Diversity of Canopy Beetles of *Schima wallichii* in Shivapuri Nagarjun National Park and Naudhara Community Forest

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RECOMMENDATION

This is to recommend that the thesis entitled "**Diversity of Canopy Beetles of *Schima wallichii* in Shivapuri Nagarjun National Park and Naudhara Community Forest"** has been carried out by Ms. Bimala Bhattarai for partial fulfillment of Master's degree in Zoology with the special paper Entomology. This is her original work and has been carried out under my supervision. To the best of my knowledge, this work has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor Mr. Indra Prasad Subedi, Lecturer, Central Department of Zoology, Tribhuvan University, the thesis entitled "**Diversity of Canopy Beetles of *Schima wallichii* in Shivapuri Nagarjun National Park and Naudhara Community Forest"** is approved for the examination and submitted to Tribhuvan University in partial fulfillment of the requirement for Master's Degree of Science in Zoology with special paper in Entomology.

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This thesis work submitted by Mrs. Bimala Bhattarai "**Diversity of Canopy Beetles of *Schima wallichii* in Shivapuri Nagarjun National Park and Naudhara Community Forest"** has been accepted as a partial fulfillment for requirement of Master's Degree of Science in Zoology with special paper Entomology.

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DECLARATION

I hereby declare that the work presented in this thesis has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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Bimala Bhattarai

ABSTRACT

The study aimed at exploring the diversity of canopy beetles associated with *Schima wallichii* was carried out from June 2014 to March 2015 in Naudhara Community Forest (NCF) and Shivapuri Nagarjun National Park (SNNP). Sampling of beetles was done by using flight interception trap (60 × 40 cm). In the study, 237 beetle samples were collected with scarabaeidae present in dominating numbers at each site: NCF (109) and SNNP (76). Shannon-Weiner Diversity Index was found highest in June followed by August and March and least in October. The diversity was found positively correlated to the change in temperatures.

NCF (140) contributed more number of beetles than SNNP (97). Abundance of canopy beetles showed no significant difference with tree DBH (NCF: $p = 0.35$, SNNP: $p=0.81$), tree height (m) (NCF: $p = 0.39$, SNNP: $p=0.47$), age of tree (years) (NCF: $p = 0.46$, SNNP: $p=0.13$), size of tree crown (NCF: $p = 0.48$, SNNP: $p=0.10$), and canopy cover (NCF: $p = 0.71$, SNNP: $p=0.41$) of the tree. The abundance was found significantly variable with change in months in SNNP ($p=1.14E-05$, $p<0.001$) and NCF ($p=5.52E-08$, $p<0.001$). With respect to the environmental treatments (natural state, fern removed, orchid removed), abundance showed significant difference only in NCF ($p=0.045$, $p<0.05$). Fern removal was found to be the most effective environmental treatment in both the sites.

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Abbreviated forms	Detail of abbreviation
DBH	Diameter at Breast Height
GPS	Global Positing System
D.f	Degree of freedom
%	percentage
m	meter
cm	centimeter
km	kilometer
asl	above sea level

1. INTRODUCTION

Forest approximately covers 37% of the total area (147,181km^2) of Nepal. Nepal harbors variety of climatic conditions and hence different forest types within width of 193 km and length of 885 km.

Jackson (1994) has classified forest in Nepal as: tropical forest, sub-tropical forest, lower temperate forest, upper temperate forest, sub alpine forest, alpine zone. Tropical forest is extended up to 1000m and includes *Shorea-robusta* forest, *Dalbergia sisso* forest, Grassland; *Terminalia- Anogeissus* deciduous hill forest, etc. Sub-tropical forest is extended from 1000-2000m and includes *Pinus* forest, *Schima-castanopsis* forest, *Alnus nepalensis* forest, riverine forest. Lower temperate forest is extended from 2000-2700m in west, 1700-2400m in east and includes different species of *Quercus* forest, broad leaved plant forest and some pine forest. Upper temperate forest is extended from 2700-3100m in west and center, 2400-2800m in east and includes different species of *Quercus* forest, *Rhododendron* forest, mixed broadleaved forest, coniferous forest. Similarly, Sub alpine forest is extended from 3000-4200m in west and center, around 3000m in east and includes Rhododendron forest, Juniperus forest, *Betula* forest, etc., and Alpine zone includes shrubby species (shrubby *Rhododendron*, Junipers etc.) but no trees.

Schima is an evergreen tree belonging to the tea family, Theaceae. It is found in warm temperate to subtropical climates across southern and southeastern Asia. It is a medium tree up to 35m tall with cylindrical stem which is branchless for up to 25m, diameter up to 1m and inner bark with skin-irritating fibers, leaves are leathery, elliptic-oblong in shape with entire or slightly toothed margin, flowers are white with fragrance and 3-4cm across (Bhabini, 2007**).**

It is a very common tree in central and eastern Nepal between 900m and 2000m, it forms dominant forest type with *Castanopsis* species at these altitudes on north-facing slopes in the drier areas, and on both north- and south-facing slopes in wetter areas (K.C., 2012). It is planted as constituent of natural forest and is valued for timber production (Adhikari and Fischer, 2010).

Subba and Paudel (2014) found that *S. wallichii* bark had strong antioxidant power and leaves exhibit high antibacterial activities against *Staphylococcus aureus* and *Escherichia coli.* It is useful for reforestation and in water conservation in catchment area (Orwa *et al*., 2009).

1.1 Epiphytes

Epiphytes are the plants that spend most or all of their lives attached to other plants. They show a neutral or commensalism symbiosis with their hosts, and have only minimal effect on nutrient relations of supporting trees and the ecosystem as a whole as well they may significantly contribute to overall nutrient cycling despite their biomass being small, relative to the ecosystem as a whole (Nadkarni,1986).

Small plants have a problem in dense forests but epiphytes are a specialized group of plants that leave forest floor altogether, grow high in the canopy on the trunks or branches of tall forest trees where light is available. But when light is more plentiful in this niche, access to water and nutrients can be limited, and since they have no contact with the soil, and, importantly, do not penetrate the living tissues of their hosts they quickly get exposed to a very harsh (Atwell, 2003).

Epiphytes are a diverse group including plants from many families and it has been found that 24,000 or more vascular plant species are epiphytes (Kress, 1986). The most common vascular epiphytes are orchids, ferns.

1.1.1Orchids

Orchids are diverse and widespread flowering plants that belong to family Orchidaceae. They often bloom with fragrance and are colorful. They belong to largest vascular plant families called Orchidaceae (Chase *et al.*, 2015).

In Nepal, nearly 388 orchid's species within 99 genera are reported (Acharya and Rokaya, 2008). Orchids are well known not only for their ornamental value, but also for their uses in herbal medicine (Sumner, 2000). Ghimire (2008) has recorded 207 species of epiphytic orchids from Nepal that belong to 49 genera including five endemic species (*Bulbophyllum ambrosia, Eria baniai, E. nepalensis, Oberonia nepalensis* and *Pleione coronaria*).

S. wallichii host more epiphytic orchids than other tree species within Kathmandu valley (Adhikari *et al*., 2012).

1.1.2 Ferns

Ferns are vascular plants that reproduce via spores. They have branched stem and leaves. There are approximately 10,560 species of fern belonging to approximately 215 genera of 21 families (Christenhusz and Byng, 2016). Nepal has 550 species of ferns; greatest number of fern species is recorded from Central Nepal (Jenkins *et al*., 2015).

Along a tropical elevational gradient, orchids contributed 71.3% and 51.4% to the total epiphyte abundance and species richness, respectively, and ferns contributed 22.2% to abundance and 33.3% to species richness. Abundance and species richness increased significantly above 800m and reached a maximum at 1,300 m (Ding, 2016).

Epiphytic lichens and bryophytes increase canopy water storage capacity by prolonging the time required for the canopy to saturate and dry, and alter the transfer of water through the canopy (Pypkar *et al*., 2006).

1.2 Beetles

Insects are, by far, the most diverse group of organisms on earth as they utilize even the smallest of microhabitats (Komonen, 2003). The Order Coleoptera belongs to the class Insecta. Coleoptera (Beetles) form the largest Order in the animal kingdom, with the highest diversity in the world and have currently about 350,000 known species (Gullan and Cranston, 2010). Beetles occur in almost all part of the world, in terrestrial habitats from mountain tops to the intertidal shoreline, from the forest to the desert, in subterranean caverns and in freshwater habitats (Booth *et al*., 1979). Coleoptera are minute to very large insects, usually with strongly hardened bodies and the forewings modified into protective covers or elytra. Some species can be beneficial to the mankind (e.g., as biological control agent against pests, weeds, etc., as pollinators). They also act in detrivores in the decomposer system (eg, bark beetles, the longhorn beetles, the jewel beetles and timberworm beetles); they help in breakdown of dead trees and other plants, animal remains, and dung, and so contribute to the recycling of nutrients essential for future production. But, some cause negative impact by competing for food resources or damaging products.

Beetles, as well as other litter arthropods, are of particular importance to study because of their roles as predators, decomposers, and herbivores (Petersen and Luxton, 1982).

Canopy of forest ecosystem supports a wide variety of plants, vertebrates, invertebrates, and microbes. Among beetles, families Chrysomelidae and Curculionidae are found abundant in the forest (Chung *et al.,* 2001). Undisturbed tree (with epiphytes) has greater abundance of invertebrates in compared to the disturbed ones (Diaz *et al*., 2012).

