INSECT FAUNA OF KHARKHOLI COMMUNITY FOREST SURKHET, NEPAL

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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).

Date...16. August 2021

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LETTER OF APPROVAL

On the recommendation of supervisor "Prem Bahadur Budha" this thesis submitted by Birendra Shahi entitled **"Insect fauna of Kharkholi Community Forest Surkhet, Nepal"** is approved for the examination in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Entomology

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Birendra Shahi entitled "**Insect fauna of Kharkholi Community Forest Surkhet, Nepal**" has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Entomology

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List of Abbreviations

Abbreviated form	Details of abbreviations
BCN	Bird Conservation Nepal
C.F	Community Forest
CFUGs	Community Forest User group
DNPWC	Department of National Parks and Wildlife Conservation
ECE	Economic Commission for Europe
FAO	Food and Agricultural Organization
GPS	Global Positioning System
HHs	House holds
KCF	Kharkholi Community Forest

ABSTRACT

Forest health is very important part of the sustainable forest management system. Forest insects are the member of forest biogenesis including pest species that can kill trees, causes dieback, decline and deformity of forest. The forest insects were studied in Sal dominated forest at Kharkholi Community Forest (KCF), Surkhet, Karnali Province, Nepal. Insects were collected from eight observation plots each one of 10 m *10 m size within the distance not less than 250 m from one to another plot. Insect were collected by using sweeping net, hand picking and beating techniques from June to August, 2019. Altogether 545 individual of insect's belonging to 6 orders, 30 families and 54 genera were identified. They belong to order Coleoptera followed by Hemiptera, Hymenoptera, Balttodae, Lepidoptera and Mantodae. Among them identified pest species of *Shorea robusta* include defoliator *Chrysolina* spp., *Apoderus* sp., stem borer *Dendroctonus* sp. and the larva of family Lasiocambidae. The Shannon-Weiner diversity index shows the highest insect diversity and evenness during pre-monsoon (H'= 3.6706) than monsoon season (H'=3.1078).

1. INTRODUCTION

1.1 General Background

Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems and trees in urban areas (FRA 2020). There is 31% of the land occupied by forests out of the total global land area (FAO and UNEP 2020). Majority of people depend on forest biodiversity for their lives and livelihoods (Zhang and Pearse 2011, Burlingame 2000, Gurung 2002 and Watson 2005, FAO 2013, FAO 2017b and HLPE 2017). Also provide home to several terrestrial floral and faunal diversities and also attract for outdoor recreation and tourism (Dhobe et al. 2014). It also serves as carbon sink which help mitigate climate change impact (Malla and Pokheral 2017). Globally, more than 700 million hectares (18%) is reported to fall within legally established protected areas such as national parks, conservation areas and game reserves (FAO and UNEP 2020). Nepal covers 23.39% of total land areas within protected areas that include 12 National parks, one wildlife reserves, one hunting reserve, six conservation areas and 13 buffer zones for the conservation (DNPWC and BCN 2018). There are 35 forest types known from Nepal (Stainton 1972).

Nepal is pioneer in community forestry management in the world which helps in conservation, management and protection of forest. Community Forestry (CF) is recognized globally as an innovative, people-centered, effective and successful model for forest resource management which was evolved in the late 1970s in Nepal, around 1.8 million ha. (31% of total national forest area) has been handed over to 18960 CFUGs in which around 2.4 million HHs have been directly benefited (Kandel and Pokhrel 2016).

Forest health is very important part of the sustainable forest management system, however there are numerous problems in forest such as anthropogenic disturbances, harsh climatic conditions and infestation of various insect pest and pathogens (DFRS 2018) and forest fire (IFFN 2006), increasing invasive species (Webster et al. 2006, Holzmueller and Jose 2010), pollution (FAO 2009), illegal felling, grazing and encroachment are other prominent problems of forest (Subedi 2017).

Insects are the most diverse group of organisms found on almost all habitats including Antarctic, arthropods contain an estimated 2 million (Hodkinson and Casson 1991) to 50 million or more species (Erwin 1988). Forest insects are the member of forest biogenesis

(Beeson 1941). They are grouped herbivorous, Carnivorous, Omnivorous or Putrivorous and can be categorized into different orders such as Hymenoptera, Heteroptera, Hemiptera, Diptera, Coleoptera, Lepidoptera, Odonata and Orthoptera (Burnie 2005). This diverse group of insects significantly contributes to different ecological functions such as pollination, nuisance control, decomposition and maintenance of wildlife species (Losey and Vaughan 2006). Insects functions as herbivores, seed disperser, predators, parasites, or ecosystem engineers in terrestrial ecosystem (Weisser and Siemann 2004). Insects are integral components of healthy forest ecosystems as they help to decompose and recycle nutrients, build soils, maintain genetic diversity within tree species, generate snags and down logs that wildlife, small mammals and fish rely on them (Black 2005). Bees and other insects pollinate forest plants, some insects prey on other insects that are harmful to plants keeping the pest outbreak in check (Morrison et al. 2007). Insects are also food for humans and insect pollinators are necessary for more than 65% of the world's angiosperm species (Stewart, New and lewis 2007). Some insects represent as major food source for predators (Nazim et al. 2009). The net primary productivity of a forest may be increased by the activity of phytophagous insects (Mattson and Addy 1975). The crucial roles of insects ensure delivery of various ecosystem services (Berenbaum et al. 2006). They have been used in landmark studies in biomechanics, climate change, developmental biology, ecology, evolution, genetics, physiology and forestry (Godfray 2002). Insects are beneficial for humans by providing products such as honey, silk, royal jelly, beeswax, as well as their bodies for human consumption and experimentation (Akunne et al. 2013) Some insect species are significant indicators in ecosystem management and Agro-biodiversity (Rosina et al. 2014). Insects reduce soil water overflow as well as rise biodiversity of soil microbes (Musgrave 2013). Some expert suggest insect as an essential component while making conservation decision due to their extraordinary species diversity, abundance, rapid growth rates, functional roles, and wide range of body sizes and insects are good bio-indicator (Kremen et al. 1993, Oliver and Beattie 1993).

