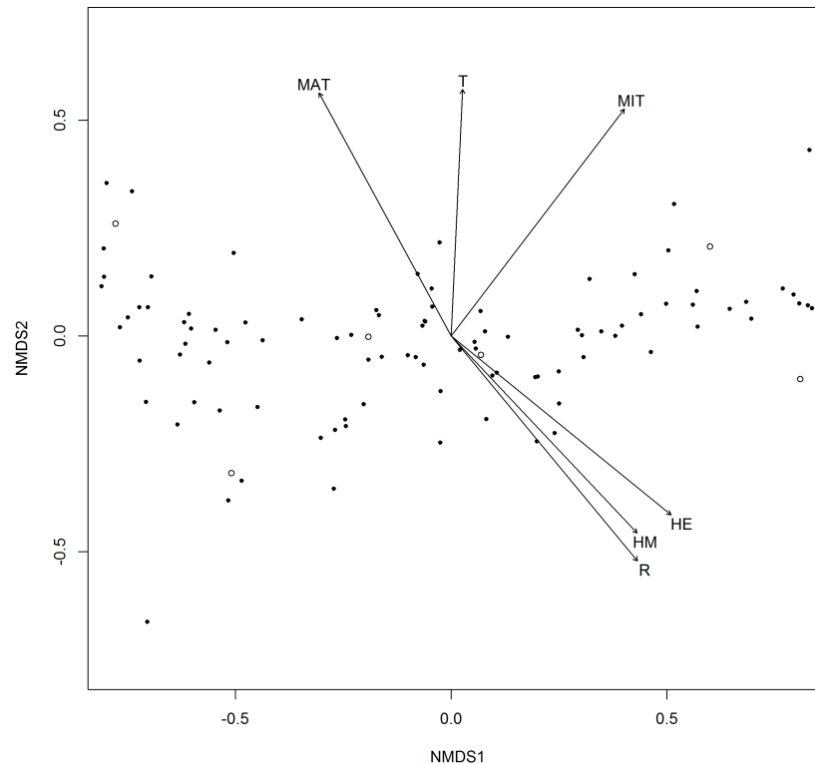


Fig 20. NMDS of the abundance data in Chitwan National park, using Bray-Curtis similarity as the pair wise distances among sample and their envfit correlations for Climatic factor (MAT; Maximum temperature, MIT; Minimum temperature, T; Average temperature, HE; Humidity at evening, HM: Humidity at morning, R: Rainfall) (Annex 11)

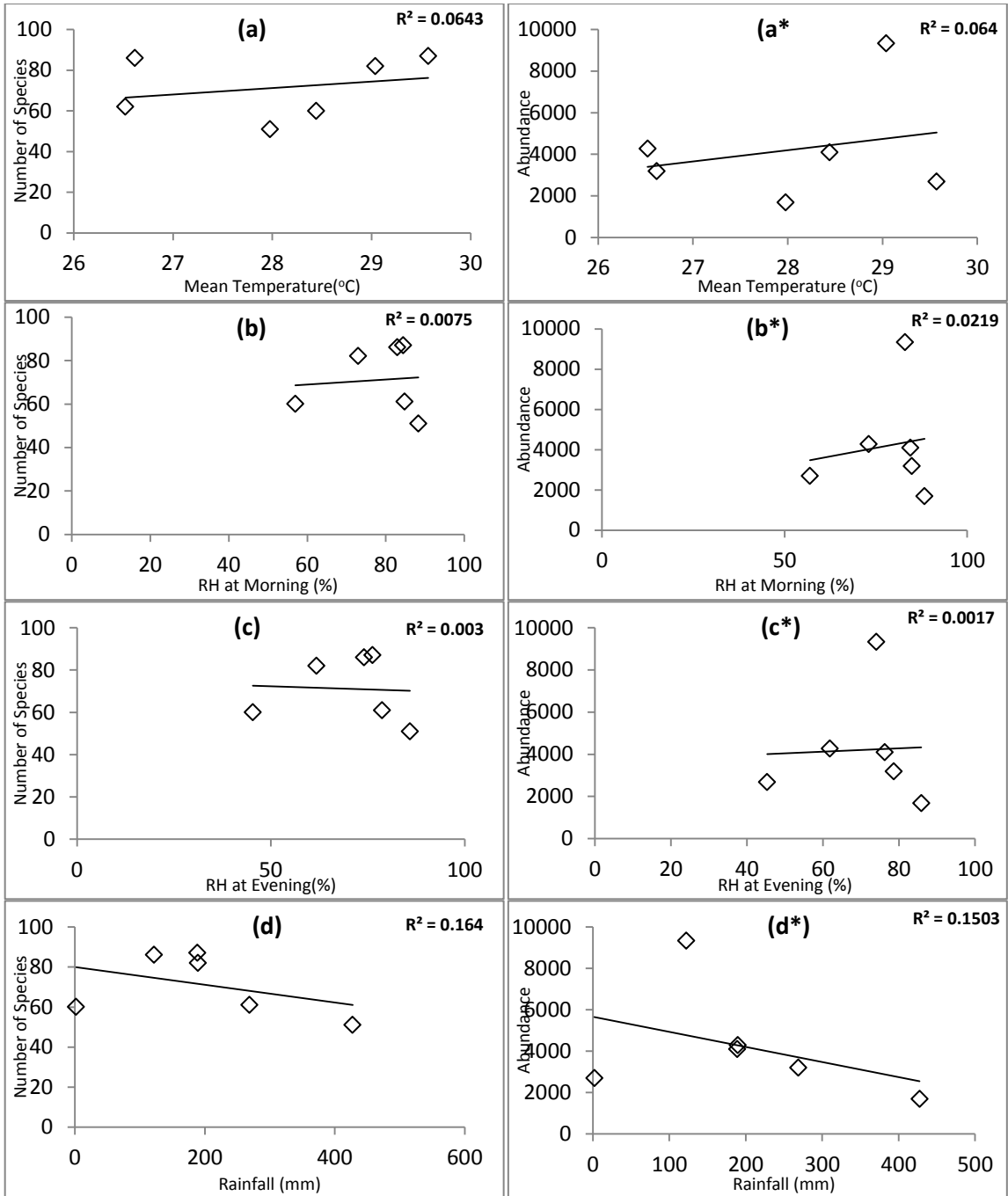
NMDS analysis (Stress = 0.195) showed that, Humidity (morning and evening), rainfall, and average minimum temperature have relation with the beetle composition whereas maximum temperature and average temperature was found to have no any significant relationship with the beetle composition (Table 13). Beetle showed no any significant relationship with any of the climatic factors (Table 14, Fig 19).

Table 13. Climatic factors applied and their fit to species composition of beetles in NMDS ordination

	NMDS1	NMDS2	r2	Pr(>r)
T	0.046	0.999	0.677	0.162
HM	0.686	-0.728	0.817	0.044 *
HE	0.775	-0.632	0.894	0.026 *
R	0.637	-0.771	0.950	0.039 *
MAT	-0.478	0.878	0.851	0.065 .
MIT	0.607	0.794	0.906	0.021 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

T; Average temperature, HM; Relative Humidity at morning, HE; Relative Humidity at evening, R; Rainfall, MAT; Maximum temperature, MIT; Minimum temperature



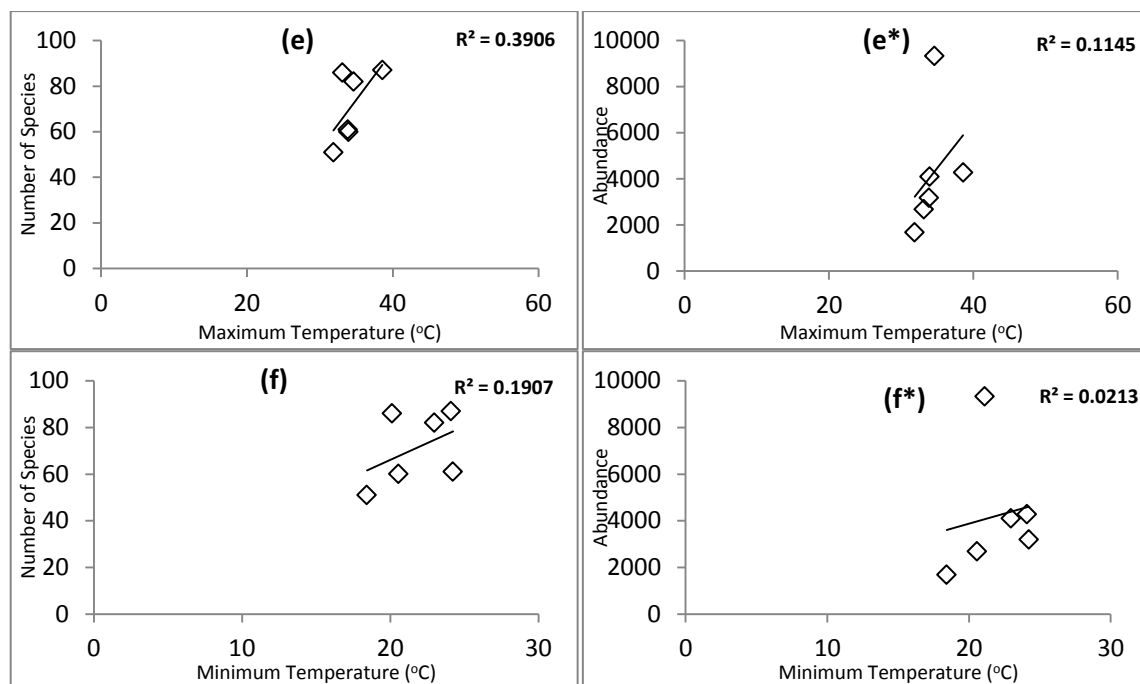


Fig 21. Linear relationship in scatterplot plotted against number of species and abundance with climatic properties (a; Mean temperature, b; Relative Humidity at morning, c; Relative Humidity at evening, d; Rainfall, e; Maximum temperature, f; Minimum temperature). On a given row, alphabet denotes relationship with number with species and asterisk in alphabet denotes relationship with abundance. R^2 ; coefficient of determination fitting the given line.