1.3 Rational

1.3.1 Justification of study

Study on various aspects of canopy is still inchoate in the context to Nepal. Though some scarce work is done, further study and research is imperative. During the study, flights intercept canopy trap was used due to its flexibility to be suspended at different heights as required and could be used for longer period of time. Likewise, beetles are the dominating group among other arthropods. As well they are the integral part of forest ecosystem; hence the study was done to see the canopy beetles on a particular evergreen plant (*Schima wallichii*).

1.5 Objectives

1.5.1 General objective

- To study the diversity of canopy beetles in relation to *Schima wallichii* of Shivapuri Nagarjun National Park (SNNP) and Naudhara Community Forest (NCF).

1.5.2 Specific objectives

- To study the effects of environmental treatments (Natural state, Orchid removed and Fern removed) on abundance of canopy beetles of *Schima wallichii.*
- To compare abundance of canopy beetles of *Schima wallichii* of Shivapuri Nagarjun National Park and Naudhara Community Forest.

2. LITERATURE REVIEW

Arthropod association with plants and microbes influence the amounts of living and dead organic matter and transfers of nutrients in terrestrial ecosystems, whereas canopy arthropods have the greatest effect on mobile elements such as potassium, whereas soil detritivores influence mineralization rates of less mobile elements such as nitrogen, phosphorus, and calcium (Seastedt and Crossley, 1984). Invertebrates are the main agents of litter fragmentation, mixing of leaf litter with mineral soil, exposing greater surface for microbial colonization which is the major pathway of nutrient and energy flux in most forest (Nadkarni and Longino, 1990). Arthropod abundance and diversity is higher in native than invaded forest (Hagen, 2010).

Insects herbivory can influence the quality of forest soils by dropping frass (feces) and leaf fragments to the floor. They can also modify the chemistry of rainwater that passes through the forest canopy and can potentially change soil fertility and the rates of decomposition of leaves that have fallen to the ground (Scowalter *et al*., 2001). Unlike abiotic factors, insect herbivores are the integral part of ecosystem and respond to the change in environmental conditions (Schowalter and Lowman, 1999). Hence, loss of insect species can cause cascade in extinction of other flora and fauna (Greenwood, 1987).

The choice of trees planted affects the insect biodiversity in the green spaces (Helden and Leather, 2004). The vertical distribution of insects shows significant different, some insect taxa are restricted to the higher traps; whereas other taxa confined to different heights, hence vertical sampling is important to compare the insect fauna in managed forests differing in vertical structure (Su and Woods, 2001).

The procedure for accessing canopy was graphically described by Max Nicholson (Mitchell, 1986 and Hingston, 1932). Canopy fogging was used in 1980s, and an estimate of 30 million species globally was made based on fogging (Erwin, 1982).

Upper foremost canopy is the primary interface between atmosphere and the forest and is a reservoir of biological diversity (Parkar *et al*., 1992). Both natural and artificial disturbances in a forest can cause tree death or injury, which in turn creates openings in the forest cover known as canopy gaps (Yamamoto, 2000) which influences plant population dynamics (Lima and Moura, 2008).

Canopy of forest ecosystem supports a wide variety of plants, vertebrates, invertebrates, and microbes and among the invertebrate group; arthropods are characterized by their great abundance, diversity, and functional importance (Cuevas and Sanchez, 2015) as forest canopies support high arthropod biodiversity (Maguire *et al*., 2014). Hagen *et al*. (2010) found that arthropod abundance was highest in the lower canopy, and canopy strata exhibited some differences in arthropod community composition. It influences the rate of recycling of nutrients in forests that are governed by temperature and moisture conditions and by the chemical and physical nature of the litter (Prescott, 2002). Canopy structure controls the quality and quantity of ecosystem that differ both in spatial and temporal availability of light (Jennings *et al*., 1999). A mature forest canopy facilitates the survival of light-intolerant understory species (Moore *et al*., 2011).

Natural disturbance to forest canopies create broad varieties of opportunities for the growth of nearby plants and establishment of new ones, largely by increasing the amount of light penetrating into the forest interior (Lawton, 1990). Opened canopy increases the amount of light reaching the forest floor and therefore promotes the germination of certain species and at the same time may diminish the germination of others (Raich and Khoon, 1990). It determines the pattern of seedling regeneration beneath them (Pacala *et al*., 1994). Canopy gap and gap size also affect species diversity and regeneration (Zang and Wang, 2002).

Several sampling methods have been developed for forest-dwelling insects (Southwood, 1978; Leather, 2005), such as interception (window) traps, malaise traps, pitfall traps, canopy fogging, sieving and direct searching. A high sampling effort is almost always required to obtain reliable information on insect communities (Longino *et al*., 2002) as collecting techniques greatly influence the knowledge of canopy invertebrate (Basset, 2001). Several techniques have been used to sample canopy invertebrates. Example: tower crane having long horizontal jib, with which investigator could perceive canopy from atmospheric perceptive rather than forest floor (Parkar *et al*., 1992), while flight intercept trap that could be suspended for long period of time could sample flying invertebrate fauna at different heights (Hill and Cermak, 1997). But it is imperative that several, complementary, methods should be used for general arthropod surveys (Basset *et al*., 1996)

Coleoptera is the most species-rich and prevalent insect order worldwide which contribute to great biodiversity in forest habitats and play various roles in ecosystem dynamics and functioning (Erwin, 1997; Lassau *et al.*, 2005).

One-year chemical knockdown study was carried out on canopy arthropods and birds in one Western Australian forest, and eastern Australian (New South Wales) forest and

Hymenoptera, Coleoptera, Diptera, and Araneae species were found the most in the canopy (Majer *et al*., 2000).

Hyvarinen *et al*. (2006) compared three different commonly used methods for sampling forest beetles, freely hanging flight-intercept (window) traps (FWT), flight-intercept traps attached to trunks (TWT) and pitfall traps placed in the ground (PFT), in Scots pine dominated boreal forests in eastern Finland and found that twts were the most effective for all species groups in terms of number of species collected.

Patricia and Theogene (2005) study showed that the undisturbed forest had higher abundance and diversity of Coleopteran families as compared to disturbed forest, and also found that relative humidity and % shade did not affect the abundance and diversity of Coleoptera in both habitats.

Pettersson *et al*. (1995) found significantly greater invertebrate diversity with large invertebrates (> 2·5 mm) like spiders (Araneae), Lepidoptera and Diptera larvae etc., in natural forest than in managed forests.

Community composition of Coleoptera and Diptera varied significantly by trap height (Maguire *et al*., 2014).

3. MATERIALS AND METHODS

3.1 Study Area

Two sites namely: Shivapuri Nagarjun National Park and Naudhara community forest were selected for beetle sampling.

Shivapuri Nagarjun National Park lies within 27° 45' to 27° 52' N and 85° 15' to 85° 30' E and has an area of 159 km^2 and altitude ranging from 1366 m to 2732 m asl. It lies at about 12 km away from the capital city. The area is prominent with subtropical and temperate type of vegetation. The subtropical zone is dominated by *Schima wallichii, Castanopsis indica, C. tribuloides* and *Pinus roxburghii*. The common associates are *Alnus nepalensis, Prunu scerasoides, Engelhardia spicata* and *Quercus glauca*. The shrubs include *Mussaenda frondosa, Osbekia stellata, Hypericum cordifolium* and *Phyllanthus parvifolius*. At higher elevations, mixed temperate forest of oak (*Quercus lanata, Q. semecarpifolia*) and Rhododendron (*Rhododendron arboreum*) are predominant. The common associates are *Lyonia ovalifolia*, *Myrica esculenta*, *Q. Lamellosa*, *Symplocus* sp., *Rhu*s sp, *Gaultheria fragrantissima*, *Potentilla fulgens, Hedyotis scandens, Rubia manjith* (Chaudhary, 1998).

Among trees, Uttis (*Alnus nepalensis* D. Don) and Chilaune (*Schima wallichii*) are the most dominant species (Pandey and Bajracharya, 2010).

Naudhara community forest lies within Phulchoki hill (27° 33'N, 85° 22'E), lies at an altitude up to 2,307 m asl and 16 km southeast of Kathmandu, Nepal. The altitudinal range is 1400 m to 2715 m with extensive diverse forests mostly dominated by broad leaved evergreen trees. It covers an area of approximately 50 square km. Phulchoki hill is characterized by three distinct evergreen broad leaved forest types: mixed *Schima castanopsis* forest at the base (1400 m to 1800 m), Oak- Laurel forest (1800 m to 2400 m) and evergreen oak forest (2000 m above) (Kattel *et al.*, 2015).

The study area has typical warm temperate monsoon with three seasons round the year: cold and dry winter (October to February), pre monsoon dry summer (March to May) and monsoon (June to September) (Poudyal *et al.*, 2014).

Lower belt (1600 m) includes *Schima-Castanopsis* forest, which was selected for the study. At about 1800 m, the area broadly consists of mixed broadleaved Forest (comprising *Schima wallichii, Castanopsis indica, Alnus nepalensis, Acer campbelli, Ilex dipyrena*, *Castanopsis tribuloides*, *Michelia* sp and more Laurels. Above this altitude (1900-2200 m), Oak and Laurels with *Rhododendron* species, *Lyonia* species are found.