There are many insects which are pests can kill trees, causes dieback, decline and deformity of forest (Wear and Greis 2002). They lead poor tree growth, poor timber quality and complete destruction and reduction of forest cover (Sharma 2016). Several groups of insects act as defoliators, borers, piercing/sucking insects, gall makers and leaf eaters causing high economic loss of forest (Beeson 1941). Asian long horned beetle is serious pest which damage maple tree in United States and china which chew the leaves,

bores on bark of trees and leaf defoliator (USDA 2001). The most of forest insect pests belong to Orthoptera, Hemiptera, Coleoptera, Hymenoptera and Lepidoptera they attack tree branches, young shoots, leaves, flowers and fruits (Stebbing 1899).

Due to sharp variations in altitude from South to North, Nepal offers luxurious microclimatic gradients to different genera and species of forest insect (Jha 2009). In Nepal 144 spider species (0.2%); 5,052 insect species (0.7%); 640 butterfly species and 2,253 moth species has been recorded (Bista and Thapa 2012). Thapa (2015) has enumerated more than 12,000 insects and some of the pest from Nepal. A larger number of forest pests are reported to damage both natural and plantation forest of Nepal. There are few publications on forest insect in Nepal (White 1985, Neupane 1992, Thapa 1992, Amatya 1992, Joshi 1994, Leuitel 1995, Shrestha and Pradhan 1996, Manandher 1996,). White moth (*Lymantriam mathura*) is the major defoliator of Sal tree in India and Nepal (Ronwal 1979, Malla and Pokhrel 2018). Tuladhar (1996) published a short note on the account of identification, biology and management of three major defoliating insects of *Dalbergia sissoo* and also explain about *Psychidae* damaging *Pinus roxburgbii* plantation in Kathmandu valley. Fruit flies are the major pests of citrus fruits in Nepal (Shrestha 2006) as well as Chinese fruit fly (*Bactocera minax*) as main cause for the massive fruit drop in eastern Nepal (NCRP 2006). *Heteropsylla cubana* is a significant pest of *Leucaena leucocephala* causing defoliation, wilting, dieback and tree death seen in Nepal on 1987 (FAO 2003).

1.2. Objectives of the study

The general objective of the study is to investigate insect fauna of Kharkholi Community Forest, Karnali Province Surkhet, Nepal. The specific objectives were to,

i. Explore the insect fauna of Kharkholi Community Forest (KFC) Surkhet, Nepal.

ii. Compare composition of insect fauna in the pre-monsoon and monsoon periods

iii. Identify insect pests on *Shorea robusta*.

1.3. Rationale of the study

Many people depend on forest for fuel wood; food, recreation, tourism, absorber of air carbon and it give home to various fauna (Zhang and Pearse 2011, FAO 2017a, Dhobe et al. 2014). Community forest play very important role to provide services to human, domestic animals as well as wild animals and it is a good strategy to help conservation, management and protection of forest. However there are numerous problems such as

anthropogenic disturbances, infestation of various insect pest and pathogens (IFFN 2006, DFRS 2018). community forest provide habitat to various insects such as Hymenoptera, Heteroptera, Hemiptera, Diptera, Coleoptera, Lepidoptera, Odonata and Orthoptera and according to feeding guilds such as herbivorous, Carnivorous, Omnivorous (Burnie 2005). Insects are useful at community forest to pollination, seed disperser, nuisance control, decomposition and maintenance of wildlife species (Losey and Vaughan 2006) and they act as predators, parasites and ecosystem engineers in terrestrial ecosystem (Weisser and Siemann 2004). Some insect species are significant indicators in ecosystem management and Agro-biodiversity (Rosina et al. 2014) and insect as an essential component while making conservation decision due to their extraordinary species diversity, abundance, rapid growth rates, functional roles, and wide range of body size (Kremen et al. 1993, Oliver and Beattie 1993). This research aimed to explore the insects in Kharkholi community forest at Birendranagar, Surkhet which will provide the baseline information about the forest insect and also helpful for future conservation strategies of the community forest. This study also helps to identify insect pest of *Shorea robusta* which promote to control plan.

2. LITERATURE REVIEW

Thapa (2000) explained briefly about the history of insect fauna of Nepal. According to him the first insect collection was carried out from 1951 onwards. Hardwicke (British diplomat) started to collect Butterflies from Nepal during British expedition in 1924. German scientific expedition of Khumbu region during the year from 1960-1965 collected wide variety of insects from Nepal and started to publish in the journal Khumbu Himal since 1966. J. Martins (1987) edited book Beitrage Zur fauna on Faunengenese und Zoogeographie des Nepal Himalaya comprised 20 articles of Nepal on arthropod fauna. From the German collections, more than 150 publications by 62 scientists of 16 countries were published. In Nepal most of the taxonomic work has been carried out on butterflies, dragonflies and damsel flies, beetles, true flies, and quite on others groups.

The limited studies on forest insect of some important tree species: *Shorea robusta* and *Eucalyptus* (Roonwal 1979, Roonwal and Rathore 1998, Malla and Pokhrel 2018), Sissoo (Kumar 2017) were found in Nepal. Thapa (2015) described more than 12, 000 species of Insects of Nepal. Lazarev and Murzin (2019) prepared Catalogue of Nepal Longhorn beetles (Coleoptera: Cerambycidae) and reported up-to 505 species Cerambycidae found on Nepal known up to 2019 with the references to the original descriptions and regional records; 52 species are newly recorded for Nepal fauna. More than 150 species of aphids are reported from Nepal on different plants like tomato potato, mustard, cucumber pea and cow pea and Soyabin (Thapa 2000, Joshi and Manandher 2000, Das and Roychaudhary1983, sharma 1981/82). Bhusal et al. (2019) studied about Assemblage of Insects on Medicinal Plants at Herbal Garden in Godavari of Lalitpur, Nepal in four different session by different collecting technique viz. hand picking, pit-fall traps, net-sweeping and stem beating, they were listed total 869 individuals of seven orders, 27 families and 42 genera were identified in five medicinal plants and found their high diversity in spring season.