Table 14. Correlation coefficient and their significance of beetle species and abundance with environmental variables

Variables	Number of Species(r)	P	Abundance(r)	P
pH	0.296	0.040.	0.314	0.035*
Organic Matter	0.436		-0.017	0.912
		0.002**		
Nitrogen	0.272	0.061.	0.277	0.056.
Phosphorus	-0.201	0.172	0.053	0.716
DBH	0.422	0.016*	0.284	0.114
Crown Size	0.173	0.343	0.033	0.856
Trap Height	0.095	0.603	-0.024	0.895
Tree Height	0.026	0.888	-0.123	0.501
Mean Temperature	0.253	0.628	0.252	0.629
Relative Humidity at Morning	0.086	0.871	0.148	0.780
Relative Humidity at Evening	0.054	0.918	0.041	0.938
Rainfall	-0.409	0.425	-0.388	0.448
Max. Temperature	0.624	0.185	0.338	0.512
Min. Temperature	0.436	0.386	0.253	0.629

Signif. codes: 0 '****' 0.001 '**' 0.01 '*' 0.05 '.' 0.1

4.5 Feeding Guilds

One hundred and Thirty eight morphospecies (97.2 %) and 25067 individuals (99.4 %) were allocated into one of the five feeding guilds (Annex 12). This included 100 morphospecies and 7305 individuals caught from the canopy layer, and 39 morphospecies and 17762 individuals caught from the ground layer. Similarly, it included 109 morphospecies and 9616 individuals caught from *Shorea* forest, and 81 morphospecies and 15451 individuals caught from *Dalbergia* forest. Of the beetles that were able to place into feeding guilds, predators, herbivores and saprophages were well represented where number of morphospecies was high in predator followed by herbivores and saprophages (Fig 24), but number of individuals was high in saprophages followed by herbivores and predators (Fig 25). Guild proportions for the number of morphospecies and individuals of various community shows huge difference in composition of guilds where herbivores were dominant in canopy layer (Fig 22, Fig 23) compared to saprophages in ground layer (Fig 22, Fig 23). Similarly saprophages, herbivores and predators in three different seasons were remarkably similar for the number of morphospecies (Fig 23) but showed differences when numbers of individuals were considered (Fig 22).

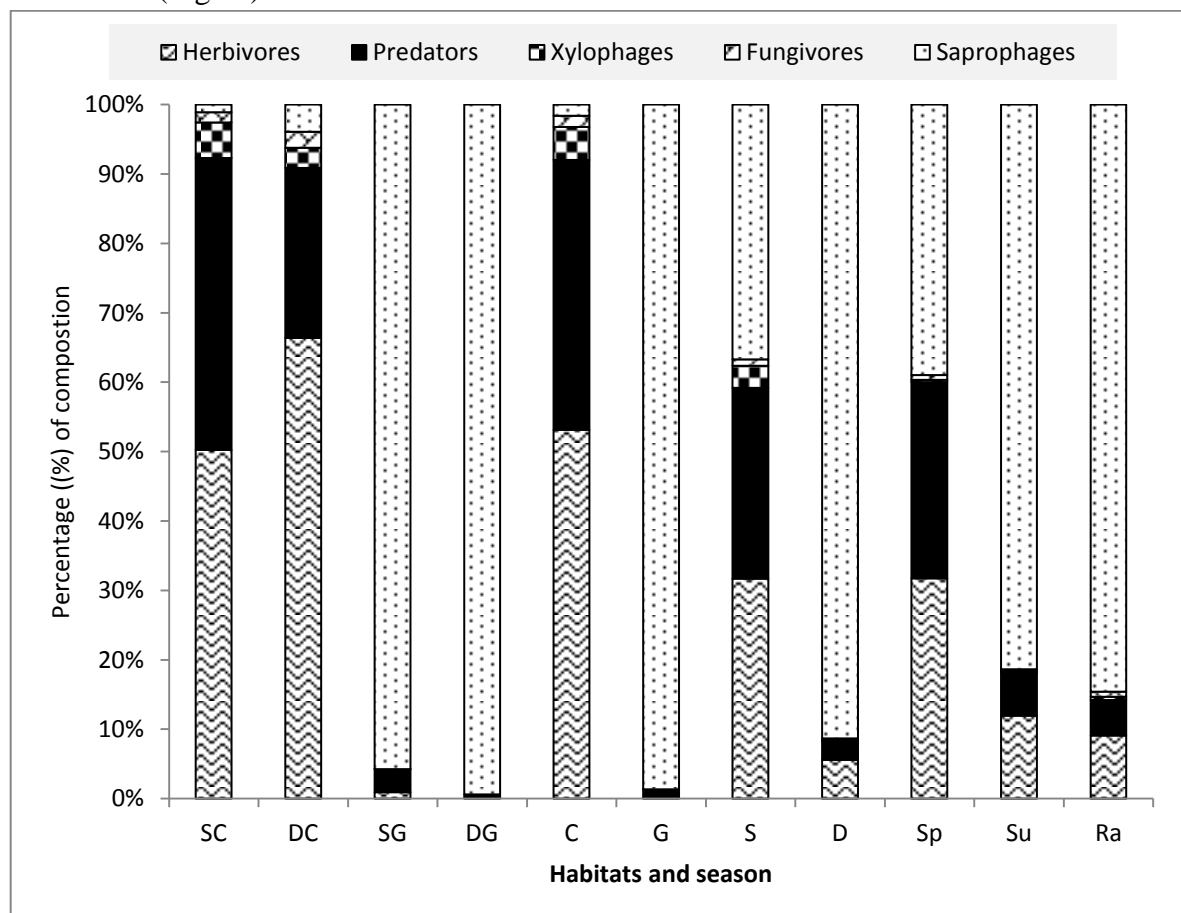


Fig 22. Feeding Guilds Composition of Beetle Individuals in Chitwan National Park (SC; *Shorea* canopy, DC; *Dalbergia* canopy, SG; *Shorea* ground, DG; *Dalbergia* ground, C; Canopy, G; Ground, S; *Shorea* forest, D; *Dalbergia* forest, Sp: Spring season, Su; Summer season, Ra; Rainy season)

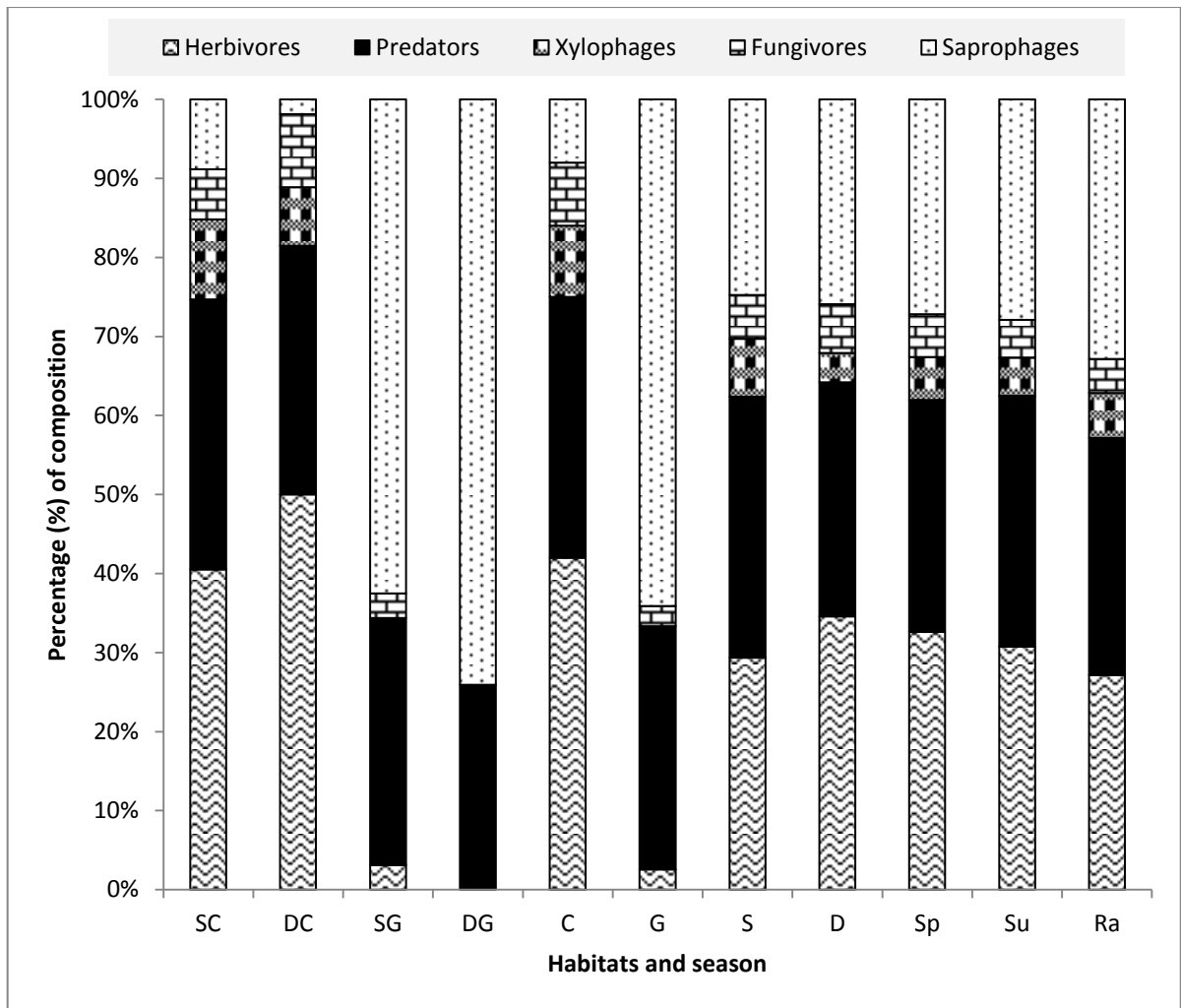


Fig 23. Feeding Guilds Composition of Beetle Species in Chitwan National Park (SC; *Shorea* canopy, DC; *Dalbergia* canopy, SG; *Shorea* ground, DG; *Dalbergia* ground, C; Canopy, G; Ground, S; *Shorea* forest, D; *Dalbergia* forest, Sp: Spring season, Su; Summer season, Ra; Rainy season)