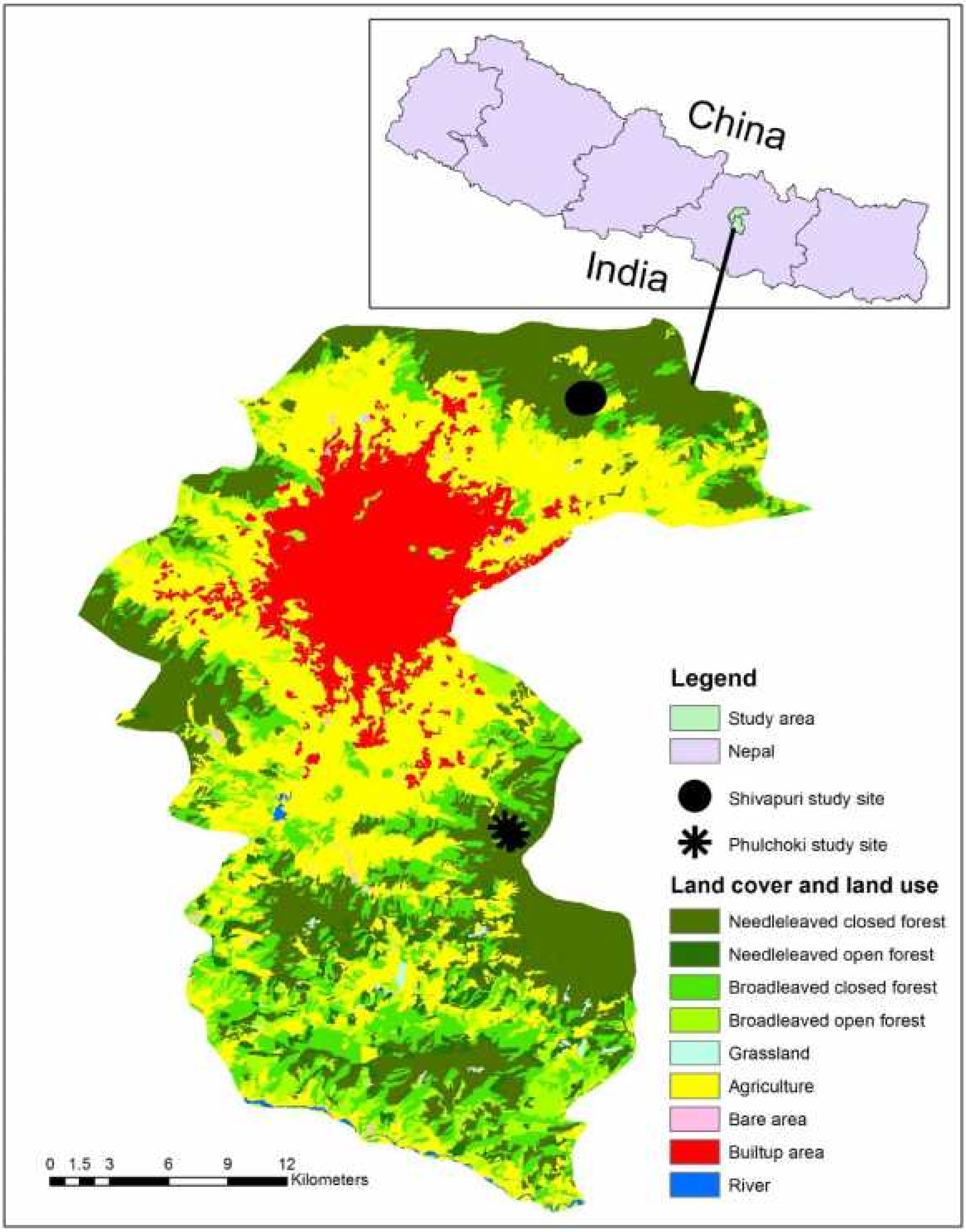

Figure 1: Study Area.

3.2 Materials

3.2.1 Canopy trap

A composite flight interception traps consisting of crossed transparent plastic shields (60×40 cm) with funnel of smooth plastic cloth attached to the bottom filled with preserving liquid (ethylene-glycol) was used to collect canopy beetle.

3.2.2 Global Positioning System (GPS)

Garmin etrex 10 GPS was used to locate *Schima wallichii* tree species.

3.2.3 DBH meter

DBH meter was used to measure the diameter of sampled trees at breast height.

3.2.4 Rope

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

3.2.5 Collection Jars

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

3.2.6 Magnifying glass and Microscope

Magnifying glass and simple microscope were used to see the morphological characters of beetle to ease the identification procedure.

3.2.7 Camera

Nikon D5200 with 18-55 mm VR lens was used to photograph the specimen.

3.3 Sampling method

Eighteen possible oldest trees of *Schima wallichii* were randomly selected on each forest type by observing the various aspects of trees and talking to the locals.

Among the eighteen selected trees, three environmental treatments were applied one meter around the trap.

i) No impact on epiphytes
ii) Orchids removed
iii) Fern removed

Six replica of each treatment was made and tagged with code for identification.

The trees with no impact on epiphyte were wrapped with red ribbon and tagged as Sm11, Sm12, Sm13, Sm14, Sm15 and Sm16 for managed forest and Sn11, Sn12, Sn13, Sn14, Sn15 and Sn16 for natural forest, where Sm11 represents *Schima* plant of managed forest with treatment 1 (i.e. No impact on epiphytes) with replication no 1.

The tree with orchids removed were wrapped with yellow ribbon and tagged as Sm21, Sm22, Sm23, Sm24, Sm25 and Sm26 for managed forest and Sn21, Sn22, Sn23, Sn24, Sn25 and Sn26 for natural forest, where Sm21 represents *Schima* plant of managed forest with treatment 2 (i.e. Removal of orchid) with replication no 1.

The trees with fern removed were wrapped with blue ribbon and tagged as Sm31, Sm32, Sm33, Sm34, Sm35 and Sm36 for managed forest and Sn31, Sn32, Sn33, Sn34, Sn35 and Sn36 for natural forest, where Sm31 represents *Schima* plant of managed forest with treatment 3 (i.e. Removal of fern) with replication no 1.

3.4 Field Survey

The chosen trees were supplied with a canopy trap which was suspended at the height of 10-15m depending on tree height. The traps were supported by pulleys and ropes attached to big branches in the crown of a large *Schima wallichii* trees, at maximum of 15m from the centre of the square grid (Sobek *et al*., 2009; Gossner *et al*., 2013; Meng *et al*., 2013). Beetles were collected using canopy trap which had two pieces of transparent plastic plates (60 × 40 cm, height × width) arranged crosswise and fixed upon a red plastic bowl of 40cm in diameter from upper surface and a collecting jar filled with ethylene-glycol as a preservative liquid (Sobek *et al*., 2009; Meng *et al*., 2013) at the bottom. All the traps were installed in the individual tree crowns using a crossbow. Sampled trees were randomly selected in a 10m wide corridor in the directly adjacent forest and clearance of traps was accomplished every 1 month over a period of 10 months from June 2014 to March 2015 where beetle were separated from plant materials and other debris and stored in 90% ethyl alcohol (Sobek *et al*., 2009) and all individuals were assigned to taxonomic levels (families).

3.5 Identification

Collected beetle individuals were identified by using keys from Johnson and Triplehorn (2004). Specimen comparison was also performed with the beetle specimens of Natural History Museum. Further confirmation was done with the help of a beetle expert, retired Associate Professor Puspa Keshari Shrestha, Natural History Museum, Tribhuvan University, Swayambhu.

3.6 Specimen deposition

Alcohol-preserved specimens were deposited in Natural History Museum, Tribhuvan University, Swayambhu.

3.7 Data Analysis

Data on canopy beetles in relation to *S. wallichii* was collected from both the study sites (Shivapuri Nagarjun National Park and Naudhara Community Forest). The collected data was assembled so as to study diversity and abundance of canopy beetles. Shannon-Weiner Diversity Index was used to see diversity of canopy beetles associated to *S. wallichii*.

Two way ANOVA was used to find the significance of abundance of canopy beetles with three treatments (Natural state, Orchid removed and Fern removed) and change in months. Likewise, significance of abundance of canopy beetles in relation to DBH, history of the tree, size of tree crown, tree height (m) and canopy cover of the tree (m^2) was analyzed using ordinary least square regression.

Line graph was used to present family composition of canopy beetles collected during the study and bar graph to present number of beetles collected in different months in two study sites (Shivapuri Nagarjun National Park and Naudhara Community Forest).

4. RESULTS

4.1 Diversity of canopy beetles

During 10 months (June-March) study period, a total of 237 individual beetle samples belonging to eight families were collected from the two study sites: Shivapuri Nagarjun National Park (SNNP) and Naudhara Community Forest (NCF). NCF contributed majority of individual beetles (i.e., 139 beetles samples) belonging to seven families: Scarabaeidae (109), Curculionidae (01), Staphylinidae (01), Carabidae (02), Lucanidae (01), Cerembycidae (03), Tenebrionidae (03). Whereas, SNP contributed only 98 beetle samples of five different families: Scarabaeidae (76), Staphylinidae (04), Lucanidae (05), Tenebrionidae (01) and Lagaridae (01). Scarabaeidae was the most abundant family in both the study sites (Figure 2); it alone represents about 78.00% of the total specimens collected.