2.1. Pest of Sal and Forest Insect pest reported from Nepal

Choubey et al. (2004) studied about incidence of seed insect pests of Sal (*Shorea robusta*) and concluded that *Sitophilus rugicollis* as the major pest of seed of Sal trees in central Indian region of Motinala range during the years from April to July 200-2002. However, Rorchaudhary et al. (2018) critically reviewed in book about problem of Sal heartwood borer (*Hoplocerambyx spinicornis*) in India and its management. They reported about 346

species insects on Sal and 155 species of insects associated with living tree. Joshi et al. (2006) also studied about Sal heartwood borer in Madhya Pradesh and revealed that 339 insect species on Sal, 147 species are associated with living tree in Madhya Pradesh India. According to Joshi et al. (2006) and Chaudhary et al. (2018) insects associated with living tree encompassing mainly defoliators followed by seed-feeders, borers, and sap-suckers. Among these, the Sal heartwood borer (*Hoplocerambyx spinicornis*) commonly known as Sal borer was the most devastating insect pest responsible for catastrophic damage of Sal forests which emerge soon after the onset of monsoon (Roychoudhary 2017, Roychaudhary et al. 2018). Dhakal (2008) and FAO (2009) reported *H. puera, E. machaeralis and S. malabaricus* were identified as major pests, while *Z. coffeae* and *H. armigera* were regarded as recently recorded emerging problems in *Tectona grandis* from Nepal. The same author in his observations on the exotic plantation tree, *Eucalyptus camaldulensis*. Reported polyphagous pests like termites, aphids and rodents damaging the plants. FAO (2009) two species, namely, *B. portentosus* and *Oxycarenus sp.*, were serious in the nursery and grown-up plants respectively. Tuladhar (1996) mention 36 insects pest of Sissoo among them *Plecoptera reflexa* is the major pest.

2.2. Insect Seasonality and Diversity

Gaudel (2016) studied about Diversity of Beetle on Oak (*Quercus lanata*) Canopy in Shivapuri National Park and Naudhara Community Forest, Nepal during June 2014 to March 2015 and reported a total of 345 individuals of beetle belonging to 15 families were recorded from two study sites viz. Shivapuri National Park and Naudhara Community Forest by the help of canopy traps. Adelusi et al. (2018) study about Diversity and Abundance of Insects Species in Makurdi, Benue State, Nigeria and founded that a total of 1042 insects of 11 orders viz. Blattodea 16(1.5%), Coleoptera 46(4.4%), Dermaptera 9(0.9%), Diptera 137(13.1%), Hemiptera 83(8.0%), Hymenoptera 146(14.0%), Isoptera 11(1.1%), Lepidoptera 143(13.7%), Mantodea 3(0.3%), Odonata 255(24.5%), and Orthoptera 193(18.5%). Chandra (2018) studied about Biodiversity of insects in the tropical moist deciduous forestlands of Kanha National Park, Madhya Pradesh during the entire survey period, a total of 52 species of insects belonging to 3 orders, 9 families and 32 genera were recorded from the 1437 samples, A systematic survey was conducted for one year from January 2016 to December 2016 by using insects sweeping nets. Bhusal et al. (2019) studied about assemblage of insects on medicinal plants: an insight from ICIMOD herbal garden in Godavari of Lalitpur, Nepal and founded that the insect diversity was high during spring season but low during autumn

season.

Various authors have demonstrated the seasonality of insect groups such as caterpillars (Casey 1993), moths (Tobi et al. 1992), Collembolans (Argyropoulou et al. 1994, Badejo and Straalen 1993) and butterflies (Spitzer et al. 1993). Most of the seasonality studies are done on the economically important insect pest species such as mosquitoes (Chadee and Tikasingh 1992, Chadee et al. 1993., Chadee 1994), Wire worms (Seal et al. 1992) and Walnut husk fly (Kasana and AliNiazee 1996). Beeson (1941) assemblage 4,300 species of forest insects in his book the ecology and control of forest insects of India and neighboring country. Gadagkar et al. (1989) studied at Insect species diversity in the tropics: sampling methods and a case study at Uttara Kannada district of Kamataka, India. Study revealed that 19 orders, 219 families 1789 species and 16852 individuals from 36 plots by three sampling methods viz. light trap, Net sweeping, pit fall traps and scented traps. Arun and Vijayan (2004) studied about Patterns in Abundance and Seasonality of Insects in the Siruvani Forest of Western Ghats, Nilgiri Biosphere Reserve, Southern India by the help of sweep net sampling methods and insects were sampled of the mixed deciduous forest and concluded that high insect abundance during the southwest monsoon in all habitats, whereas Valverde and lobo (2005) studied about determining a combined sampling procedure for a reliable estimation of Araneidae and Thomisidae assemblages (Arachnida: Araneae) and study revealed a total of 661 individuals were captured, representing 26 species, 11 Araneids and 15 Thomisids from 80 sampling units. Hyvarinen et al. (2006) used three trapping methods to survey forest dwelling coleopteran viz. 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 59760 beetles belonging to 814 species were collected over a period of a month. However Nazim et al. (2009) Studied about diversity and seasonal variations of insects in Sandspit mangrove forest and reported that a total of 26 species of insects were recorded, most of the species belonging to order Diptera. The highest diversity and richness of insects were found in October while maximum value of evenness 1 was calculated in September. Silva et al. (2011) Studied about Seasonality in insect abundance in the Cerrado of Goias State, Brazil using a light trap and study revealed that a total of 34,741 insect specimens belonging to 19 orders which represent 97.3% of all the specimens collected. All the orders except for Diptera, Isoptera and Trichoptera showed a relationship with the climate variables (temperature) and all the orders except for Diptera presented a grouped distribution with greater abundance in the