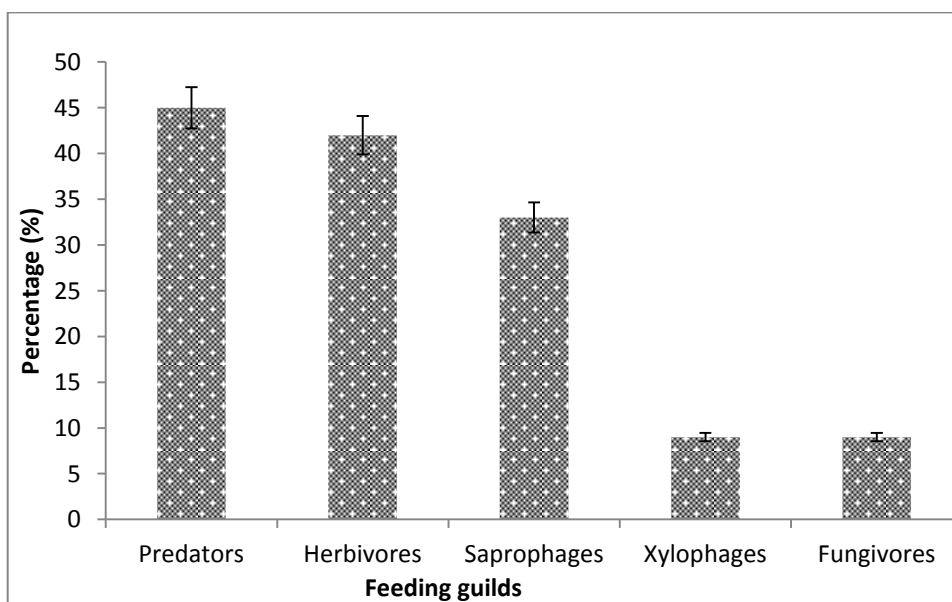


Fig 24. Feeding Guilds Composition of beetle species in Chitwan National Park

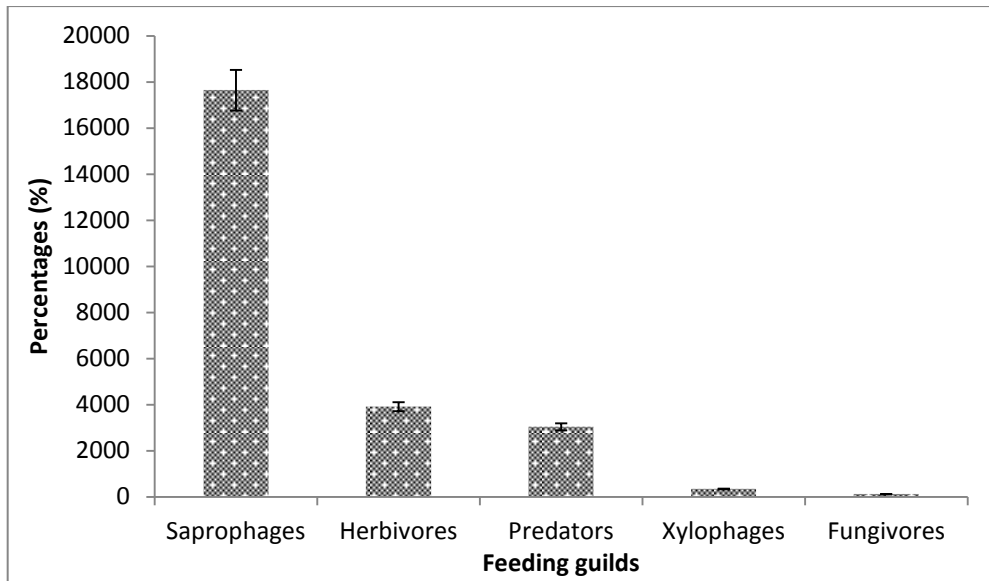


Fig 25. Feeding Guilds Composition of beetle individuals in Chitwan National park

4.6 Indicator taxa

Fifteen genera were found to be significantly associated with one of the habitats investigated (Annex 13, Annex 14).

Nine genera were associated with canopy layer of *Shorea* forest, where three genera were associated with canopy layer of *Dalbergia* forest (Table 15). *Dromius* caught in 5 traps out of 16 traps in *Shorea* canopy compared to 0 traps in *Dalbergia* canopy, *Paraphaea* (9 traps in *Shorea* canopy, 0 in *Dalbergia* canopy), *Derolus* (7, 0), *Basilepta* (7, 0), *Cryptocephalus* (8, 0), *Rodolia* (16, 7) with 586 individuals in *Shorea* canopy and 43 in *Dalbergia* canopy, *Dercetina* (0, 5), *Sumnius* (16, 13) with 1746 individuals in *Shorea* canopy and 115 in *Dalbergia* canopy, *Melanotus* (16, 6) with 246 individuals in *Shorea* canopy and 15 in *Dalbergia* canopy, *Paracardiophorus* (12, 0), *Adoretus* (4, 10) with 5 individuals in *Shorea* canopy and 27 in *Dalbergia* canopy, *Strongylium* (0, 8), *Monomma* (14, 6) with 63 individuals in *Shorea* canopy and 14 individuals in *Dalbergia* canopy are significantly associated with canopy layer of either forest (Annex 13).

Two genera were found to be significantly associated with ground layer of *Shorea* forest (Table 15) whereas only 1 genus was significantly associated with ground layer of *Dalbergia* forest. *Anomatarus*, 5 traps out of 16 get trapped in *Shorea* ground compared to 0 traps in *Dalbergia* ground, *Hybosorus* (0, 16) and *Gonocephalus* (14, 0) are significantly associated with ground layer of either forest (Annex 14).

Out of all associated genus, *Hybosorus* with indicator 1.00 shows that it is exclusively found in *Dalbergia* ground where all of the traps get trapped the beetles (Annex 14).

Table 15. Significant Indicator beetle genera of various sites in Chitwan National park

Associated site	Genus	A	B	Stat	p. value
<i>Shorea</i> canopy	<i>Melanotus</i> spp.	0.943	1.000	0.971	0.001***
	<i>Sumnius</i> spp.	0.938	1.000	0.969	0.001***
	<i>Rodolia</i> spp.	0.931	1.000	0.965	0.001***
	<i>Paracardiophorus</i> sp.	1.000	0.750	0.866	0.001***
	<i>Monomma</i> spp.	0.818	0.875	0.846	0.004**
	<i>Cryptocephalus</i> spp.	1.000	0.500	0.707	0.008**
	<i>Paraphaea</i> sp.	0.852	0.563	0.692	0.010**
	<i>Derolus</i> sp.	1.000	0.438	0.661	0.006**
	<i>Basilepta</i> sp.	1.000	0.438	0.661	0.011*
<i>Dalbergia</i> canopy	<i>Adoretus</i> spp.	0.844	0.625	0.726	0.017*
	<i>Strongylium</i> sp.	1.000	0.500	0.707	0.005**
	<i>Dercentina</i> sp.	1.000	0.313	0.559	0.039*
<i>Shorea</i> ground	<i>Gonocephalus</i> spp.	1.000	0.875	0.936	0.001***
	<i>Anomatarus</i> sp.	1.000	0.313	0.559	0.036*
<i>Dalbergia</i> ground	<i>Hybosorus</i> sp.	1.000	1.000	1.000	0.001***

A: specificity of species, B; Fidelity of species, Stat; Indicator value
 Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05

5 DISCUSSION

5.1 Taxonomic Composition

5.1.1 Beetle family composition

Beetles belonging to 25 families were collected in the forests of Chitwan National Park, Nepal. It represented 11.8% of the family listed by Bouchard *et al.* (2011) from the world. This proportion is low if compared to Mawdsley (1994) who recorded 87 families (41.2%) from a single 10,000 hectares of lowland dipterocarp forest in Brunei. Also, Hammond (1990) listed 98 families (46.4%) from a 500 ha of a similar kind of forest in Sulawesi. However, this can be reasonable considering that present sampling was confined to only 8 approximately 0.5 hectares sites.

This collection represents 29.9% of the coleopterous families listed for Nepal by Thapa (2015). Six families (Zopheridae, Salpingidae, Prionoceridae, Hybosoridae, Byturidae and Chelonariidae) encountered in the present study are not included in the list by Thapa (2015). Beside Geiser (2010) who has studied the Prionoceridae in Nepal and Chandra *et al.* (2012) who reported the distribution of Hybosoridae in Nepal. There are no any documented evidence of presence of remaining 4 families in Nepal.

Scarabaeidae was the dominant family in species in the study area and was reported from both forests and both layers in majority of number. This result concurs the study of Ballerio and Wagner (2005) in African forest who reported the dominance of Scarab beetles. Also Gaudel (2016) found the family Scarabaeidae as dominant family in canopy of Shivapuri National Park and Nagarjun Community forest. Dung beetles (Scarabaeidae) are important in nutrient recycling, soil aeration, transport of other organism and burial of vertebrate dispersed and defecated seeds (Vulinec, 2000). They are dominant organism among the dung feeders with high diversity and tropical forests are supported by the presence of various dung producing animals (Davies *et al.*, 2008). Both canopy layer and ground layer do not differ in species number of Scarabaeidae in this study. However, abundance of Scarabaeidae is significantly higher is ground layer while compared to canopy layer, and in *Dalbergia* ground while compared to *Shorea* ground. This may be due to the fact that ground layer consists dung of animals. The main reason to the scarab beetles reported in *Dalbergia* ground was might be due to the presence of elephant dungs which supports more number of dung beetles which was observed during the study. Surprisingly, *Shorea* canopy supported the large number of scarab beetles compared to *Dalbergia* canopy. This is due to large number of scarab beetles belonging to subfamily Melolonthinae which rely on non-dung food sources (Scholtz *et al.*, 2009). Besides Scarabaeidae, Coccinellidae contributed to the alteration on beetle community between *Shorea* forest and *Dalbergia* forest, canopy layer and ground layer, *Shorea* canopy and *Dalbergia* canopy, and *Shorea* canopy and *Shorea* ground. These two families along with Elateridae were the main differences between *Shorea* canopy and *Dalbergia* canopy. The sweet fragrance of Sal flowers attracts the varied groups of insects and also displays the diverse number of species (Bhardwaj, 2015), might be the reason that dominant families

in *Shorea* canopy were different while comparing the beetle communities. Curculionidae, Carabidae, Cerambycidae, Chrysomelidae, and Tenebrionidae were in majority in number in canopy layer. Basset (1991) in his findings, said that Chrysomelidae, Curculionidae, Scarabaeidae, Elateridae, Carabidae and Tenebrionidae are usually common families of beetles in arboreal habitats. The reason behind these families to found in canopy layer might be due to the fact that most of them are herbivores (except Carabidae which are predatory) which depends on the leaves and woods of the plant. Also, Birtele and Hardersen (2012) and Bouget *et al.* (2011) suggested that the composition of beetle families assemblages generally differed between the ground and canopy layers. The differences in family composition between canopy and ground layer can be related to sampling approach, as each method appeared to be sampling certain families or a specific part of the beetle assemblage. Trogossitidae, Zopheridae, Attelabidae, Cleridae, Histeridae, Melyridae, Prionoceridae, Bostrichidae, Byturidae, Chelonariidae, Dryophthoridae, Hybosoridae, Lucanidae, Salpingidae and Silvanidae were least observed families. Fraction of species and abundance represented by these families are relatively low in the world (Basset, 1991). Hybosoridae, on the other hand, was absent in *Shorea* forest and canopy layer and is present only in ground layer of *Dalbergia* forest. With only a single species, it was the most abundant beetle specimens (40%) of the study. The unusual number of the beetle has altered the beetle community of *Dalbergia* forest and *Shorea* forest, canopy layer and ground layer, *Shorea* ground and *Dalbergia* ground, *Dalbergia* canopy and *Dalbergia* ground, and *Shorea* canopy and *Dalbergia* ground floor. Surprisingly, temporal composition of beetles was not significantly different. However, abundance of families Attelabidae, Carabidae, Cerambycidae, Chrysomelidae, Cleridae, Coccinellidae, Curculionidae, Elateridae, Hybosoridae, Lucanidae, Melyridae, Nitidulidae, Prionoceridae, Scarabaeidae, Tenebrionidae, Trogossitidae, and Zopheridae was found different in three different times. Stork (1988) suggested that minor changes in family composition with season was obvious as seasonality remained particularly important factor for beetle community structure because of its being determinant in the abundance and quality of their primary resources (i.e., manure and carcasses) (Camberfort, 2014). Also, Wolda (1978) in his finding, tropical insect community structure varied over time due to changes in climatic conditions and the availability of food resources.