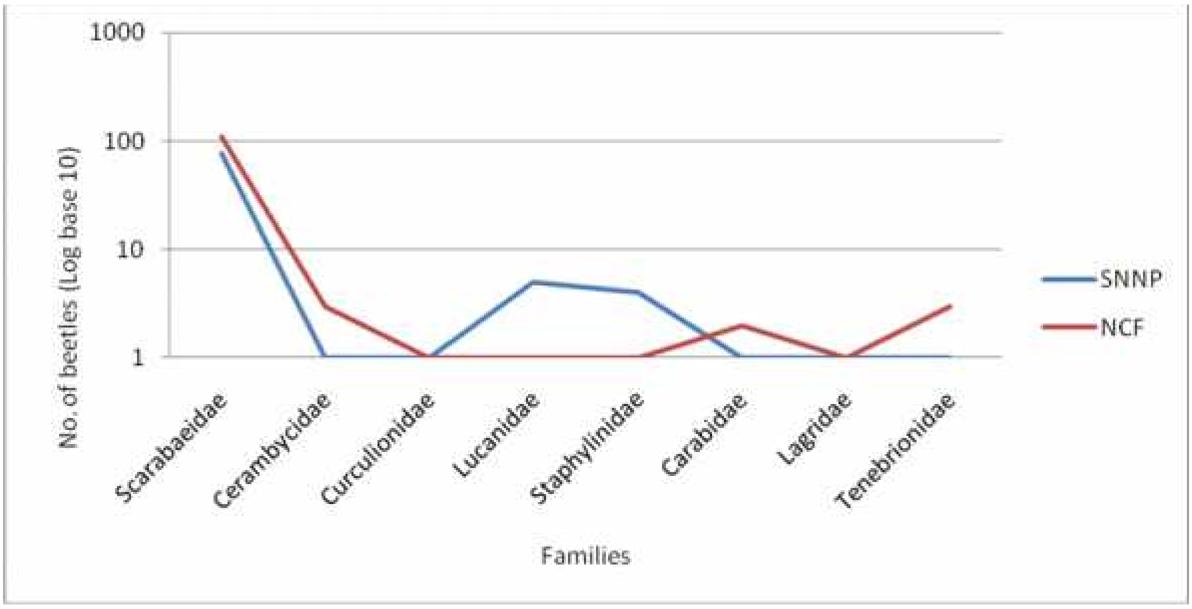

Figure 2: Logarithmic family composition of canopy beetles in SNNP and NCF.

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Diversity of beetles had a high degree of correlation with the temperature in both the study sites (figure3 and figure 4). In both the study sites, more families were recorded at the time of the highest temperature (i.e., 19°C to 21°C), the least at 9°C to 13°C, but families like Lagridae and Tenebrionidae were only encountered at temperature between 14°C to 16°C.

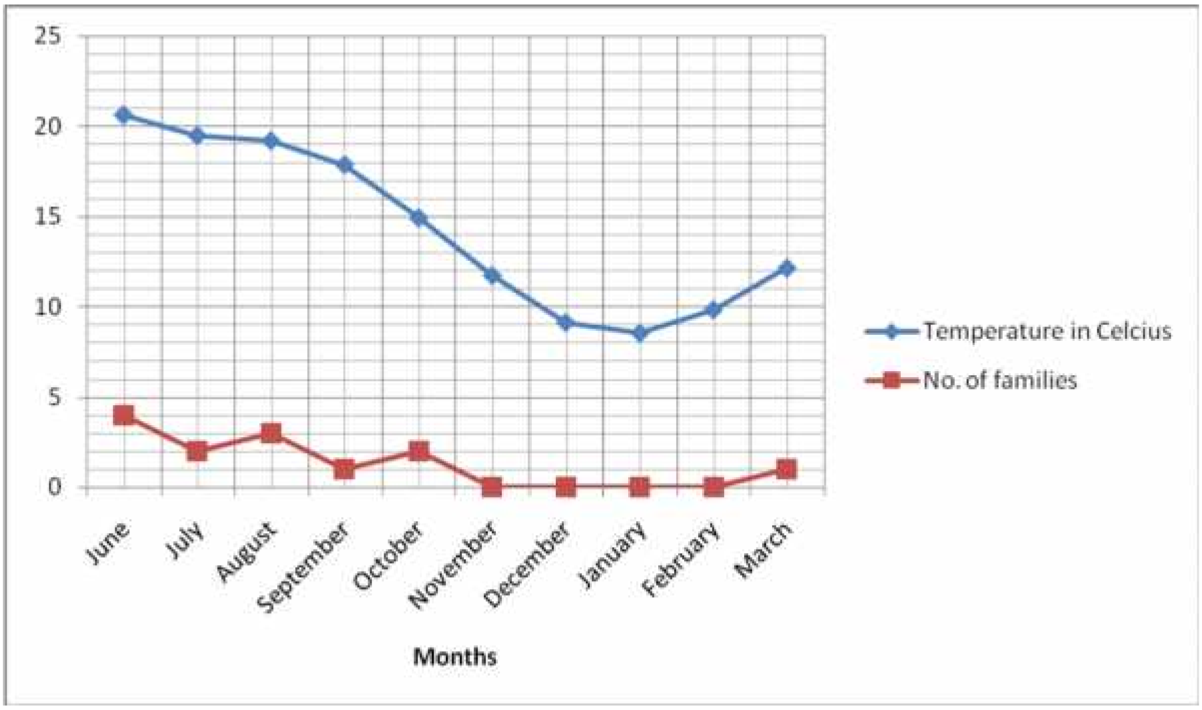


Figure 3: Plotting of Temperature (Celsius) vs. Number of families in NCF.

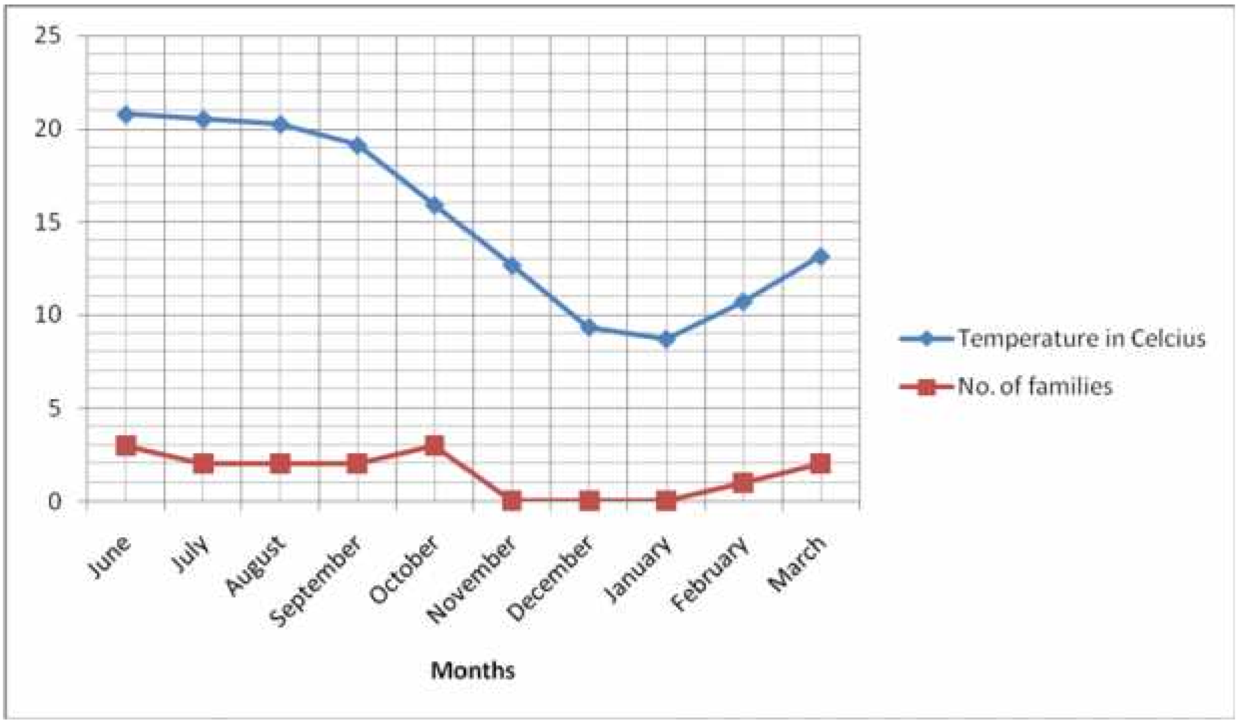


Figure 4: Plotting of Temperature (Celsius) vs. Number of families in SNNP.

Shannon index of diversity ranged from 0- 3.0. The diversity index was found highest in June (SNNP: 2.96; NCF: 2.75), followed by March (SNNP: 2.58; NCF: 2.21) and August (SNNP: 2.34; NCF: 2.21) (Figure 5).