transition from the end of the dry season (September) to the start of the rainy one (October/November). Unstad (2012) studied about predictors of insect diversity and abundance in a fragmented tall grass prairie ecosystem of southeast Nebraska and 28 ant species from eighteen genera were identified by pitfall trapping sampling methods from 2010 – 2011. Kannagi et al. (2013) study about Hymenopteran diversity in a deciduous forest from South India during July 2009 to June 2010 they collected 38 species among them they identified 36 species belong to 21 genera and 9 families. Siddiki (2015) Studied about insect diversity and composition during the wet and dry seasons in three forest types of Johor, Malaysia during November, 2013 to June, 2014 in the wet and dry seasons they concluded that the diversity and abundance of insect were higher during the wet season. Aidoo et al. (2016) studied about Abundance and Diversity of Insects Associated with Citrus Orchards in two different Agro ecological Zones of Ghana and study revealed that a total of 20, 285 individual insects belonging to 387 species from 107 families and 13 orders and Diversity indices such as Shannon-Wiener index, higher during both the wet and the dry seasons by the help of Malaise traps, flight interception traps, pitfall traps, chemical knock down and visual observation methods. Emmanuel and Anuoluwa (2019) reported a total of 4,501 insects spread across 9 orders, 34 families and 77 species during the survey conducted from March to May at Taraba State, Nigeria. Mia et al. (2019) Studied about Scenario of insect pests, predators and pollinators associated with crop plants in an agroforestry in Bangladesh and studied reveled 25 species of insects belonging to 19 families in 5 orders as pest of citrus, 15 species of insects under 13 families in six orders were found as pests of mango, Four species of insects belonging to 4 families in 3 orders were found as pest of pineapple. There were 20 species of predator insects belonging to 13 families in 6 orders and their abundance ranged from 0.8 to 2.5/ 40 sweeps. In total 19 species of insects belonging to 12 families in 4 orders were found as pollinators by using sweeping net. Faitz et al. (2020) studied about insect diversity and association with plants: a case study in rural areas of Dhirkot, Azad Kashmir Pakistan and study revealed that a total of 65 species of insects in association with 150 plants were recorded during March, 2019 to September, 2019 by line transect methods with the help of sweeping nets.

3. MATERIALS AND METHODS

3.1 Study area

Kharkholi Community Forest lies at Birendranagar Municipality, Surkhet, Karnali province. The winter temperature of Surkhet drops to about 5°c and in summer it goes up to 38°c. The Karnali province has diverse climate ranging from tropical to the alpine containing 4483 community forest (Acharya and Paudel 2020) among them Kharkholi community forest is one which covers 58 hector. The main trees in the community forests are Sal (*Shorea robusta*) Pine (*Pinus*), Jamun (S*yzygium cumini*) and medicinal trees Harro (*Terminilia chebula*), Barro (*Terminilia bellerica*), Amala (*Phyllanthus emblica*) etc.

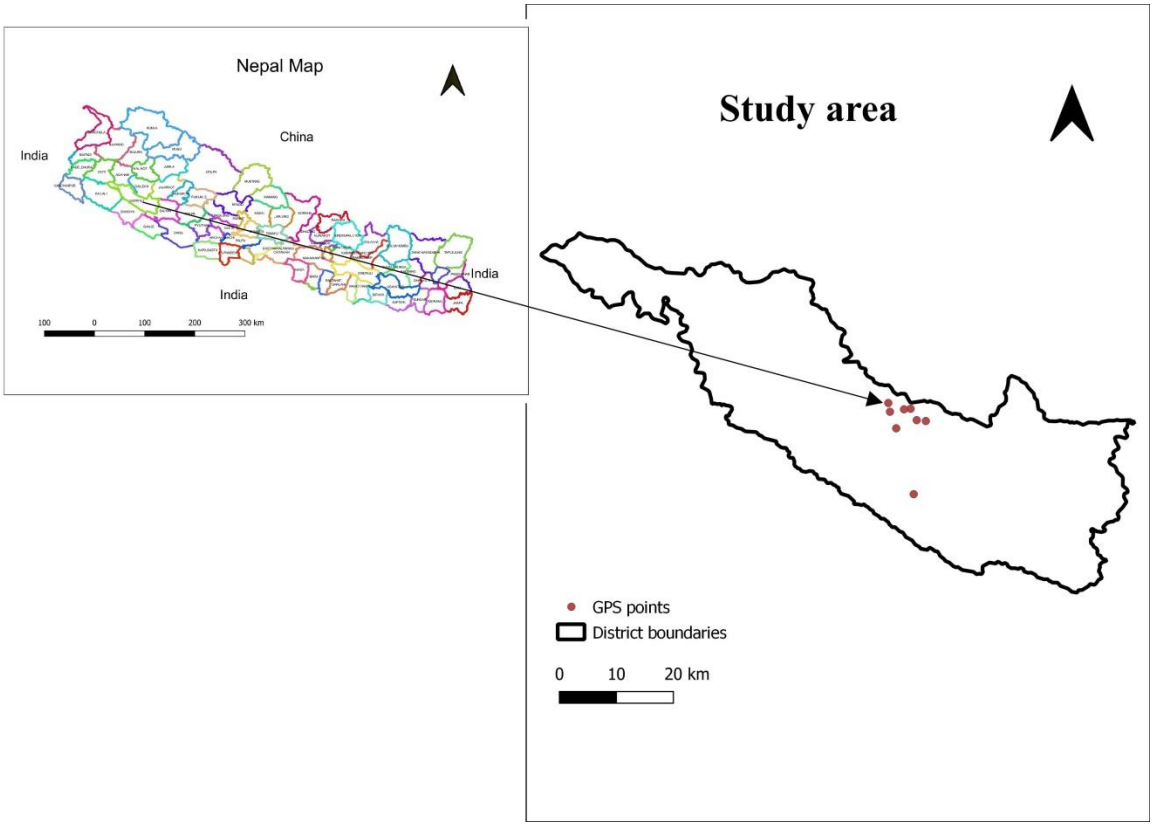

Fig.1. Map of study area

3.2 Material

Following materials were used during field work

Sweeping net (opening diameter of 30cm and 60cm in length)

Killing bottle

Forceps

Absolute alcohols

Ethyl acetate

Insect pins

Insect box Pinning block,

Stretching board,

Naphthalene balls

Plastic vials

Lead pencil

White cloths

Polyethylene sheet

Measuring tape

3.3 Methods

3.3.1 Field Sampling Design

Altogether 8 observation plots (10m *10m sizes) were laid on four permanent blocks of Kharkholi Community Forest. The gap between two plots was not less than 250 m. Plots were assigned according to the blocks such as A (A1 and A2) and B (B1 and B2) were Sal dominant forest, C (C1 and C2) and D (D1 and D2) were mixed type of forest.