5.2 Beetle Community characterization

5.2.1 Species diversity, shared species and turnover

In total, 142 was the species richness observed in CNP. Species richness was not distributed evenly in different types of forest. Significant variation in species richness was found in two different types of forest. Relatively high diversity indices in *Shorea* forest and canopy layer suggested that habitats in *Shorea* forest and canopy layer were qualitatively suitable for beetles than in *Dalbergia* forest and ground layer. High dominance value in *Dalbergia* forests and ground layer retarded the suitability for beetle diversity.

Dalbergia canopy possessed significantly high Shannon-Wiener index and Simpson diversity index values compared to *Shorea* canopy whereas *Shorea* canopy possessed high (was not significant) Fisher's alpha index and Margalef index values compared to *Dalbergia* canopy. These alteration are due to the fact that Shannon-Wiener index and Simpson index get influenced by evenness and dominance respectively (Yeom and Kim, 2011) whereas Fisher's alpha index and Margalef index are more weighted to species richness ((Fisher *et al.*, 1943; Yeom and Kim, 2011). Our results also concurred them as beetles in *Dalbergia* canopy had significantly high evenness values and significantly low dominance value compared to *Shorea* canopy. Similarly species richness was high (was not significant) in *Shorea* canopy than in *Dalbergia* canopy. Even though species richness was not significant different between *Shorea* ground and *Dalbergia* ground, beetle diversity indices were comparatively rich in *Shorea* Ground than in *Dalbergia* ground. This is due to the unusual dominance of single species of Genus *Hybosorus*. Low evenness in the community structure resulting from the domination of a single species in *Dalbergia* might be associated with habitat disturbances, such as fodder collection, vegetation cutting or livestock grazing (Davis *et al.*, 2001; Halffter and Arellano, 2002) which was observed in *Dalbergia* forest.

Shorea represented 78.16% while *Dalbergia* represented 59.15% of collected species. Most of the species (89 species, 62.68%) found to be specialist of either type of forests while 53 species (37.32%) found to be generalist species shared by both types of forests. Chao's Sørensen index (0.447) and turnover index value (0.451) suggested that different type of beetle were supported by *Shorea* and *Dalbergia* forest which also supported by NMDS diagram. This results is just opposite from the results of Sobek *et al.* (2009) in forests of Germany (Europe) where most species were habitat generalists (228 species, 54%), whereas habitat specialist constituted roughly quarter of the total (115 species, 27.3%). Erwin (1983) analyzed data from four different forest in the central Amazon around Manaus, Brazil (South America) where he showed that 83% of the beetle species in the sample were found in only the samples of one of the types of forest, 14% species were shared between two, and only 1% of the species of beetles was found between four forest types. Different proportion of results for shared species across the world for different forests types followed the fact that any community did not contains the same biodiversity as any of the others, due to site-specific characteristics of soil, topography, vegetation, weather, and other environmental factors that might govern each species settlement (Kim, 2009).

Similarly canopy represented 72.5% of collected species while ground layer represented only 28.16% of collected species. Out of this only 1 species was shared by both layer. Both observed and estimated shared species index value was 0.002 with highest turnover of species (0.986). That insect species composition differs among forest strata seemed not be surprising given that resources (i.e., foliage, dead wood, fungi, carrion, etc.) differed considerably in both abundance and kind with height above the forest floor (Ulyshen and Hanula, 2007). However, this value was far different from Hardersen *et al.* (2014) in temperate forest of Europe where more than half of the species were shared by both

strata. Many insects in tropical forests are thought to spend their entire lives in the canopy appear to be tied throughout their life cycle to the canopy (Erwin, 1982) and are sometimes morphologically adapted to that environment (Ober, 2003). This large variation is may be due to the fact that seasonally stable and structurally complex canopies of tropical forests likely encourage many insects to complete development in a variety of arboreal habitats including the organic material accumulated near mats of epiphytes (Nadkarni and Longino, 1990), water-filled plant structures (Kitching, 2000) and under bark (Arndt *et al.*, 2001) resulting low overlapping and high turnover of species of canopy with floor. In contrast, in temperate zones, strict canopy specialization, or complete freedom from the ground, is probably quite rare because most insects are driven back to the forest floor following the seasonal loss of foliage and the onset of winter (Schaeffer, 1991) resulting less turnover. It is surprising to find that although more species were caught in the canopy than the ground, this difference was the consequence of there being many more rare species in the canopy (Table 9, Table 10). To our knowledge, this is the first time in South Asia, that this has been demonstrated although rare species are an important component of all tropical insect assemblages (Novotny and Basset, 2000). Difference in the abundance of rare species in the canopy and ground could be due to possible differences in the flight strategies of beetles in these strata and also canopy is more heterogeneous in structure than the ground, and thus there might be more rare species.

Species richness of some coleopteran families (Carabidae, Elateridae, Histeridae, Lucanidae, Melyridae, Scarabaeidae, Trogossitidae and Zopheridae) peaked in summer season and two families (Chelonariidae, Silvalidae) were exclusively reported in summer season resulting summer season with peaked species richness. However, some families showed specific phenologies, which often deviated from this pattern. Cerambycidae, Chrysomelidae, Coccinellidae, Curculionidae, Prionoceridae and Tenebrionidae peaked in spring season with two exclusive families (Antrhibidae, Salpingidae). Rainy season continued with similar or less species from respective families (except Bostrichidae which was exclusively recorded in rainy season) than spring and summer season. This results can be compared with the findings of Hardersen *et al.* (2014) where species richness of most of the coleopteran families peaked in summer season. Also, findings of Liberal *et al.* (2011) showed that more than 90% of the species were caught in the spring season. In the study of Andresen (2005), in tropical forest in Mexico, approximately twice the number of dung beetles was captured at the beginning of the rainy season when compared to the middle of the rainy season in two types of forest. In the study of Gc *et al.* (2009) the number of beetles collected had decreased during the rainy season. This might be due to the effects of rain on the beetles' normal activities.

Higher species richness in summer season resulted higher Margalef and Fisher's diversity index. However, species evenness was high in spring season which ultimately pushed spring season to have higher Shannon-Wiener and Simpson index.

Numbers of species shared between spring and summer season were higher, however, Chao's Sørensen index showed that summer and rainy season had higher species shared

index. This is due to the fact that beetle species were least observed in rainy season than spring season which got more weighted by the index.

5.2.2 Species richness estimation, sampling effort, and rarefaction curves

In this study, six nonparametric estimators (3 for ABE and 3 for IBE) of species richness were used. ABE revealed presence of 18.73%, 23.34%, 26.21% and 4.79% more species in SC, SG, DC and DG respectively. High estimation of DC and SG is due to the fact that the species-abundance distribution of these habitats was characterized by a high percentage of singletons in SG (15.6 %) and high percentage of singletons and doubletons in DC (23.21% singletons and 8.9% doubletons). These results ultimately affected the sampling effort which was comparatively less in DC and SG. Furthermore, this caused the individuals based rarefaction curves of DC and SG, insufficiency to reach asymptote. High number of singletons and doubletons signifies the possibility of more species present yet to be captured. In total, 823 species (48%) 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 (Basset and Kitching, 1991; Mawdsley, 1994).

Similarly, IBE revealed presence of 40.73% more species in DC. This is due to the fact that this habitat was also characterized by a high percentage of unique and duplicates samples (28.57% unique, 7.14% duplicates) which caused the lowest sampling effort in DC. Eventually low sampling effort of DC contributed in lowering sampling effort in *Dalbergia* forest and can be seen its effect in Chitwan National park. Also the sample based rarefaction curves of DC had not reached asymptote. The failure to reach an asymptote is not uncommon (Hammond *et al.*, 2004; Audisio *et al.*, 2008). As the rarefaction curve did not reach an asymptote suggested that our sampling design despite its spatial extent and temporal collection was not sufficient to account for all the species present in the sampling area. This result would have been satisfied either by extending the number of samples or the collection period.

Sampling efforts were calculated with 8 samples (48 subsamples), in each types of habitat which is acceptable for optimal sampling and efficient comparison for ecological communities (Agonsti and Alonso, 2000). In this study, rarefaction curves for each of the habitats (SC, SG, DC, DG) were built on the base of, respectively, 6126, 3617, 1339, 14146 individuals. The ratio of observed species richness to the average of abundance-based/sample-based species richness estimators revealed a powerful sampling effort higher than 71% in all cases. The saturation plateau (~asymptote) was well established in sample based rarefaction on SC, SG and DG indicated an acceptable quality of the sample in these sites.

5.2.3 Species rank-abundance curve

Steepest curve of DG (Geometric series) resembles that a few species are dominant with the remainder fairly uncommon (Magurran, 1988). This pattern was 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 SG curve. The shallower but protracted curves of SC and DC resemble the log normal distribution, indicating a large, mature and varied natural community (Magurran, 1988). Results of the abundance curve could be correlated with the fact that in *Dalbergia* ground there was domination of a single species of Hybosoridae which could be associated with habitat disturbances which was observed in *Dalbergia* forest with indication of negative impact in beetle diversity.