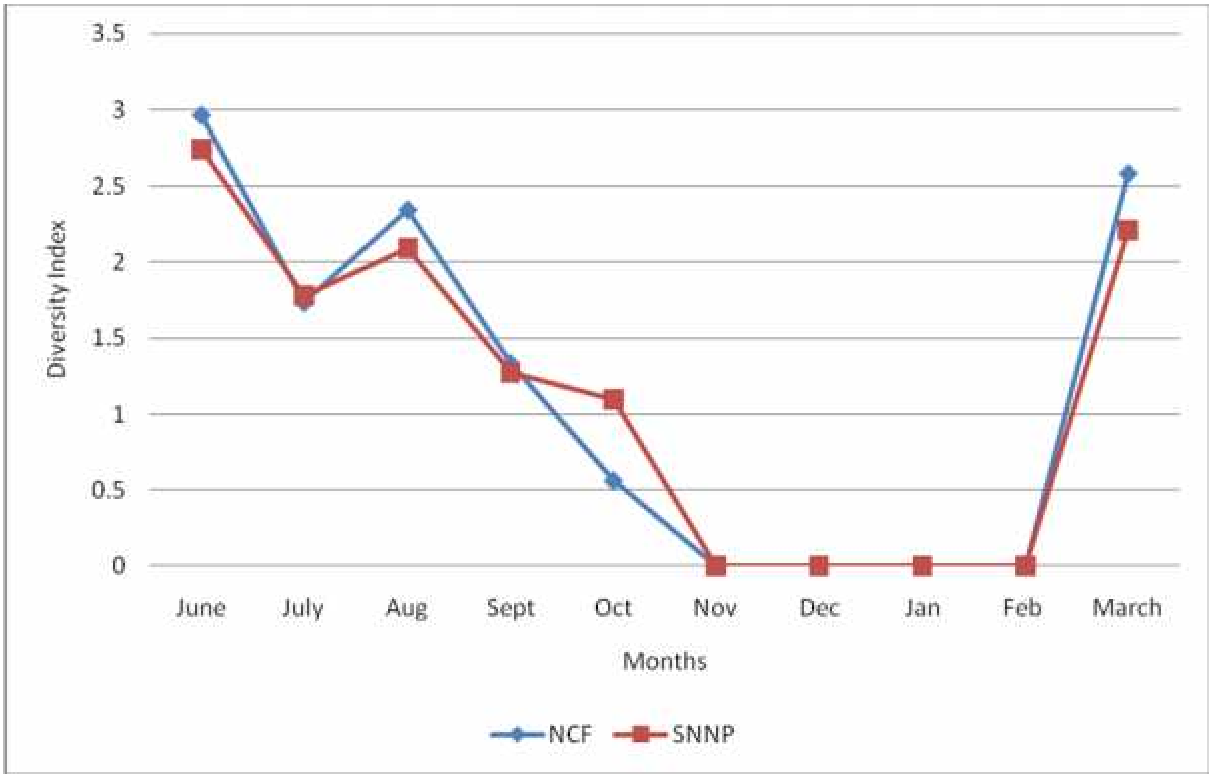


Figure 5: Shannon-Weiner Diversity Index of canopy beetles of SNNP and NCF.

4.2 Abundance of canopy beetles

NCF had more abundance of beetles (139 individual beetles) than SNNP (96 individual beetles). Likewise, more beetle samples were recorded in June followed by March and August (Table 1; Figure 6).

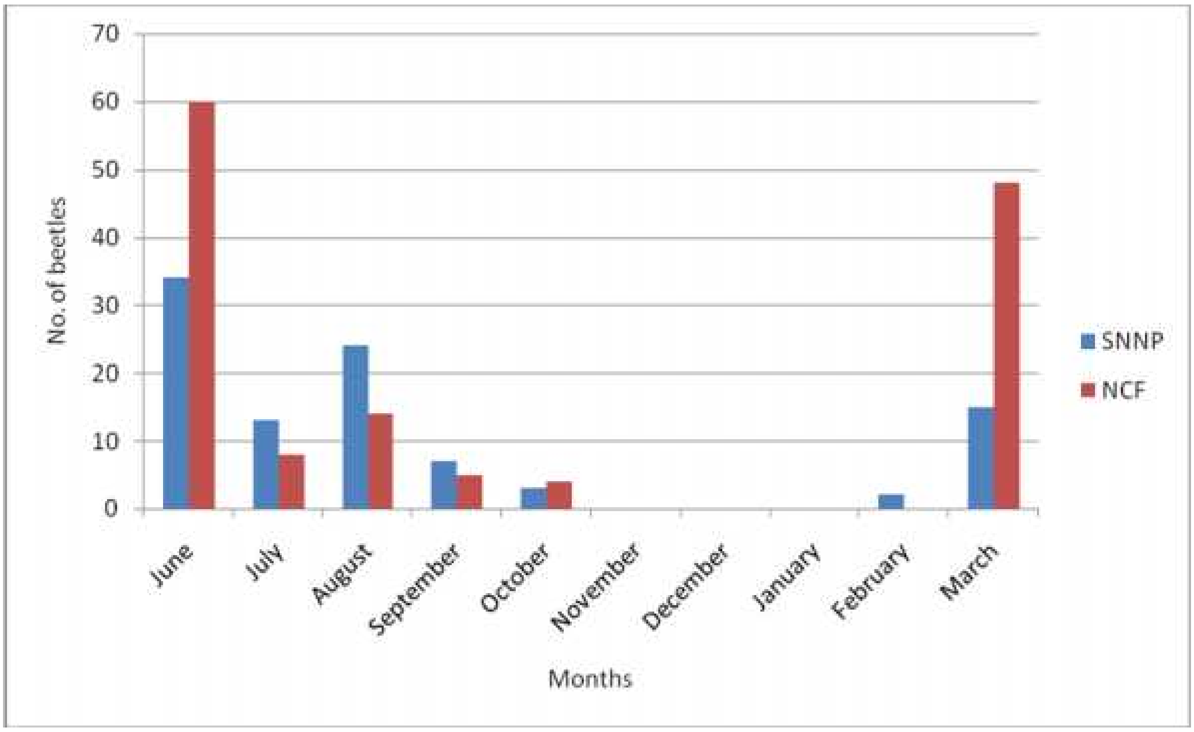
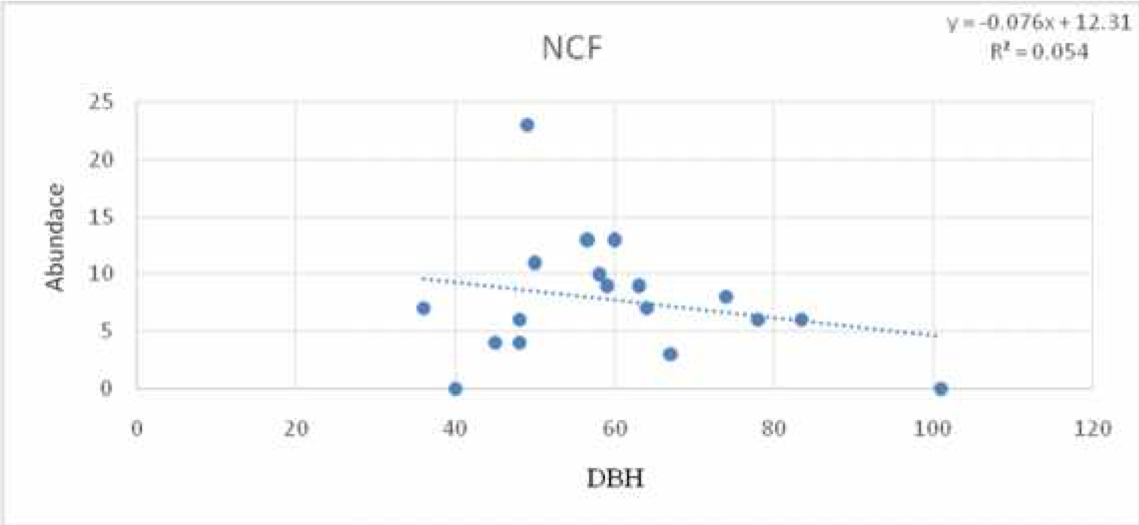


Figure 6: Comparison of abundance of canopy beetles in NCF and SNNP.

The significance of abundance of beetles was calculated in relation to DBH, age of the tree (years), size of tree crown, tree height (m) and canopy cover of the tree. The abundance of canopy beetles was found statistically insignificant to DBH (NCF: p= 0.35, p>0.05; SNNP: p=0.81, p>0.05; figure 7), age of the tree (years) (NCF: p= 0.46, p>0.05; SNNP: p=0.13, p>0.05; figure 8), size of tree crown (NCF: p= 0.48, p>0.05; SNNP: p=0.10, p>0.05; figure 9), tree height (m) (NCF: p= 0.39, p>0.05; SNNP: p=0.47, p>0.05; figure 10) and canopy cover of the tree (NCF: p= 0.71, p>0.05; SNNP: p=0.41, p>0.05; figure 11) in both the study sites (SNNP and NCF).