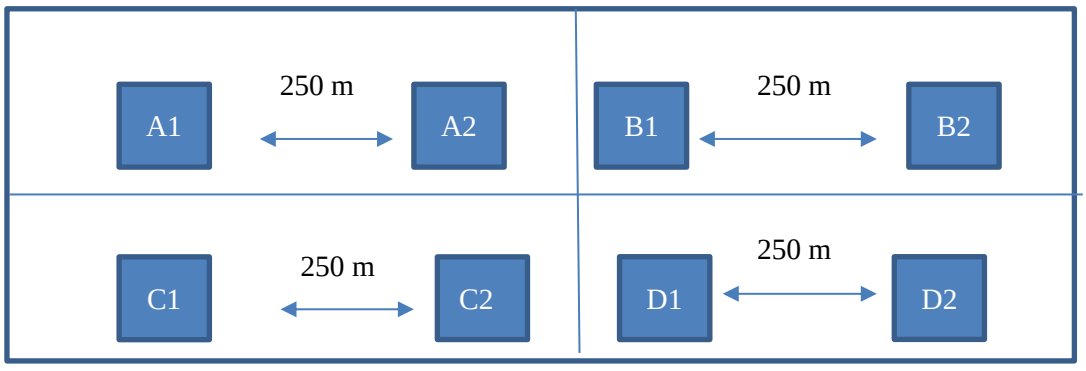

Figure 2: Field sampling design of study area

3.3.2 Insect collection

Field visit were conducted during Pre-monsoon (June-6-30, 2019) and monsoon (August-3-27, 2019) from 9AM – 5PM. up to 1 hours in one plot and then repeated in a week i.e. Three times were visited in one plot in one season. Insects were collected by using beating foliage, direct searching under fallen logs, woods and stone and direct hand collection in tree trunk and tree. Butterflies were observed and photographed. Each plots was carefully searched to note symptoms of insect damage such as yellowing or red foliage, number of freshly attacked trees, dead or deformed shoots, holes in bark, or the exudation of grass and resin as they are important indicators of the insect and pathogens within

Hand collection were carried out for insects which feed directly on twig and shoots such as scale, aphids with the help of forceps for adults, larvae and pupae by pulling off the loose bark.

Inverted umbrella was used for beating foliage and dead tree branches. Beatings were done in bushes and dominant tree species. Altogether 8 beating samples from bushes and tree species were taken. Inverted umbrella were placed under the bushes/foliage which were hit downward strokes by a steady stick or shake abruptly to dislodge insects which fallen down on inverted umbrella. Fallen insects were collected by using forceps and brush.

For the damage patterns Sal tree, damage parts of Sal were directly observed in the field. Insects found eating on leaves, damaging wood, were collected. Community Forest User Groups (CFUGs) were also consulted to know damages they noticed in the field.

All collected samples were placed in a killing jar. After killing, specimens were transferred to suitable container with preservative (preferably 90 % alcohol) depending on the type of insects.

Plot information such as, GPS location, date, time, number of individual; damage parts were noted.

3.3.3 Insect identification

The collected specimens were identified with different identification keys and color guide books (Smith 2011). Following publication were used to identify up-to genus level (Hill 1993, Thapa 2015, Beeson, 1941, Borror and DeLong 1971, Grazia et al. 2015, Nemes and Price 2015, Manickavasagam and Menakadevi 2014, Hunting and Yang 2019 Christofides 2017, Tsintidis et al. 2002 and Bezdek 2010)

3.3.4 Data analysis

Shannon-Weiner (H) diversity index was used to determine insect diversity at study area with the help of Microsoft Excel 2010

Shannon Diversity Index $H' = -\sum Pi\ ln\ Pi$ ..... [1]

Where $Pi = n_i/N$

H'= Index of species diversity

Pi= the proportion of individual in the i^{th} species= n_i/N

n_i= importance value for each species (number of individual)

N= Total importance value (Total number of individuals)

4. RESULTS

4.1 Composition of forest insect fauna of Kharkholi Community Forest

A total of 545 individuals of insects belonging to 6 orders and 30 families and 54 genera of insects were collected during the study (ANNEX -1). Among them Coleoptera was the most dominant order including 24 genera with 290 individuals followed by Hemiptera including13 genera with 127 individuals and Lepidoptera including10 genera with 66 individual while least dominant order were Mantodae including one family with five genera (figure 3)

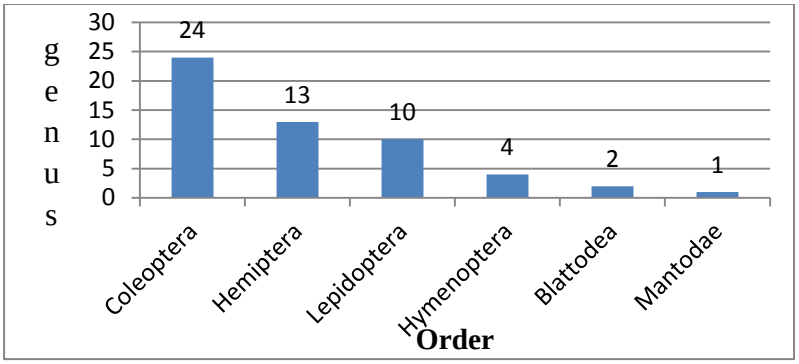

Figure 3: Total Number of Insect orders Recorded in the Study Area

At the family level the highest number of genus was from Chrysomelidae having 7 genera followed by Curculionidae having six genera and Nymphalidae having four genera (Figure 4)