5.3 Beetle composition relation with environmental variables

The results suggested that the pH, organic matter, nitrogen and phosphorus were quantitatively different among two types of habitats and among them, pH and phosphorus had significant influence on ground layer beetle composition. So that it could be asserted that phosphorus and pH content of the soil are the most important factor for the differentiation of the beetle assemblages between two forests. pH of soil also influenced the abundance of beetles in ground layer. Organic matter had no any significant effect on ground layer beetle composition but had significant positive relationship with number of species this might be due to the addition of presence of peat soil inhabiting beetles (Irmiler, 2003). There are only few studies that show a correlation of the activity of soil properties with ground layer beetles. Chung *et al.* (2000) in primary forest, logged forest, acacia plantation and oil palm plantation area in Malaysia did not observed any significant relationship between beetle numbers and soil pH. However, Basualdo (2011) observed that 40% of the beetle species showed a significant correlation with the pH. In present study different parameters of soil properties may have affected some particular families of beetles which have not been studied in this research.

Similarly, tree characteristics (DBH, crown size, tree height and trap height) were also quantitatively different among trees. Among the tree characteristics, DBH showed significant influence ($p < 0.1$) on canopy layer beetle composition and also positively correlated with species richness of beetles. Several studies had shown that tree size was important for the species richness of beetles (Ranius and Jansson, 2000; Gough *et al.*, 2015). Beetles may prefer larger trunks because the larger the girth has more stable the microclimate (Ranius and Jansson, 2000). Large tree size also provides more stable microclimates and make easier for more fungus to establish, thus providing more habitats for fungi-associated beetles (Ranius and Jansson, 2000) which might have affected the beetle composition. This can be concluded that both *Shorea* and *Dalbergia* are much similar in its beetle species composition regardless of their physical properties.

While talking climatic factors, all of the measured factors (humidity, rainfall, maximum temperature, minimum temperature) found to influence the beetle composition significantly. The results suggested that the climatic factors were quantitatively different among sampling periods and thus potentially having an influence on beetle species composition. Both species richness and abundance were found to be positively correlated (not significant) with temperature and humidity. This might be due to the fact that abundance of beetles increases with an increase in temperature as the activity of beetles generally increases with increased temperature (Chiverton, 1988; Ranius and Jansson,

2000) and their catch ability might be higher in sun-exposed trees (Ranius and Jansson, 2000). So, sun-exposure might have contributed to higher abundance of beetles while rainfall might have affected the normal activities like flying and crawling (Gc *et al.*, 2009) resulting negative influence in beetle species and abundance.

5.4 Feeding Guilds

The present study showed that predators were the most speciose group representing more than 2/5th of the guild, a proportion strikingly consistent with the study of Chung *et al.* (2000) in the forests of one of the Asian country (Malaysia). Predators tended to be the most speciose guild in various studies, a pattern that seemed to be uniform throughout different climate zones and vastly independent of stand structure and vegetation diversity (Southwood *et al.*, 1982; Jukes *et al.*, 2002). In this study, herbivores followed predators in species number. However, other non-herbivores beetles (saprophages, xylophages and fungivores) standing together outnumbered the herbivores species. These results thus broadly oppose with other studies suggesting that non- herbivorous beetles make up the majority of individuals and species (Erwin and Scott, 1980; Hammond, 1990). This result has important implications for global species richness estimates that imply that most tropical insects are herbivores (Erwin, 1982; Ødegaard, 2000; Novotny *et al.*, 2002), as this assumption may be false.

Herbivores were the largest feeding guilds in terms of both numbers of individuals and species in canopy layer. This result confirms what many others have previously shown (Erwin and Scott, 1980; Hammond, 1990) that herbivores are the largest trophic group in terms of both numbers of individuals and species in canopy layer. Unlike herbivores in canopy layer, saprophages were the largest feeding guilds in terms of both numbers of individuals and species in ground layer. This difference between the canopy and the ground is due to the difference in kinds of resources and their quality and quantity in two layers. For example, the canopy is where most leaves, flowers and fruits appear, while the ground is where these resources and dead wood accumulate and decompose. As a result, canopy insects should be more likely to be associated with key canopy processes such as herbivory, whereas ground-based insects should be more likely to be associated with decomposition. Saprophages were the most abundant guilds in Chitwan National Park. This is due to the dominant species of Hybosoridae which made 4/5th of beetle individuals in Chitwan National park.

While talking forest types, *Shorea* forest and *Dalbergia* forest showed consistent in proportion of different feeding guilds in terms of species. Also, canopy layer of *Shorea* and canopy layer of *Dalbergia*, and ground layer of *Shorea* and ground layer of *Dalbergia* showed similarity in proportion of feeding guilds in term of species. Stork (1987) also had a similar finding with canopy insects from trees in Borneo. In this light, our finding that there was a high level of similarity in the guild structure of the beetle assemblages from the canopy and the ground, and among separate trapping locations is therefore not surprising. This indicates that taxonomic relatedness of tropical trees does not affect the number of guilds showing proportional constancy of which result is similar

with Stork (1987). So that the relative proportions within each plot remained constant. This outcome appears to be typical for forest habitats, and different tree species have shown to be consistent by means of relative abundance of feeding guilds (Southwood *et al.*, 1982; Jukes *et al.*, 2002). Also, Moran and Southwood (1982) found that proportional representation of each guild was highly consistent between different tree species and between trees in South Africa and the UK. This conclusion is supported by additional evidence showing that different insect taxa are present in very similar proportions of trophic guilds regardless of whether they are from subtropical or tropical rainforest samples (Kitching *et al.*, 2001). However, individuals of feeding guilds were different among these two types of forest. Due to the dominant species (*Hybosorus* sp.) in *Dalbergia* forest, herbivores and predators were in low number compared to *Shorea* forest. Ultimately this result reflected in guilds of ground layer of *Dalbergia* forest where saprophages constituted more than 99% of the feeding guilds. This dominance of single dominant species as well as single guilds suggests that these habitats might have severely disturbed environments. However, in canopy layer, different feeding guilds had similarity in proportion.

Even though there were significant difference in species composition between different seasons, family composition was found to be similar in three seasons which consequently resulted in similarity in guild composition in terms of species. However, guilds in individuals were slightly different in spring season compared to summer and rainy season. These results showed that rainfall caused benefit to individuals of saprophages guilds.

5.5 Indicator taxa

Some of the genus of families Elateridae, Coccinellidae, Zopheridae, Chrysomelidae, Carabidae, Cerambycidae, Scarabaeidae, Hybosoridae and Tenebrionidae were found to be specialist of particular types of habitats. In this study, as in Picazo *et al.* (2012), more than one indicator taxa was identified within a habitat type (except in *Dalbergia* ground), and the combination of genera could be considered as an indicator assemblage of the respective habitat type in the region. So that, we can say that assemblages of *Melanotus*, *Sumnius*, *Rodolia*, *Paracardiophorus*, *Monomma*, *Cryptocephalus*, *Paraphaea*, *Derolus* and *Basilepta* genera were the indicator assemblage of *Shorea* canopy. Similarly, *Adoretus*, *Strongylium* and *Dercentina* genera were indicator assemblage of *Dalbergia* canopy, and *Gonocephalus* and *Anomatarus* were of the *Shorea* ground. *Hybosorus* was only one genus which indicated the *Dalbergia* ground. Among all of them, Hybosoridae (*Hybosorus*) showed a strong statistics value for the association with *Dalbergia* ground. This association with a habitat types can be related with the strong influence of a specific range of environmental factors and vegetation. However, this study is still lacking.

More work would be needed to show if the patterns shown in the current study has similar results, although the current data do provide a base-line and point of reference for future studies.

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

A total of 25,228 specimens belonging to 25 families with 142 morphospecies were collected. Scarabaeidae was the most speciose family whereas Hybosoridae was the most abundant family. Beetle family compositions differed in spatial scale where Coccinellidae, Scarabaeidae, Elateridae and Hybosoridae were the families for the difference. In temporal scale, beetle family compositions were similar but species composition was significantly different. Canopy layer and *Shorea* forest was more diverse in beetle community compared to the ground layer and *Dalbergia* forest respectively. Amongst all habitats, *Dalbergia* ground was the least diverse habitat which was observed to be affected by human disturbance. Phosphorus, pH, DBH, relative humidity, Rainfall, maximum temperature and minimum temperature had influenced the species composition of beetles and had varying effect on them. Feeding guilds composition of beetle species were similar in two types of forest whereas vertical strata showed difference where canopy was dominated by herbivores and ground layer was dominated by saprophages. Fifteen genera were found to be specific with one of the habitats.

6.2 Recommendations

- Further research for extended time is required to show if the patterns shown in the current study hold up to further scrutiny in whole year.
- Restrictions should be employed in *Dalbergia* forest so that human disturbances should be minimized.
- More research regarding the habitat preferences of specific beetle fauna should be employed.

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ANNEXES

Annex 1. Morphospecies collected in the forests of Chitwan National Park



MSSN 1 (Scale=1mm)



MSSN 2 (Scale=1mm)



MSSN 3 (Scale=1mm)



MSSN 4 (Scale=1mm)



MSSN 5 (Scale=1mm)



MSSN 6 (Scale=1mm)



MSSN 7 (Scale=1mm)



MSSN 8 (Scale=1mm)



MSSN 9 (Scale=1mm)



MSSN 10 (Scale=1mm)



MSSN 11 (Scale=1mm)



MSSN 12 (Scale=1mm)



MSSN 13 (Scale=1mm)



MSSN 14 (Scale=1mm)



MSSN 15 (Scale=1mm)



MSSN 16 (Scale=1mm)



MSSN 17 (Scale=1mm)



MSSN 18 (Scale=1mm)



MSSN 19 (Scale=1mm)



MSSN 20 (Scale=1mm)



MSSN 21 (Scale=1mm)



MSSN 22 (Scale=1mm)



MSSN 23 (Scale=1mm)



MSSN 24 (Scale=1mm)



MSSN 25 (Scale=1mm)



MSSN 26 (Scale=1mm)



MSSN 27 (Scale=1mm)



MSSN 28 (Scale=1mm)



MSSN 29 (Scale=1mm)



MSSN 30 (Scale=1mm)



MSSN 31 (Scale=1mm)



MSSN 32 (Scale=1mm)



MSSN 33 (Scale=1mm)



MSSN 34 (Scale=1mm)



MSSN 35 (Scale=1mm)



MSSN 36 (Scale=1mm)



MSSN 37 (Scale=1mm)