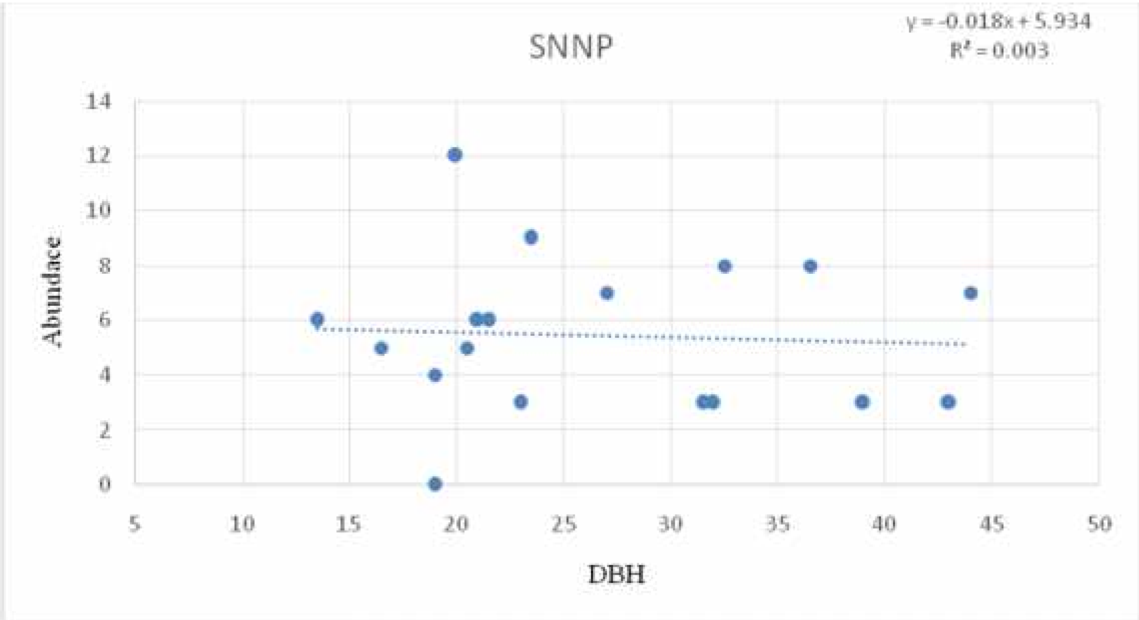
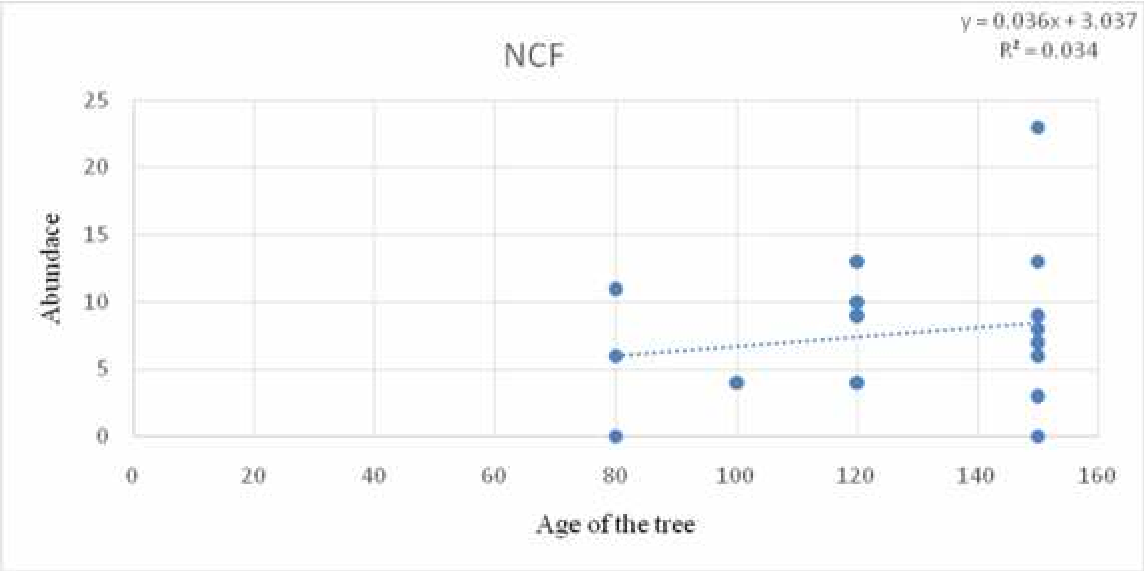


Figure 7: DBH vs. No. of Beetles (abundance) in SNNP and NCF.



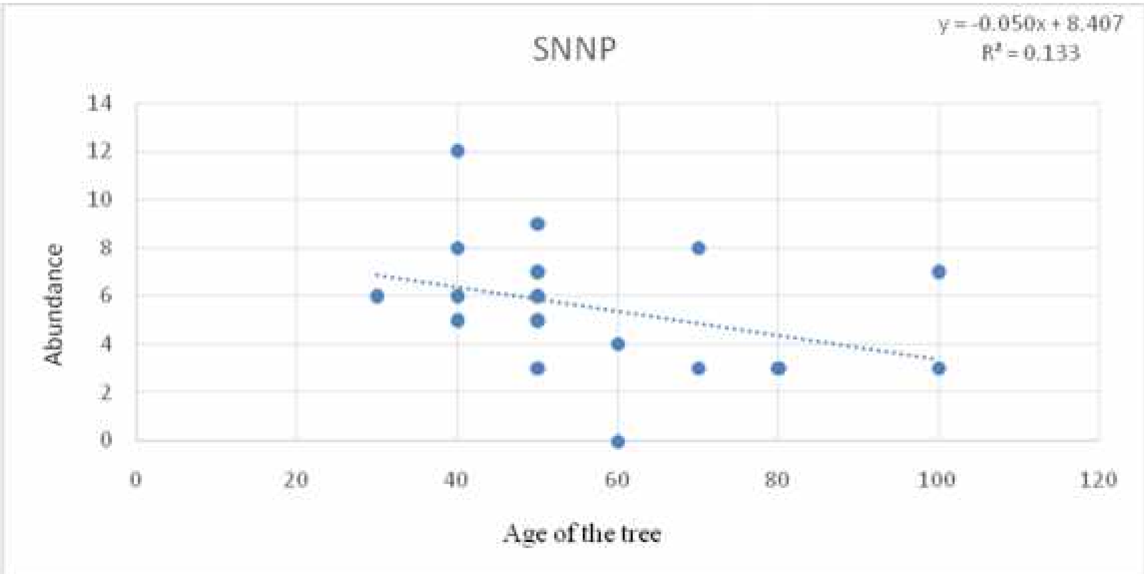


Figure 8: Age of the tree (years) vs. No. of Beetles (abundance) in SNNP and NCF.

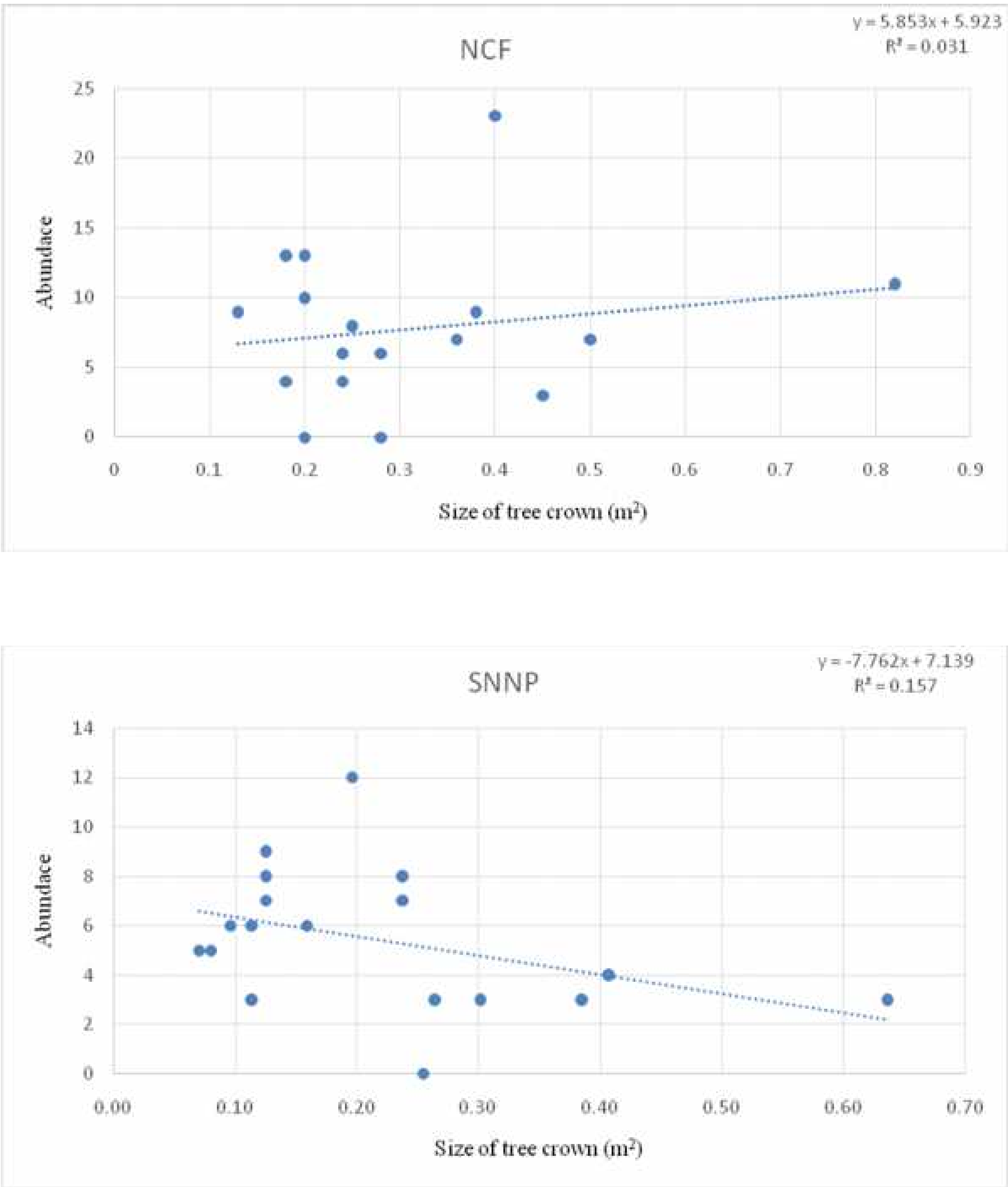


Figure 9: Size of tree crown (m^2) vs. No. of Beetles (abundance) in SNNP and NCF.