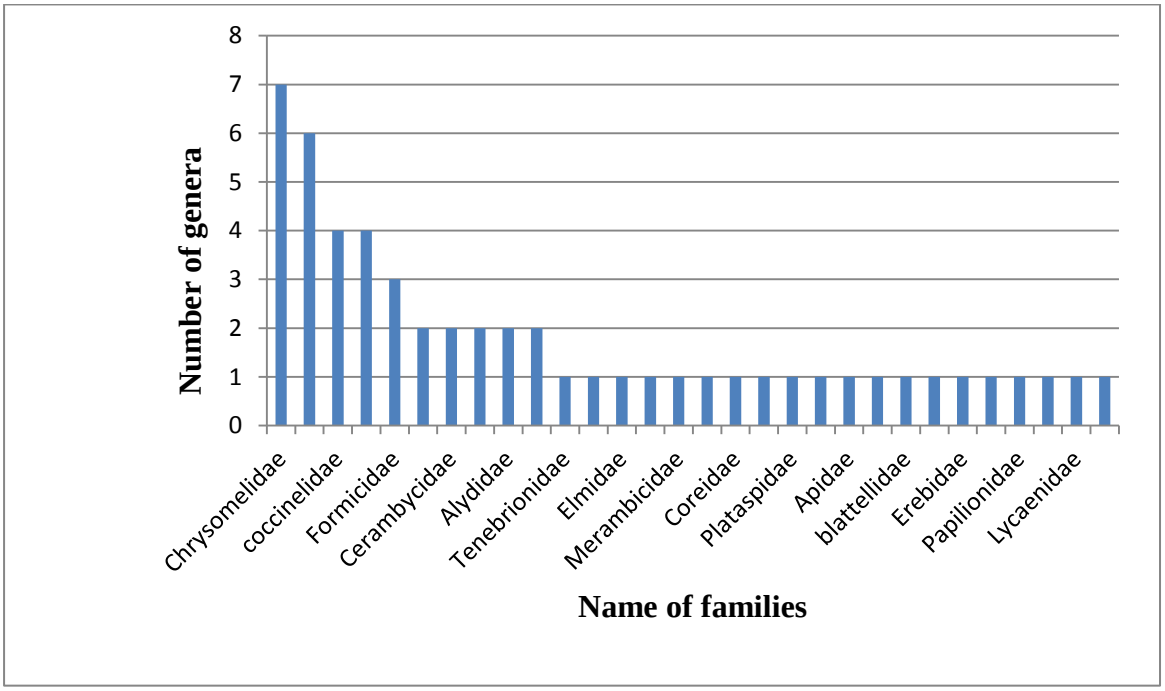

Figure 4: Total Number of insect families Recorded in the study Area

4. 2 Pre-monsoon and monsoon diversity of insect fauna of KCF

From the 545 individuals of insects identified during the study periods, 47 genera including a larva belonging to six order and 26 families were found in monsoon season. Likewise, 45 genera including 2 unknown sp. and 1 unknown larva from six orders and 25 families were found in pre-monsoon (ANNEX-2). 38 genera were recorded in both the season. 7 genera including *Raphidopalpa* sp., *Harmonia* sp., *Lygus* sp., *Kanzoata* sp., *Precis lemonias*, *Symbrenthia lilaea* and unknown larva were found in monsoon season only whereas 9 genera including *Popillia* sp., *Lagria* sp., *Eysarcoris* sp., *Bothrogonia* sp., *Cletus* sp., *Aulocophora* sp., 2 unknown sp. and unknown larva were found in pre-monsoon season only.

The insect diversity index was slightly higher in Pre-monsoon (H'= 3.6706) along with the Evenness value (H/S= 0.9202) than Monsoon (H'=3.1078 and H/S= 0.7791) (Table 1, ANNEX-2)

Table 1: Pre-monsoon and monsoon diversity of insect fauna of KCF

Season	No. of genus	No. of individual	H	E
Pre-monsoon	47	276	3.6706	0.9202
Monsoon	45	269	3.1078	0.7791

Higher number of insects individual was collected on pre-monsoon season (276) than monsoon season (269) (Figure 5)

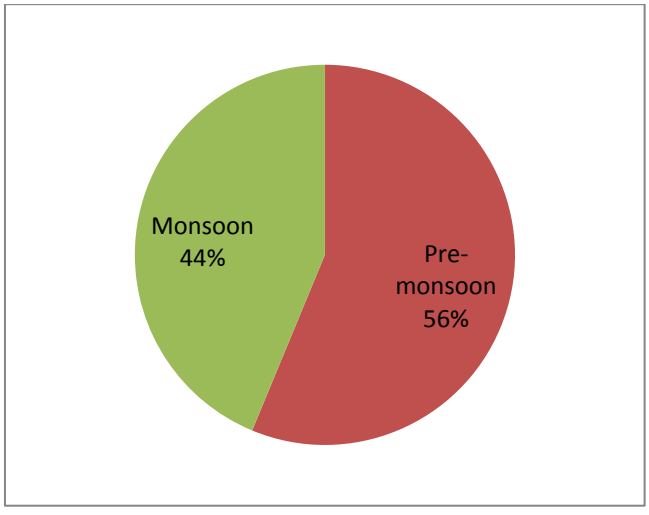

Figure 5. Season wise composition of Insect Fauna of KFC.

4. 3 Insect pest species of *Shorea robusta* and Damage patterns

Out of 545 individual of insects 45 individual of insects belonging to 4 genera were noted as pests of Sal (*Shorea robusta*) tree. They were observed while damaging the leaves and stem of the Sal tree (Table 2).

Table 2: Number of pest genus observed from different damaged parts of Sal and damage patterns by insects pests

Genus	Damage parts	Damage patterns	No. of Individual
Chrysolina	Leaf	Wood borer/leaf defoliator	21
Dendroctonus	Wood	Making tunnels and holes	10
Apoderus	Wood	Stem borer	10
Family Lasiocambidae Larva	Leaf	Wood borer	4

5. DISCUSSION

In the present study, higher number of insect diversity was found higher within the area. Relatively high diversity of insect fauna in the area might be responses to local biotic and abiotic conditions such as the availability of specific (micro) habitats and resources in the respective forest types (Donsen and Fahrig 1997, Devictor et al. 2008), hosts, breeding sites (TaipeLagos and Natal 2003, Pinto et al. 2009, Nnko et al. 2017, Sawalha et al. 2017, (Jain and Balakrishnan 2011), complex type of vegetation cover and a high tree diversity (Perry et al. 2016). temperature (Rahbek 1995),undisturbed area (Mathew et al. 2003), altitudinal gradients (Joshi and Arya 2007). The higher number of coleopteran were collected in forest which might be due to the lesser diurnal temperature, more green vegetation, availability of water, the rainfall and the flower abundance and also adults tend to emerge from the ground in response to rainfall (Arun 2000 and Adelusi et al. 2018, Murali and Sukumar 1993). Also their preference might be due to moist soil, leaf litter, and rotting wood (Hall 2001, Sawada and Hirowatari 2002 and Sorensson 2003). Differences in distribution and abundance of insects might be due to variation in season, habitat, food resource and temperature (Neuza et al. 2009, Bale et al. 2002, Currano et al. 2008). Numbers of insects were found different in two seasons which might be due to host plant factors, natural enemies, weather conditions life history traits and ecology (Bjorkman et al. 2011, Martinat 1987, Berryman 1996, Benton et al. 2008, White 2009, Hunter 1991). Higher number of forest insects in pre-monsoon is probably due to the sparse foliage density within the forest which helped to attract insects from more distances compared to other seasons (Arun 2000, Arun and Vijayan 2004, Dhobe et al. 2014, Schmitz et al. 2016).