MSSN 38 (Scale=1mm)



MSSN 39 (Scale=1mm)



MSSN 40 (Scale=0.5mm)



MSSN 41 (Scale=1mm)



MSSN 42 (Scale=1mm)



MSSN 43 (Scale=1mm)



MSSN 44 (Scale=1mm)



MSSN 45 (Scale=1mm)



MSSN 46 (Scale=1mm)



MSSN 47 (Scale=1mm)



MSSN 48 (Scale=1mm)



MSSN 49 (Scale=1mm)



MSSN 50 (Scale=1mm)



MSSN 51 (Scale=1mm)



MSSN 52 (Scale=1mm)



MSSN 53 (Scale=1mm)



MSSN 54 (Scale=1mm)



MSSN 55 (Scale=1mm)



MSSN 56 (Scale=1mm)



MSSN 57 (Scale=1mm)



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MSSN 85 (Scale=1mm)



MSSN 86 (Scale=1mm)



MSSN 87 (Scale=1mm)



MSSN 88 (Scale=1mm)



MSSN 89 (Scale=1mm)



MSSN 90 (Scale=1mm)



MSSN 91 (Scale=1mm)



MSSN 92 (Scale=1mm)



MSSN 93 (Scale=1mm)



MSSN 94 (Scale=1mm)



MSSN 95 (Scale=1mm)



MSSN 96 (Scale=1mm)



MSSN 97 (Scale=1mm)



MSSN 98 (Scale=1mm)



MSSN 99 (Scale=0.5mm)



MSSN 100 (Scale=1mm)



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MSSN 118 (Scale=1mm)



MSSN 119 (Scale=1mm)



MSSN 120 (Scale=0.5mm)



MSSN 121 (Scale=1mm)



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MSSN 123 (Scale=1mm)



MSSN 124 (Scale=1mm)



MSSN 125 (Scale=0.5mm)



MSSN 126 (Scale=1mm)



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MSSN 131 (Scale=1mm)



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MSSN 135 (Scale=1mm)



MSSN 136 (Scale=1mm)



MSSN 137 (Scale=1mm)



MSSN 138 (Scale=1mm)



MSSN 139 (Scale=1mm)



MSSN 140 (Scale=1mm)



MSSN 141 (Scale=1mm)



MSSN 142 (Scale=1mm)

MSSN: Mosphospecies ID of Table (1)

Annex 2. Photographs of fields and laboratory











Annex 3. Morphospecies (MSSN 1- 33) collected in traps of CNP

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
C1	0	17	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5	0	0	0	0	0	0	0	2	0	0	0	0	1
C2	0	11	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C3	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
C4	0	79	0	0	7	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C5	0	5	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
C6	0	6	0	0	0	0	0	0	0	0	1	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
C7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
C8	0	3	0	0	0	0	0	0	0	0	0	1	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	2
C9	0	29	0	1	10	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0
C10	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3	4	1	0	0	0	0	0	0	0	0	0	1	2	1	0	0	0	1
C11	0	13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	3
C12	0	45	0	0	9	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0
C13	0	12	0	0	3	0	0	0	0	0	0	0	0	0	13	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C14	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C15	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	5
C16	0	7	0	0	0	0	0	0	0	0	1	0	4	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D2	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D4	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D7	0	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D8	0	0	2	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D10	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
D11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0
D13	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
G2	0	0	0	0	0	1	0	0	0	16	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0
G3	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
G4	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
G5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
G6	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G7	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
G8	0	0	0	0	0	0	1	0	0	11	0	0	1	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0
G9	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G10	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
G11	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

D4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0		
D5	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	6	0	0	0	0	1	0	1	0	0	
D7	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
D8	0	0	0	1	0	2	0	0	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	
D9	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	5	0	0	0	0	0	1	0	0	0	0	
D10	0	0	0	0	0	0	0	0	2	12	0	1	0	0	0	0	0	0	1	0	0	2	3	1	0	0	0	1	0	
D11	0	0	0	0	0	0	0	0	0	8	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
D12	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	4	0	0	0	1	0	0	1	0	0	0	
D13	0	0	0	1	0	0	0	0	0	10	0	3	0	0	2	0	0	0	3	0	0	0	3	1	0	0	0	0	0	
D14	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
D15	0	0	0	0	0	0	0	0	0	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
D16	0	0	0	0	0	0	0	0	0	13	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	
G1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	
G3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	
G8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	
G12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	
G13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
G16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
H16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
T	3	16	5	8	1	2	6	1	2	546	1245	70	1	1	13	77	1	18	70	374	89	2	2	60	43	22	7	46	2	13

C : *Shorea* canopy trap, D: *Dalbergia* canopy trap, G: *Shorea* ground trap, H: *Dalbergia* ground trap, Numbers indicate trap numbers, Bold numbers in top row and bottom row indicates MSSN and total respectively

Annex 5. Morphospecies (MSSN 64- MSSN 91) collected in traps of CNP

	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91
C1	0	0	0	0	3	0	37	1	3	9	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	15
C2	0	0	0	0	0	0	9	0	15	0	0	0	0	0	1	0	0	0	0	0	0	0	12	0	0	0	3	24
C3	0	1	0	1	16	0	20	4	7	9	0	0	0	0	1	0	0	0	0	0	0	0	0	0	22	0	0	31
C4	0	0	0	1	0	0	137	9	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
C5	0	0	0	0	5	0	23	7	16	0	0	0	0	3	0	0	0	0	0	0	0	7	0	1	0	0	0	18
C6	0	0	0	0	2	0	17	0	7	2	0	0	0	0	1	0	0	0	0	0	3	0	13	0	4	0	7	9
C7	0	0	1	1	7	0	16	3	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	7
C8	0	0	0	2	1	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	4	0	5	0	0	0	0	10
C9	0	0	0	2	1	0	22	1	14	6	0	0	0	3	2	0	0	0	0	0	0	0	2	0	6	0	2	12
C10	0	0	0	0	6	1	0	11	4	0	0	0	0	0	1	0	0	0	0	0	0	1	11	0	7	3	2	0
C11	0	0	0	4	2	0	7	0	17	3	0	0	0	0	0	0	1	0	1	2	0	12	0	12	1	2	5	
C12	0	0	0	0	6	3	114	0	17	9	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	2	0	8
C13	0	0	0	0	6	0	23	0	12	1	0	0	0	6	0	0	0	0	0	0	3	0	24	0	3	0	2	9
C14	0	0	0	1	0	0	0	0	12	1	0	0	0	0	0	0	0	0	0	0	0	0	4	0	42	1	3	12
C15	0	0	0	4	0	6	0	12	15	6	0	0	0	2	0	0	0	0	0	0	0	0	8	0	0	0	1	28
C16	0	0	0	0	4	5	6	0	12	0	0	0	0	0	0	0	1	0	0	2	0	11	0	25	0	1	0	
D1	0	0	0	0	8	0	0	0	0	4	0	0	0	9	0	0	0	0	1	0	0	0	0	0	14	0	0	1
D2	0	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	4
D3	1	0	0	0	0	0	0	3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	1	0	0	0	5
D4	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	6	0	0	0	0
D5	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	5
D6	0	0	0	1	4	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	3	0	12	0	0	1
D7	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	17
D8	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	10
D9	0	0	0	0	18	0	0	1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	9	0	0	14
D10	0	0	0	3	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
D11	0	0	0	0	0	0	0	4	0	1	0	0	0	2	0	0	0	0	0	0	0	0	9	0	19	0	0	11
D12	0	0	0	0	1	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	7	0	2	0	0	0	0	1
D13	0	0	0	1	10	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	20	0	0	15
D14	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	5	0	0	3
D15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	7	0	7	0	0	0	2
D16	0	0	0	0	1	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	16	0	0	10
G1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
G4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

H16	0	0	0	0	0	0	0	0	0	0	0	0	0	7	18	32	0	9	5	10	3	4	4	0	8	1	11
Tot	512	88	86	1007	330	2	5	9	17	1	47	63	881	463	12	36	112	233	1	7	25	288	398	318	177	368	

C : *Shorea* canopy trap, D: *Dalbergia* canopy trap, G: *Shorea* ground trap, H: *Dalbergia* ground trap, Numbers indicate trap numbers, Bold numbers in top row and bottom row indicates MSSN and total respectively

Annex 7. Morphospecies (MSSN 118- MSSN 142) collected in traps of CNP

	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142
C1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
C2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2
C3	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	5	0	0	1	0	0	0	1
C4	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	1	3
C5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	1	1	0	0	0	0	3
C7	0	0	0	0	0	1	0	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
C8	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	3	0	0	2	1
C9	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	4	2
C10	0	0	0	0	0	0	0	2	0	0	0	0	2	0	1	0	0	5	0	0	0	0	0	4	1
C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	0	0	0	0	3
C12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	0	0	6	6
C13	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	2	0	0	5	0	0	16	0
C14	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	6	5	0	0	0	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	1	3	0	0	4	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	9	0	0	0	1
D1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	2	5	5	0	0	0
D2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	2	0	0	0
D4	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	3	3	0	0	0
D5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
D6	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	4	0	0	0	0
D7	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	4	6	0	0	0
D8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	0	0	0	3
D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	2
D10	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	4	10	3	0	0	0
D11	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	3	0	0	0	2
D12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	13	0	0	0	3
D13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	0	0	0
D14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	0	1	0	2
D15	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	8	0	0	0	2
D16	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	2	0	0	0	0	0
G1	0	0	7	0	12	0	42	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
G2	0	13	1	0	41	0	39	0	0	0	0	0	0	0	0	23	3	0	0	0	0	0	0	0	0
G3	0	0	12	0	11	0	12	0	0	0	0	0	0	0	0	6	2	0	0	0	0	0	0	0	0
G4	3	0	0	0	180	0	10	0	0	3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
G5	38	18	38	17	65	0	12	0	0	0	0	0	0	0	0	13	5	0	0	0	0	0	0	0	0
G6	3	3	9	0	19	0	27	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0

11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	14	13	8	0	0	12	9	8	0	0	0			
12	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
13	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	8	2	1	0	0	0	0	0	0	0		
15	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
16	1	10	9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
17	7	6	7	3	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
18	0	2	2	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0		
20	0	0	8	0	7	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0		
22	0	0	0	0	0	0	0	0	0	0	0	0	2	15	5	2	0	0	1	7	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
23	0	0	0	0	0	0	0	0	0	0	0	0	0	4	8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
24	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	2	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
25	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
26	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
27	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
28	7	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
29	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
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31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	
32	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	4	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	1	10	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	2	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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41	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	213	135	35	22	30	10	4	38	19	23	9	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	152	654	234	132	59	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	31	18	7	0	0	4	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	3	2	0	0	5	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	48	25	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	8	7	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	4	8	10	18	15	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	242	65	17	5	2	0	2	32	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	23	39	13	8	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