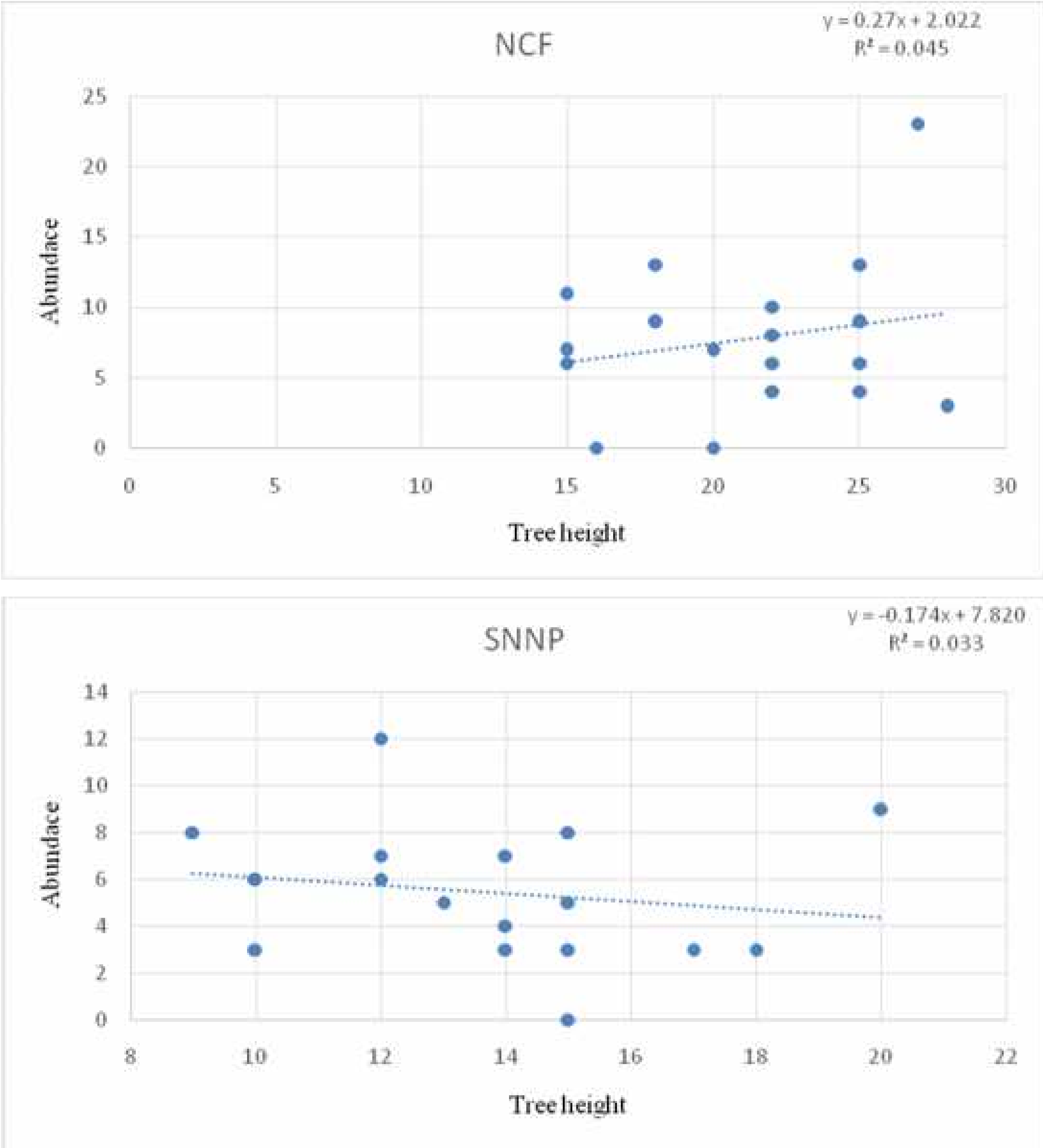
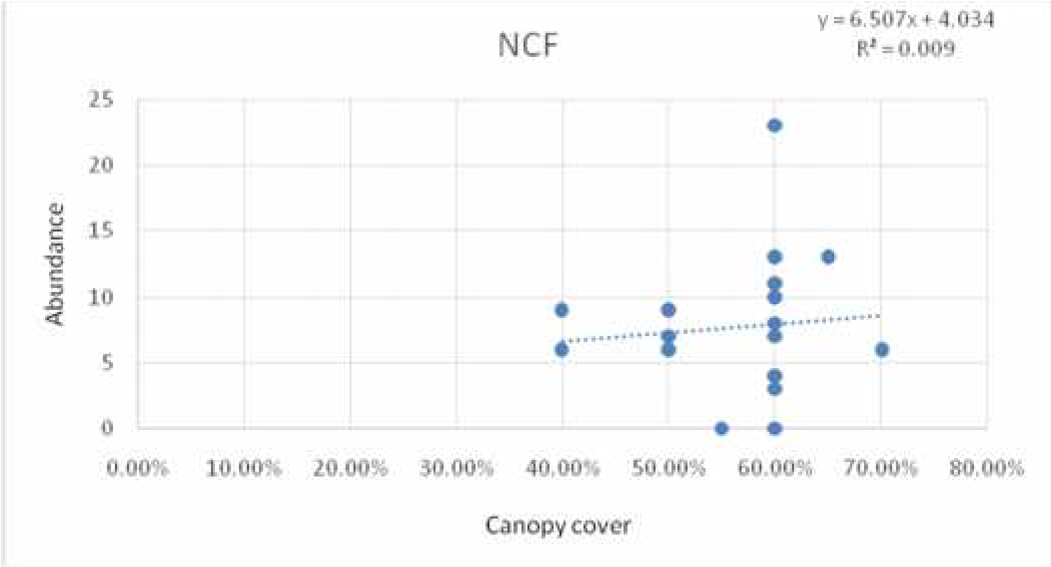


Figure 10: Tree height (m) vs. No. of Beetles (abundance) in SNNP and NCF.



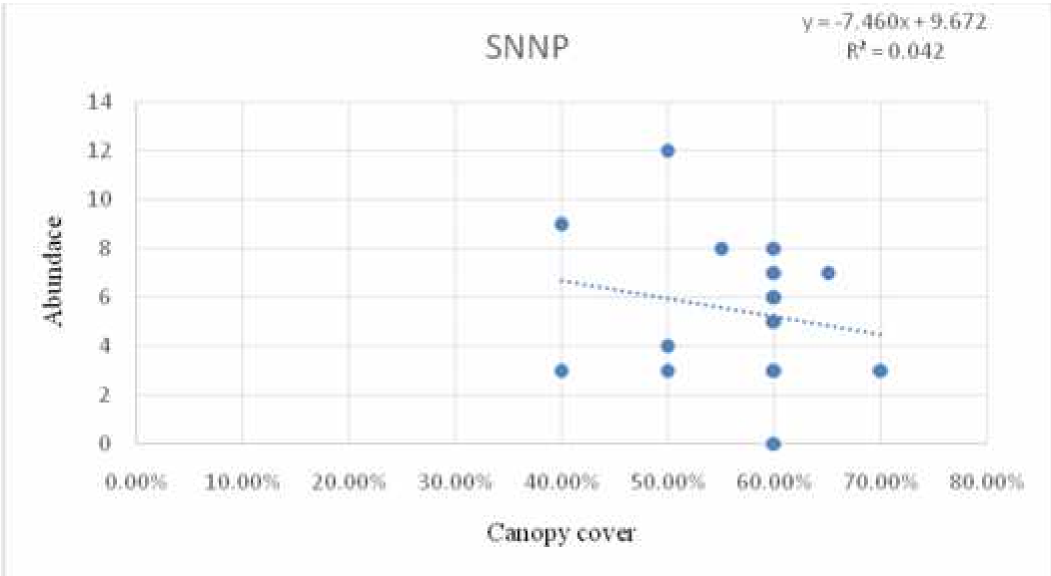


Figure 11: Canopy cover vs. No. of Beetles (abundance) in SNNP and NCF.

The abundance of canopy beetles was found to be significantly affected by change in months in SNNP ($p=1.14E-05$, $p<0.001$) and NCF ($p=5.52E-08$, $p<0.001$). Similarly, environmental treatments (i.e., Natural state, Orchid removed and Fern removed) also had significant influence ($p=0.045$, $p<0.05$) in abundance of canopy beetles of NCF. In contrast, use of the same treatments showed no effect on abundance ($p=0.59$, $p>0.05$) of canopy beetles in SNNP. In both the study sites, fern removed was noted as most effective treatment amongst three (Table 1, Table 3).

Table 1: Calculation of two way ANOVA without replication to see abundance of beetles between months and between treatments in Shivapuri Nagarjun National Park (SNNP).

Months	Count	Sum	Average	Variance
June	3	60	20	52
July	3	8	2.666666667	0.333333
August	3	14	4.666666667	14.33333
September	3	5	1.666666667	0.333333
October	3	4	1.333333333	2.333333
November	3	0	0	0
Decenber	3	0	0	0
January	3	0	0	0
February	3	0	0	0
March	3	48	16	21
Undisturbed	10	36	3.6	37.15556
Orchid removed	10	38	3.8	39.28889
Fern removed	10	65	6.5	96.05556

Table 2: Calculation of F-value and P-value to see the effect of treatments and change in months on abundance of beetles in SNNP.

Source of Variation	SS	Df	MS	F	P-value	F crit
Rows	409.2	9	45.46667	11.02965	1.14E-05	2.456281
Columns	4.466667	2	2.233333	0.541779	0.590906	3.554557
Error	74.2	18	4.122222			
Total	487.8667	29				

Table 3: Calculation of two way ANOVA without replication to see abundance of beetles between months and between treatments in Naudhara Community Forest (NCF).

Months	Count	Sum	Average	Variance
June	3	34	11.33333	17.33333
July	3	13	4.333333	10.33333
August	3	24	8	4
September	3	7	2.333333	4.333333
October	3	3	1	0
November	3	0	0	0
December	3	0	0	0
January	3	0	0	0
February	3	2	0.666667	0.333333
March	3	15	5	3
Undisturbed	10	29	2.9	12.98889
Orchid removed	10	31	3.1	13.21111
Fern removed	10	38	3.8	27.51111

Table 4: Calculation of F-value and P-value to see the effect of treatments and change in months on abundance of beetles in NCF.