There was high diversity of insets during pre-monsoon season might be due to higher temperature and low humidity (Kannagi et al. 2013, Schmitz et al. 2016), favorable environmental condition and abundant food for insect herbivore (Bhusal et al. 2019), phenology (Tauber and Tauber 1981, Vanasch and Visser 2007) which renders species being most active during spring, summer, autumn, and even winter. Also might be due to the seasonality of insects depends upon the floral diversity, diet and shade (Sparks and Parish 1995, Sparks et al. 1996, Assad et al. 1997) and appearance of new flushes along with floral shoots (Tripathy et al. 2020), this may be due to favorable temperature for insect emergence and fruit ripening period (Choube et al. 2004). Adults overwinter and

become active in spring as buds burst and leaves unfold (Ciesla 2011) so high diversity can be obtained on spring seasons. Variation of insect in different session might be due to various climatic conditions, host plants and habitat management (Mia et al. 2019) but contrastingly (Balakrishnan et al. 2014) low insect diversity in pre-monsoon was due to habitat loss, overexploitation, pollution, overpopulation and the threat of global climatic changes.

During the field survey and Leaf defoliated by insect pest were observed must on the Sal it is probably due to a synchronization of insect activity with the availability of young, highly nutritious plant leaf and tissues (Neves et al. 2014) also it might be due to relationship between the age of leaf favored and the degree of polyphagy of the insects, insects use leaf for many purpose such as they chew holes in unfolding leaves and deposit eggs, make nest on the leaves and pupate in leaves, shelter on leaf to protect them from weather and natural enemies, larvae of some species roll leaves, tie them with silken threads and feed inside the rolled leaf, others build nests of webbing, bits of foliage (Bluthgen and Metzner 2007, Ciesla 2011). This study shows four insects as the pest of *Shorea robusta* which were supported by (Beeson 1941 and Roychaudhary 2015) but other authors shows different insects as the Sal pest such as (Joshi et al. 2006, Bista 2011, Rouchaudhary 2017, Roychaudhary et al. 2018) Sal heartwood borer, *Hoplocerambyx spinicornis* as major pest of *S. robusta* similarly *Sitophilus rugicollis* (Choubey et al. 2004). In Nepal different authors report different insect pest on different plant species such as Sissoo (Tuladhar 1996a) *Plecoptera reflexa* as major pest White (1988) Longhorn beetle, *Aristobia horridula* as a severe pest of Sissoo. *Plecoptera reflexa* and *Apoderus sissoo* (KC 2007). The occurrence of *leucaena psyllid*, *Heteropsylla cubana* a destructive insect pest of *Leucaena* spp. Joshi (1992). carpenter worm *Prionoxystus* sp. on Teak plant (Dhakal 2008). *Helicoverpa puera* (FAO 2009). *B. portentosus* and *Oxycarenus* sp. on *Paraserianthes* spp (Neupane (1992). bagworm on *Eucalyptus camaldulensis* (Tuladhar (1996b).

6. CONCLUSION AND RECOMENDATIONS

6.1. Conclusion

The exploration of insect diversity was done Kharkholi Community Forest for the first time. The Kharkholi Community Forest supports different types of insects, including pollinators, predators, pest and pathogens. Coleoptera and Chrysomelidae were found most dominating order and family respectively. Insect diversity and evenness was higher during pre-monsoon season than during monsoon season as shown by Shannon winner diversity index which revealed that insects were more diverse and evenly distributed during pre-monsoon season than during monsoon season. Some of the insect pest was observed on *Shorea robusta* and their diversity were higher on pre-monsoon season which were damaging the leaves of *Shorea robusta.*

6.2. Recommendations

1. Forest pests are neglected filed of studies. It is recommended to focus on the insect pests of various tree species including pest life cycle studies,
2. Insect fauna of all season can give detail information of particular forest type by applying different insect collection methods such as light traps, pitfall traps and baited traps for precise insect diversity in the area.

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APPENDICES

Appendix 1 Checklist of insect fauna of KFC.

Insect	Genus	No. of specimens	No.of individual	Methods of collection
Order Blattodea				
Family Blattellidae	*Sorineuchora* spp.	3	17	Hand collection
Elateridae	*Dalopius* spp.	3	21	Hand collection
order coleoptera				
Family cerambycidae	*Oemerigida* spp.	4	14	Hand collection
	Larva	3	9	Beating
Chrysomelidae	*Aulacophora* spp.	3	6	Hand collection
	Catascopus sp.	1	10	Hand collection
	Chrysolina spp.	2	21	Beating
	Clytrasoma sp.	1	9	Hand collection
	Lilioceris spp.	4	7	Beating
	Mimastra spp.	4	20	Beating
	Raphidopalpa spp.	5	5	Beating
Curculionidae	*Apoderus* spp.	7	18	Hand collection
	Dendroctonus sp.	1	13	Hand collection
	Eupholus sp.	1	6	Hand collection
	Hyponeces spp.	3	11	Hand collection
	Lixus sp.	1	10	Hand collection
	Larva	3	13	leaf letter collection
Coccinelidae	*Coccinella septumpuntata*	3	14	leaf letter collection