57	2	0	0	8	25	15	0	0	6	4	0	0	0	0	0	0	0	0	0	0	0	0		
58	0	0	0	24	8	3	0	0	0	0	3	5	0	0	0	0	0	0	0	0	0	0		
59	12	3	2	0	0	0	0	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0		
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61	0	8	0	2	0	2	0	0	0	0	0	0	8	24	2	0	0	0	0	0	0	0		
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63	2	0	2	1	0	0	2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0		
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66	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
67	3	4	3	2	1	3	0	0	0	2	3	4	0	0	0	0	0	0	0	0	0	0		
68	0	32	12	6	0	9	0	32	0	7	3	8	0	0	0	0	0	0	0	0	0	0		
69	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
70	0	0	325	89	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
71	0	7	29	12	0	0	0	0	8	12	7	0	0	0	0	0	0	0	0	0	0	0		
72	130	13	26	4	12	15	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0		
73	9	8	12	17	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0		
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	4	
75	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	4	2	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	145	5125	2280	1798	744	
77	0	0	2	9	3	0	0	0	3	9	4	0	0	0	0	0	0	0	0	0	0	0	0	
78	0	4	2	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
79	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
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81	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
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84	18	3	0	0	0	0	10	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
85	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
86	17	52	16	11	19	11	0	16	7	9	0	0	0	0	0	0	0	0	0	0	0	0	0	
87	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
88	62	21	15	40	6	0	36	6	36	6	24	12	0	0	0	0	0	0	0	0	0	0	0	
89	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
90	18	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
91	98	43	19	26	15	8	20	19	7	31	13	13	0	0	0	0	0	0	0	0	0	0	0	
92	220	30	81	0	0	0	117	19	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
93	0	0	12	0	0	0	29	0	34	13	0	0	0	0	0	0	0	0	0	0	0	0	0	
94	15	2	19	10	1	0	0	8	25	3	2	1	0	0	0	0	0	0	0	0	0	0	0	
95	258	502	204	29	13	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
96	26	60	42	32	16	23	19	27	29	12	25	19	0	0	0	0	0	0	0	0	0	0	0	
97	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
98	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
99	0	0	0	0	0	0	0	0	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	
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101	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	
102	0	0	10	7	0	0	0	0	0	12	9	9	0	0	0	0	0	0	0	0	0	0	0	

103	0	0	0	28	12	5	0	0	0	5	10	3	0	0	0	0	0	0	0	0	0	0	0		
104	0	0	0	0	0	0	0	0	0	0	0	0	0	167	20	12	7	3	0	67	452	35	73	45	
105	0	0	0	0	0	0	0	0	0	0	0	0	0	19	27	19	25	4	0	0	243	66	48	12	
106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	118	9	17	5	0	0	76	132	8	24	
107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	17	12	
108	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	4	1	0	0	27	54	9	0	0	
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110	0	0	0	0	0	0	0	0	0	0	0	0	0	298	134	98	198	56	12	165	498	176	143	205	
111	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	2	0	0	
112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	8	7	0	0	0	
113	0	0	0	0	0	0	0	0	0	0	0	0	0	21	43	36	20	0	0	40	39	18	36	25	10
114	0	0	0	0	0	0	0	0	0	0	0	0	0	94	123	9	4	9	63	0	11	72	7	4	2
115	0	0	0	0	0	0	0	0	0	0	0	0	0	34	42	56	0	0	0	120	45	13	8	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0	90	13	12	0	0	25	30	5	2	0	0	
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118	0	0	0	0	0	0	0	0	0	0	0	0	0	56	12	13	5	3	0	0	0	0	0	0	
119	0	0	0	0	0	0	0	0	0	0	0	0	0	13	8	68	23	0	7	46	21	56	10		
120	0	0	0	0	0	0	0	0	0	0	0	0	0	17	94	21	2	0	0	3	17	9	4	0	
121	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	29	18	0	0	27	14	12	8	
122	0	0	0	0	0	0	0	0	0	0	0	0	0	212	164	81	34	22	12	29	34	32	17	24	48
123	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
124	0	0	0	0	0	0	0	0	0	0	0	0	0	56	102	76	21	12	3	0	0	0	0	0	0
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127	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	2	1	0	0	0	0	0	0	0	0
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130	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
131	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0	0	53	10	18	11	0	0	0	0	0	0	0	0
134	0	0	0	0	0	0	0	0	0	0	0	0	0	8	37	10	0	0	0	0	0	0	0	0	0
135	0	0	15	7	9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
136	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
137	6	3	2	3	2	0	1	5	4	5	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
138	0	17	18	7	0	0	25	33	16	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
139	0	0	0	0	0	0	0	0	0	6	12	4	0	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
141	0	0	0	9	20	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
142	0	9	10	3	2	1	0	2	6	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	1701	1929	1345	634	325	192	277	304	288	202	162	106	448	1296	871	352	446	204	256	742	6825	2901	2250	1172	

S1: First sampling of spring, S2: Second sampling of spring, U1: First sampling of summer, U2: Second sampling of summer, R1: First sampling of Rainy, R2: Second sampling of spring, Numbers in first column indicate MSSN and Numbers in bottom row indicate total

Annex 9. Tree properties and location of tree

	DBH	CS	HT	TH	Longitude	Lattitude
SC1	58.57 cm	23.1 m	36.65 m	14.31 m	84.3280	27.5500
SC2	40.72 cm	10.23 m	28.08 m	8.5 m	84.3261	27.5484
SC3	67.23 cm	12.87 m	21.22 m	15.05 m	84.3250	27.5478
SC4	41.3 cm	10.45 m	22.08 m	9.23 m	84.3241	27.5474
SC5	39.55 cm	13.7 m	12.65 m	7.5 m	84.2770	27.5073
SC6	36.91 cm	9.5 m	10.94 m	7.71 m	84.2773	27.5068
SC7	42 cm	11.21 m	18.65 m	16.5 m	84.2778	27.5065
SC8	57.34 cm	19.67 m	21.22 m	16.2 m	84.2783	27.5061
SC9	37.23 cm	11.98 m	32.37 m	10 m	84.4413	27.6168
SC10	64.43 cm	23.12 m	26.37 m	14.43 m	84.4407	27.6163
SC11	57.18 cm	19.07 m	4.08 m	13.3 m	84.4422	27.6167
SC12	27.36 cm	9.1 m	8.37 m	10.17 m	84.4415	27.6152
SC13	78.94 cm	24.56 m	17.80 m	14.19 m	84.0950	27.5437
SC14	90.65cm	19.55 m	51.22 m	16 m	84.0937	27.5425
SC15	26.85 cm	7.77 m	18.65 m	8.43 m	84.0945	27.5417
SC16	35.73 cm	12.3 m	39.22 m	9.12 m	84.0925	27.5412
DC1	47.09 cm	15.1 m	36.65 m	16.03 m	84.3253	27.5575
DC2	32.77 cm	12.57 m	28.08 m	7.97 m	84.3246	27.5570
DC3	45.5 cm	16.76 m	21.22 m	13.71 m	84.3236	27.5569
DC4	31.18 cm	14.59 m	22.08 m	8.42 m	84.3224	27.5566
DC5	31.75 cm	13.33 m	12.65 m	10.22 m	84.2765	27.5052
DC6	47.73 cm	17.43 m	10.94 m	15.7 m	84.2760	27.5053
DC7	48.36 cm	16.89 m	18.65 m	14.65 m	84.2754	27.5052
DC8	29.27 cm	12 m	21.22 m	9.44 m	84.2771	27.5052
DC9	44.86 cm	18.9 m	32.37 m	13.32 m	84.4218	27.6153
DC10	30.86 cm	11.32 m	26.37 m	7.87 m	84.4217	27.6145
DC11	33.09 cm	11.91 m	4.08 m	8.37 m	84.4211	27.6138
DC12	44.55 cm	17.65 m	8.37 m	14.29 m	84.4205	27.6134
DC13	42.95 cm	16.09 m	17.80 m	16.24 m	84.1041	27.5569
DC14	42 cm	12.3 m	51.22 m	13.31 m	84.1036	27.5563
DC15	28.63 cm	10.1 m	18.65 m	9.73 m	84.1030	27.5560
DC16	30.54 cm	13.33 m	39.22 m	10.62 m	84.1022	27.5559

CS: Crown size, HT: Height of tree, TH: Trap height, SC: Shorea canopy, DC: Dalberiga canopy, Number indicates tree's number

Annex 10. Soil properties in different sampling periods and different sectors of CNP

	pH	OM	N	P		pH	OM	N	P
	First sampling period					Fourth sampling period			
Kasara	7.35	1.88	0.15	12.36	Kasara	7.20	2.38	0.14	22.10
Madi	7.30	3.73	0.29	11.81	Madi	6.90	3.72	0.29	18.67
Sauraha	7.25	2.88	0.11	13.84	Sauraha	7.10	3.44	0.24	20.43
Amaltari	7.50	2.02	0.13	16.06	Amaltari	7.10	1.35	0.09	27.21
Kasara	7.15	1.69	0.29	13.33	Kasara	7.37	2.18	0.22	22.30
Madi	7.12	3.54	0.44	12.77	Madi	7.11	3.54	0.36	19.88
Sauraha	7.11	2.67	0.27	14.88	Sauraha	7.18	3.27	0.32	22.20
Amaltari	7.32	1.77	0.21	17.11	Amaltari	7.19	1.67	0.16	26.34
	Second sampling period					Fifth Sampling period			
Kasara	7.23	1.90	0.14	19.88	Kasara	6.65	2.33	0.13	22.17
Madi	7.29	3.82	0.29	12.30	Madi	6.60	3.36	0.25	31.42
Sauraha	7.20	3.01	0.26	16.34	Sauraha	6.80	2.99	0.21	22.17
Amaltari	7.44	2.01	0.10	17.43	Amaltari	7.05	1.52	0.07	29.57
Kasara	7.15	1.68	0.22	20.42	Kasara	6.87	2.12	0.22	20.22
Madi	7.21	3.68	0.23	13.21	Madi	6.72	3.19	0.32	31.65
Sauraha	7.15	2.73	0.32	17.21	Sauraha	6.88	2.76	0.29	22.23
Amaltari	7.38	1.88	0.18	18.34	Amaltari	7.13	1.33	0.15	29.22
	Third sampling period					Sixth sampling period			
Kasara	7.20	2.41	0.16	22.17	Kasara	6.64	2.31	0.15	22.12
Madi	7.00	3.99	0.32	14.77	Madi	6.61	3.40	0.22	31.41
Sauraha	7.20	3.55	0.27	18.47	Sauraha	6.76	3.01	0.21	22.14
Amaltari	7.15	1.84	0.11	18.47	Amaltari	7.02	1.52	0.09	29.40
Kasara	7.33	2.20	0.25	23.11	Kasara	6.86	2.11	0.21	20.87
Madi	7.25	3.63	0.41	15.67	Madi	6.74	3.17	0.31	30.87
Sauraha	7.38	3.32	0.36	19.34	Sauraha	6.78	2.76	0.28	22.54
Amaltari	7.37	1.65	0.20	19.24	Amaltari	7.09	1.36	0.14	29.11