Source of Variation	SS	Df	MS	F	P-value	F crit
Rows	1424.3	9	158.2555556	22.21997	5.52E-08	2.456281
Columns	52.46667	2	26.23333333	3.683307	0.045613	3.554557
Error	128.2	18	7.122222222			
Total	1604.967	29				

5. DISCUSSION

5.1. Diversity of canopy beetles in relation to *Schima wallichii* of Shivapuri Nagarjun National Park (SNNP) and Naudhara Community Forest (NCF)

Canopy beetles associated with *S. wallichii* tree was studied using canopy trap on both the study sites: NCF and SNNP. The result suggests comparatively higher diversity in managed forest (NCF with seven families) than in natural forest (SNNP with five families). But, Paillet *et al*. (2010) noted slightly higher species richness in unmanaged forest than in managed forests. According to Grove (2002), managed forest supports fewer individuals and fewer species. Marini *et al*. (2009) found decline in the diversity orthopterans and butterflies with management intensity. Franklin *et al*. (2002) found that abundance of wildlife is enhanced in natural forest due to abundance of standing dead and down wood and large old trees. NCF was found more diversified due to lower anthropogenic disturbance; Onaindia *et al*. (2004) study also resulted in highest species diversity in lowest disturbance area.

Scarabaeidae (185 individuals) was noted as dominating family followed by Lucanidae with six individuals and Staphylinidae with five individuals. But Chung *et al.* (2001) found highly abundant Chrysomelidae and Curculionidae in the forest. The contradiction in the result may be due to the presence of mammals. Dung beetles (Scarabaeidae) are mostly associated with mammal presence, because of their specificity towards dung (Estrada *et al.,* 1998). Monkey visits were too frequent in the sites as fruits, flowers, leaves at the canopy provide food for them (Bishop, 2000). So presence of monkeys as source of food for the beetles seems to contribute in abundance of family Scarabaeidae.

The Shannon Index of Diversity is considered to be the most complete measure of diversity because it takes into account both the number of species and the abundance of each species. The monthly diversity index was noted highest in the month of June which is associated with rainfall in tropical countries like Nepal, followed by March and August. Usha and John (2015) found maximum diversity in the month of May followed by June and July. Rains start gently in the month of May-June which must have made the conditions more suitable for the insect growth and reproduction.

Beetles were found positively correlated with the changes in temperature as insects being ectothermic, their physiological rates, including consumption and growth rates, are directly tied to environmental temperature (Lemoine *et al*., 2014).Temperature directly affects development, survival, range and abundance of insects (Bale *et al*., 2002). It causes difference in diversity of insects. Jacobsen *et al.* (1997) found liner increase in number of families with increase in temperature.

5.2 Factors influencing abundance of canopy beetles

The abundance of insects in forest is greatly influenced by factors like month and the characteristics of tree, canopy cover of the tree, height of tree, size of tree crown, DBH, age of the tree (years). In month of June, abundance of beetles were recorded as highest which coincides to the study by Pinheiro *et al.*(2002) which recorded peak of coleopterans in the second half of the rain period i.e. in June-July.

The study revealed insignificant association of abundance of beetles with canopy cover of the tree. Whereas, Ranius and Jansson (2000) study showed increase in the number of saproxylic beetles with low canopy cover. Scarabaeidae abundance was, too, found to be greatly influenced by tree canopy cover (Lassau *et al*., 2005). Similarly, colony size of ants was negatively influenced by canopy cover (Rodriguez-Garcia *et al*., 2011)

But unlike other earlier studies, height of tree, size of tree crown, DBH and age of the tree showed no significant relation with abundance of the beetles. Rodriguez-Garcia *et al*. (2011) found significant increase in abundance of insect herbivores with the increase in tree height, which contradicts the results obtained. Similarly, old trees are found to support rich community of invertebrates in the forest canopy (Diaz *et al*., 2012), as they are important structural components in forest which support additional structures like epiphytic load, enhancing invertebrates population. But the study showed negative relation with the history of the tree as well.

Large girth increases the frequency of occurrence of several species (Ranius and Jansson, 2000). Ranius (2002) found higher species richness in trunk with large girth and in tree hollows with entrances situated high up on the trunks and not directed upwards. Likewise, the *Monochamus sutor* (Cerambycidae) was found to be ceased at thickness of bark less than 0.3cm in burned larch and pine and was found to increase with thickness of trunk (Zhang *et al.*, 1993). But the result obtained showed insignificant relation between DBH and abundance of canopy beetles. Large tree size provides stable microclimates and hence promotes fungus growth which provides more habitats for fungi-associated beetle (Ranius and Jansson, 2000).

The insignificant relation of abundance of beetles with characteristics of tree (i.e., canopy cover, height of tree, size of tree crown, DBH and age of the tree) contradicts the earlier studies. This may be due to the influence of other environmental factors (temperature, rainfall, humidity, precipitation) and factors like anthropogenic disturbances, ground coverage of the forest and so on.

5.3 Effect of treatments (Natural state, Fern removed, Orchid removed) on abundance of canopy beetles

Three types of environmental treatments (Natural state, Fern removed, Orchid removed) were applied on different trees. Among the environmental treatments used, fern clearance was the most effective treatment followed by Orchid removal in NCF and SNNP. Unlike the result, (Diaz *et al*., 2012) found greater abundance of invertebrates in control trees (with epiphytes) or natural state trees compared to the trees from which epiphytes were removed. Cruz-Angon *et al.* (2009) also noted significantly higher number of individuals of canopy insects (larger than 5 mm) in trees with epiphytes, the number of individuals noted was 90% more in plots with epiphytes than plots without epiphytes.

Natural state treatment has increased epiphytes number. More epiphytes results increase in number of parasites and predators as well (Wittman, 2000). This may have resulted in dissimilarity of the finding with previous studies made.

6. CONCLUSIONS AND RECOMMENDATIONS

NCF was found more abundant and diversified compared to SNNP. In addition, NCF showed significant difference in abundance of canopy beetles between months as well as between treatments, whereas SNNP showed uniformity in abundance (of beetles) between treatments and variability between months. In both the study sites, Scarabaeidae was noted as a dominating family.

Based on the study, following recommendations are drawn:

- During the period, epiphytes were removed only at the time of canopy installation. So, removing the epiphytes in every visit can help to obtain more accurate data.
- Visiting the site twice or thrice a month for collection can help avoid decaying of specimens.
- Casual visit is also recommended during rainy season as well as during hot summer for adding preservative.
- Once the specimens are collected, it is best to be photographed to note its colour, and other physical body parts as well.

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ANNEXES

Annexes 1: Canopy beetles composition in Shivapuri Nagarjun National Park.

Family	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Scarabaeidae	28	12	22	6	1	0	0	0	1	6
Cerambycidae	0	0	0	0	0	0	0	0	0	0
Curculionidae	0	0	0	0	0	0	0	0	0	0
Lucanidae	2	1	1	1	0	0	0	0	0	0
Staphylinidae	4	0	0	0	0	0	0	0	0	0
Carabidae	0	0	0	0	0	0	0	0	0	0
Lagridae	0	0	0	0	1	0	0	0	0	0
Tenebrionidae	0	0	0	0	1	0	0	0	0	0
Unknown	0	0	1	0	0	0	0	0	1	9

Annexes 2: Canopy beetles composition in Naudhara Community Forest.

Family	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Scarabaeidae	45	7	10	5	1	0	0	0	0	41
Cerambycidae	0	1	2	0	0	0	0	0	0	0
Curculionidae	0	0	1	0	0	0	0	0	0	0
Lucanidae	1	0	0	0	0	0	0	0	0	0
Staphylinidae	1	0	0	0	0	0	0	0	0	0
Carabidae	1	0	0	0	0	0	0	0	0	1
Lagridae	0	0	0	0	0	0	0	0	0	0
Tenebrionidae	0	0	0	0	3	0	0	0	0	0
Unknown	12	0	1	0	0	0	0	0	0	6

Annexes 3: Shanon Diversity Index of Shivapuri Nagarjun National Park and Naudhara Community Forest.

Months	Naudhara Community Forest	Shivapuri Nagarjun National Park
June	2.959	2.745
July	1.733	1.782
August	2.342	2.095
September	1.332	1.277
October	0.562	1.099
November	0	0
December	0	0
January	0	0
February	0	0
March	2.581	2.211

Annexes 4: Monthly Mean Temperature of the study sites from June 2014 to March 2015

Months	Temperature of S.N.N.P. in degree Celsius	Temperature of N.C.F. in degree Celsius
June	20.7831	20.59954
July	20.51913	19.46129
August	20.25345	19.17881
September	19.12245	17.86403
October	15.9013	14.92016
November	12.66042	11.74472
December	9.342608	9.149149
January	8.685887	8.557616
February	10.71349	9.854911
March	13.14694	12.15417

Annexes 6: Photographs Collection from the field.

Photo 1: Canopy Trap.

Photo 2: Collecting specimen.

Photo 3: *Schima wallichii* tree with code.

Photo 4: Pulling canopy trap.

Photo 5: Recording GPS location of the site. Photo 6: Seperating sample from preservative.

Annexes 7: Some photographs of collected specimens.

Photo 1: Scarabaeidae

Photo 2: Scarabaeidae

Photo 3: Scarabaeidae

Photo 4: Scarabaeidae

Photo 5: Lucanidae

Photo 7: Chrysomelidae

Photo 8: Lucanidae