	Harmonia spp.	2	5	leaf letter collection
	Novius sexnotatus	2	9	Beating
	Unknown	2	4	Beating
Elmidae	Larva	1	8	Hand collection
Meloidae	*Zonitoschema* sp.	1	9	Hand collection
Scarabidae	*Popillia* spp.	2	15	Hand collection
	Larva	1	8	Hand collection
Tenebrionidae	*Lagria* spp.	2	3	Hand collection
Order Hemiptera				
Family Pentatomidae	*Eysarcoris* spp.	3	7	Hand collection
	Thyanta spp.	3	17	Beating
Alydidae	*Dieuches* sp.	1	16	Beating
	Leptocorisa spp.	6	9	Beating
Cicadellidae	*Bothrogonia* sp.	1	5	Hand collection
Cercopidae	*Callitettix* sp.	1	4	Hand collection
	Cosmoscarta sp.	1	7	Hand collection
Cercotidae	*Kanozata* spp.	3	4	Beating
Lygaeidae	*Lygus* sp.	1	5	Beating
Plataspidae	Unknown sp.	1	4	Beating
Coreidae	*Cletus* spp.	4	4	Hand collection
Pyrrhocoridae	*Dysdercos* spp.	5	15	Beating
Merambicidae	*Poophilus* sp.	1	24	Beating
Order Hyminoptera				
Family Apidae	*Apis* sp.	1	8	Sweeping neat
Formicidae	*Brachyponera*	1	19	Hand collection

	sp.			
	Camponotus spp.	8	15	Beating/Hand collection
	Crematogaster spp.	3	24	Beating
Order Lepidoptera				
Family Erebidae	Larva	2	7	Hand collection
Hesperidae	*Parnara Guttata* spp.	2	6	Sweeping neat
Lasiocambidae	Larva	4	13	Hand collection/beating
Lycaenidae	*Lampides boeticus* sp.	1	7	Sweeping neat
Nymphalidae	*Cupha erymanthis* sp.	1	8	Sweeping neat
	Precis lemonias spp.	4	5	Sweeping neat
	Symbrenthia lilaea sp.	1	2	Sweeping neat
	Vagrans egista sp.	1	8	Sweeping neat
Papilionidae	*Papilio polytes* spp.	3	4	Sweeping neat
Pieridae	*Piris canadia indica* sp.	1	8	Sweeping neat
Order Mantodae				
Family Mantidae	*Mantis* sp.	1	5	Hand collection/sweeping neat

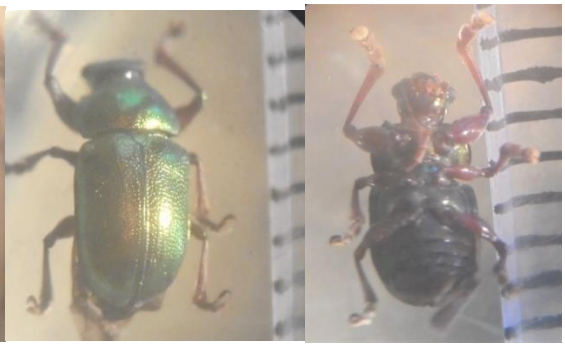
Appendix 2 Number of insect of KCF in different seasons

S.N.	Name of the genus	No. of individual(s) in different seasons	
		Pre-monsoon	Monsoon
1	*Catascopus*	6	4
2	*Lilioceris*	2	5
3	*Chrysolina*	18	3
4	*Raphidopalpa*	0	5
5	*Mimastra*	8	12
6	*Clytrasoma*	7	2
7	*Aulacophora*	6	0
8	*Dendroctonus*	9	4
9	*Lixus*	5	5
10	*Apoderus spp.*	9	9
11	*Eupholus*	3	3
12	unknown larva	3	9
13	*Hyponeces*	7	4
14	*Popillia*	15	0
15	unknown larva	11	5
16	Unknown	4	0
17	*Coccinella septumpuntata*	9	5
18	*Novius sexnotatus*	6	3
19	*Harmonia*	0	5
20	*Oemerigida*	3	11
21	Unknown larva	5	4
22	*Lagria*	3	0
23	*Zonitoschema*	4	5
24	Unknown larva	3	4
25	*Thyanta*	4	13
26	*Eysarcoris*	7	0
27	*Bothrogonia*	5	0
28	*Dieuches*	4	12
29	*Leptocorisa*	4	5

30	*Poophilus*	8	16
31	*Dysdercos*	7	8
32	*Cletus*	4	0
33	*Lygus*	0	5
34	*Cosmoscarta*	3	4
35	*Callitettix*	2	2
36	Unknown	4	0
37	*Kanozata*	0	4
38	*Crematogaster*	10	15
39	*Brachyponera*	11	8
40	*Camponotus*	9	6
41	*Apis spp.*	4	5
42	*Dalopius*	12	9
43	*Sorineuchora*	12	5
44	unknown larva	0	8
45	Unknown larva	4	0
46	*Parnara Guttata*	2	4
47	*Papilio polytes*	1	3
48	*Piris canadia indica*	4	4
49	*Lampides boeticus*	2	5
50	*Precis lemonias*	0	5
51	*Vagrans egista*	2	6
52	*Symbrenthia lilaea*	0	2
53	*Cupha erymanthis*	3	5
54	*Mantis spp.*	2	3
Total		276	269

PHOTO PLATES

Periplanata sp.



Chrysolina spp

Aulacophora sp.

Callitettix sp.

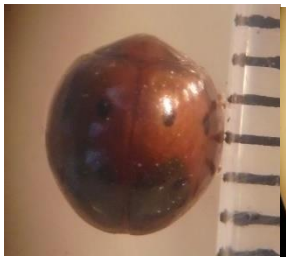
Clytrasoma sp.

Eysarcoris sp.

Popillia sp.

Lilioceris sp.

Curculionidae




Coccinella septempunctata *Catascopus sp.* *Mimastra sp.* *Apoderus sp.*

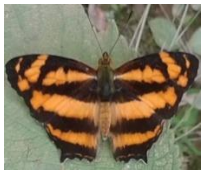




Lixus sp. *Thyanta* sp. *Dieuches* sp. *Onthophagus* sp. *Parnara guttata*




Papilio polytes *Precis lemonias* *Lampides boeticus* *Cupha erymanthis*



Symbrenthia lilaea