OM: Organic matter, N: Nitrogen, P: Phosphorus

Annex 11. Climatic factors in different sampling periods in CNP

	Avg. T	HM	HE	Rainfall	Max. T	Min. T
First sampling	29.57	56.96	45.33	1.9	38.59	20.55
Second sampling	26.52	73.02	61.80	189.6	34.62	18.42
Third sampling	26.61	82.96	74.07	122	33.12	20.11
Fourth sampling	28.44	84.47	76.26	188.7	33.92	22.95
Fifth sampling	29.03	84.82	78.67	268.8	33.85	24.22
Sixth sampling	27.97	88.34	85.88	427.5	31.86	24.09

Avg. T: Average temperature, HM: Humidity at 8:45 am, HE: Humidity at 5:45 am

Annex 12. Beetle families and subfamilies allocated in different feeding guilds

Family/Subfamily	Feeding guilds	Family/ Subfamily	Feeding guilds
Anthribidae	Fungivores	Hybosoridae	Saprophages
Attelabidae	Herbivores	Lucanidae	Xylophages
Bostrichidae	Xylophages	Melyridae	Predators
Byturidae	Herbivores	Nitidulidae	Fungivores
Carabidae	Predator	Prionoceridae	Unknown
Cerambycidae	Xylophages	Salpingidae	Unknown
Chelonariidae	Unknown	Scarabaeinae*	Saprophages
Chrysomelidae	Herbivores	Melolonthinae*	Herbivores
Cleridae	Predators	Rutelinae*	Herbivores
Coccinellidae	Predators	Silvanidae	Saprophages
Curculionidae	Herbivores	Tenebrionidae	Saprophages
Dryophthoridae	Xylophages	Trogossitidae	Predators
Elateridae	Herbivores	Zopheridae	Fungivores
Histeridae	Predators		

* indicates subfamily

Annex 13. List of genera of Beetle collected in 16 canopy traps in Shorea canopy and 16 canopy traps in Dalbergia canopy layer.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
<i>Calleida sp.</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Calosoma sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Dromius sp. *</i>	0	0	0	0	2	3	0	2	0	3	0	0	13	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Harpalus sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	1	0	2	0	0	4	2	0	0	0	0	0	0	0	0
<i>Holcoderus sp.</i>	0	0	1	1	0	0	0	0	0	1	0	0	1	0	0	1
	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Mirolestes sp.</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Orthogonius sp.</i>	5	0	0	0	0	0	0	0	0	0	0	0	1	0	8	1
	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	3
<i>Paraphaea sp.*</i>	0	0	3	0	0	2	2	1	4	4	1	3	0	3	0	0
	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0
<i>Coptops sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

<i>Derolus sp.**</i>	2	0	0	0	0	1	1	3	0	2	1	2	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrestes sp.</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Xylotrechus sp.</i>	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Basilepta sp.**</i>	2	2	3	0	0	0	0	0	1	2	0	4	0	2	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Callosobruchus sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Cryptocephalus spp.**</i>	1	0	2	1	6	0	0	2	0	1	3	0	0	0	5	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dercetina sp.*</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	3	1	2	0	0	0	1	0	0	0	0	1	0	0	0
<i>Brumoides sp.</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Chilocorus sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
<i>Coccinella sp.</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Menochilus sp.</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ortalia spp.</i>	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
<i>Phrynocaria sp.</i>	1	1	1	0	0	0	0	2	0	0	0	0	0	0	0	0
	1	0	1	0	1	3	0	0	0	0	0	0	2	0	0	0
<i>Rodolia spp.***</i>	24	33	26	8	30	14	77	8	37	52	18	126	71	17	30	15
	11	9	4	0	0	6	0	0	5	1	0	4	3	0	0	0
<i>Sumnius spp.***</i>	81	110	64	217	47	144	95	162	40	168	197	51	99	49	101	121
	23	0	3	0	2	0	5	7	3	13	9	9	13	5	7	16
<i>Adelocora sp.</i>	0	0	0	0	0	0	0	0	0	1	0	3	0	0	6	5
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Agrypnus sp.</i>	3	0	16	0	5	2	7	1	1	6	2	6	6	0	0	4
	8	5	0	0	0	4	1	0	18	2	0	1	10	0	0	1
<i>Melanotus spp.***</i>	12	15	16	15	16	9	10	24	20	4	20	26	13	13	21	12
	4	0	0	0	3	0	0	0	3	0	1	2	0	2	0	0
<i>Melanoxanthus sp.</i>	1	0	4	9	7	0	3	0	1	11	0	0	0	0	12	0
	0	1	3	2	0	2	0	7	1	1	4	0	3	0	0	3
<i>Paracardiophorus sp.***</i>	37	9	20	137	23	17	16	0	22	0	7	114	23	0	0	6
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Figulus sp.</i>	0	0	0	0	3	0	0	0	3	0	0	0	6	0	2	0
	9	0	2	0	0	2	0	0	1	0	2	0	0	0	0	0

<i>Apogonia sp.</i>	0	0	22	0	0	4	23	0	6	7	12	0	3	42	0	25
	14	6	0	6	2	12	2	2	9	0	19	0	20	5	7	16
<i>Holotrichia sp.</i>	15	24	31	21	18	9	7	10	12	0	5	8	9	12	28	0
	1	4	5	0	5	1	17	10	14	4	11	1	15	3	2	10
<i>Maladera spp.</i>	10	8	21	26	23	123	2	7	5	12	10	0	8	16	23	49
	5	8	13	2	11	6	34	13	30	6	41	9	10	50	9	10
<i>Idgia sp.</i>	12	12	0	0	1	13	0	5	2	11	12	11	24	4	8	11
	0	0	2	0	1	3	0	0	2	0	9	2	0	4	7	2
<i>Adoretus spp. **</i>	1	0	1	1	0	2	0	0	0	0	0	0	0	0	0	0
	3	0	2	0	1	2	0	2	0	5	0	1	3	1	7	0
<i>Anomala sp.</i>	0	0	0	0	1	0	0	5	0	0	2	5	0	4	0	0
	0	0	0	3	0	4	1	6	0	7	0	4	5	0	0	0
<i>Elacatis sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cerogria sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hemicera sp.</i>	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Strongylium sp. **</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	12	0	3	2	0	0	2	8	0	0	0	15	6
<i>Tribolium sp.</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gempylodes sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Monomma spp. **</i>	0	3	1	4	1	3	1	3	6	5	3	12	16	0	4	1
	0	0	0	0	0	0	0	3	2	0	2	3	0	2	2	0

Species marked with * were significantly associated with canopy layers of one of the forest (*<0.05, **<0.01, ***<0.001). Bold numbers indicate significant associations. Each row with shade represent *Shorea* forest and unshaded row represent *Dalbergia* forest, C: Canopy traps, numbers indicates trap numbers

Annex 14. List of genera of Beetle collected in 16 ground traps in *Shorea* ground and 16 ground traps in *Dalbergia* ground layer

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15	G16
<i>Anomatarus sp. *</i>	0	0	0	5	0	0	4	1	0	0	0	0	1	0	0	1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Calathus sp.</i>	0	2	0	5	3	0	0	0	0	2	0	0	8	2	2	0
	0	5	2	0	0	2	0	0	0	1	1	1	0	0	0	0
<i>Chalaenius spp.</i>	0	0	0	0	0	2	0	1	0	0	0	0	0	0	1	1
	0	0	5	0	0	0	0	0	5	2	0	0	1	4	3	0
<i>Cicindela sp.</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

<i>Clivina sp.</i>	1	2	0	0	0	0	0	2	0	0	0	0	0	2	0	
	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	
<i>Omphra sp.</i>	1	16	2	0	0	2	0	11	8	5	5	0	0	0	1	
	0	4	3	2	6	0	0	0	4	0	0	0	3	7	0	
<i>Scarites sp.</i>	0	0	6	0	3	0	3	0	0	0	0	0	0	0	4	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Trigonotoma sp.</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
<i>Chelonarium sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	
<i>Hybosorus sp.***</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	41	2324	637	402	50	893	567	454	95	9	1393	218	91	1207	849	862
<i>Catharsius spp.</i>	16	29	3	75	13	0	13	22	14	2	14	11	5	12	10	4
	19	65	49	27	2	12	110	13	39	5	144	54	6	28	22	50
<i>Copris spp.</i>	0	13	11	38	21	0	8	9	10	7	13	0	4	0	1	0
	13	2	7	9	35	15	7	5	3	64	17	2	7	1	9	14
<i>Onthophagus spp.</i>	44	98	72	150	173	93	60	88	96	21	47	55	32	42	39	34
	65	73	40	42	126	58	73	52	96	48	68	61	45	86	66	59
<i>Paragymnopleurus sp.</i>	19	119	0	36	158	1	61	85	33	27	2	56	14	138	15	20
	46	148	24	84	105	114	114	46	89	91	130	25	25	145	3	10
<i>Sisyphus sp.</i>	12	41	11	180	65	19	57	34	13	5	46	0	5	30	0	7
	12	15	19	25	21	32	11	0	0	0	2	8	7	17	10	5
<i>Gonocephalus spp.***</i>	1	26	8	2	18	12	14	15	9	16	11	10	0	2	3	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Luprops sp.</i>	0	0	0	3	0	0	0	0	0	1	0	1	0	0	0	1
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species marked with * were significantly associated with ground layers of one of the forest (*<0.05, **<0.01, ***<0.001). Bold numbers indicate significant associations. Each row with shade represent *Shorea* forest and unshaded row represent *Dalbergia* forest, G: Ground traps, numbers indicates trap numbers