



ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

**STUDY ON INSECT DIVERSITY OF ANKORCHA FOREST
AND SHEGER PUBLIC PARK IN WET AND DRY SEASONS
IN ADDIS ABABA**

BY
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TABLE OF CONTENTS

	Pages
ACKNOWLEDGMENTS.....	i
TABLE OF CONTENTS.....	ii
LIST OF TABLES.....	iv
LIST OF FIRURE.....	v
LIST OF APPENDICES.....	v
ABSTRACT.....	vi
1. INTRODUCTION.....	1
2. LITRATURE REVIEW.....	2
2.1. Biodiversity.....	2
2.2. Insects as biodiversity indicators.....	5
2.3. Habitat specificity of Insects	6
2.4. Environmental factors which affect Insect Diversity.....	7
2.4.1. Weather.....	8
2.4.1.1. Temperature.....	8
2.4.1.2. Rainfall.....	11
2.4.1.3. Light.....	12
2.4.2. Food	14
2.4.3. Altitude.....	17
2.4.4. Soil	17
2.5. Interaction of Insects with other organisms	19

2.5.1. Interaction of Insects and Plants.....	19
2.5.2. Interaction of Insects and Other Insects.....	23
2.5.3. Interaction of Insects and the Human Being.....	28
2.5.4. Interaction of Insects and Microorganisms.....	30
2.5.5. Interaction of Insects and Other Animals	31
3. MATERIALS AND METHODS.....	32
3.1. Description of the study sites	32
3.1.1. Ankorcha forest.....	32
3.1.2. Sheger Public Park.....	33
3.2. Materials.....	35
3.3. Methods.....	35
3.3.1. Selection of the Sample spots and Sampling time.....	35
3.3.2. Sampling Method and Data Collection.....	35
3.3.3. Data Analysis.....	36
4. RESULTS.....	38
4.1. Diversity of Insects in Ankorcha forest and Sheger park	39
4.2. Insects family richness in Ankorcha forest and Sheger park.....	43
4.3. Similarity of insects among different habitats of Ankorcha forest and Sheger Park.....	45
4.4. Frequency, abundance and distribution of insects.....	47
4.5. Habitat Association of Insects in Ankorcha forest and Sheger Public park.....	50
5. DISCUSSION.....	53
6. CONCLUSIONS AND RECOMMENDATIONS.....	57
REFERENCES.....	59

LIST OF TABLES

Table 1. Insect diversity in Ankorcha forest in 2008/2009**40**

Table 2. Insect diversity in Sheger park in 2008/2009.....**42**

Table 3. Margalef's richness index values of Insects in Ankorcha forest
in 2008/2009**43**

Table 4. Margalef's richness index values of Insects in Sheger park
in 2008/2009.....**44**

Table 5. Values of Jaccard's index of similarity in Ankorcha forest
in 2008/2009.....**45**

Table 6. Values of Jaccard's index of similarity in Sheger Park
in 2008/2009.....**46**

Table 7. Frequency, abundance and distribution of insects in Ankorcha forest
in 2008/2009.....**47**

Table 8. Frequency, abundance and distribution of insects in Sheger Park
in 2008/2009.....**48**

Table 9. Habitat association of insects in Ankorcha forest in 2008/2009.....**50**

Table 10. Habitat association of insects in Sheger park in 2008/2009.....**51**

LIST OF FIGURE

Figure 1. Topographic map of Ankorchha Forest and Sheger Public Park.....	34
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LIST OF APPENDICES

Annex 1: T-test results of the comparison of means in wet and dry seasons in Ankorchha forest.....	67
Annex 2: T-test results of the comparison of means in wet and dry seasons in Sheger park.....	67
Annex 3: T-test results of the comparison of means of Ankorchha forest and Sheger park in wet season	68
Annex 4: T-test results of the comparison of means of Ankorchha forest and Sheger park in dry season	68
Annex 5: Photo of insects collected.....	69
Annex 6: Diversity of insects in Ankorchha forest and Sheger Park in wet and dry seasons.....	69
Annex 7: Figures of different habitats.....	70

ABSTRACT

A study on insect biodiversity was carried out in Addis Ababa in Ankorcha forest and Sheger Park. Different parameters such as diversity index, species richness, frequency, abundance, distribution were measured. Sampling was done using sweeping net from different microhabitats of each ecological setting. In the forest, the presence of eighteen families of insects which belong to six orders were observed. In the park, twenty-five families of families of insects which belong to seven orders were recorded. Order Diptera was found to be the dominating order in both settings.

In Ankorcha forest, highest diversity of insects was observed in the natural forest habitat in all seasons. In the wet season, the best even distribution of insects was observed in the grass land habitat. But, in the dry season insects were best evenly distributed in the artificial forest habitat. In Sheger Park, the highest diversity of insects was observed in the mixed vegetation habitat. Insects were best evenly distributed in the flowers and grass mixed habitat in the wet season. But in the dry season, grassland habitat was the best habitat regarding even distribution of insects. In Ankorcha forest, the most similar habitats in the distribution of insects in both the wet and dry season were natural forest and grassland habitat. In Sheger park, the highest similarity of insects was seen in flowers and grass mixed habitats and mixed vegetation habitat in all seasons. In Ankorcha forest, the highest habitat association was observed in the artificial forest habitat. In Sheger Park, the grassland habitat was the habitat which showed the highest habitat association. The t-test result of the comparison of insect abundance in wet and dry seasons of both Ankorcha forest and Sheger Park showed significance difference. But when insect abundance of Sheger Park and Ankorcha forest were compared during the respective wet season and dry season no significant difference were observed.

1. INTRODUCTION

Biological diversity refers to the variety and variability among living organisms and the ecological complexes in which they occur (Gaston and Spicer, 1998). Thus, biological diversity refers to variety within the living world. It also refers to ecological structures, functions, and processes on each of these levels. All organisms and ecosystems are interconnected. The presence or absence of an organism affects the overall ecological community and the ecosystem as a whole (Putman, 1994).

The more numerous the species that inhabit in an ecosystem, the more productive and stable is the ecosystem. Biological diversity is a basic characteristic of the ecosystem that has economic, social, and ecological implications (Tilman *et al.*, 1999). Biological diversity has evolved over time through the influence of ecological processes, including historical disturbance regimes such as fire, flood, wind and diseases (Pickett and White, 1985). Ecological processes are necessary for the maintenance of biological diversity. But, researches indicate that, human development have major effects on biodiversity, to the point that, as a result of habitat fragmentation and destruction, many species became extinct (Kormondy, 1996).

The pathologies of human caused effects on environment and the species that inhabit certain areas have been the source of significant scientific study. The study of these pathologies, such as habitat destruction and habitat fragmentation along with their associated effects, can give us a greater understanding of how human activities affect habitat.

Arthropods in general may be very sensitive to what happens to their habitats and populations may vary in the amount of habitat disturbance (Collinge *et al.*, 2003). Insects are

strong indicative of environmental change through close adaptation to their environment and because they embody the majority of the links in the community food chain (McGeoch, 1998).

Therefore, the loss of insects can have negative effects in the ecosystem as they play very important roles in the maintenance of ecosystem diversity and stability (Ananthkrishnan, 1988). The present study is initiated to study insect diversity in the disturbed and undisturbed habitats of Ankorchha forest and Sheger Park respectively.

OBJECTIVES

General Objective

To study the level of impact of human disturbance on biological diversity

Specific Objectives

- To study the diversity of insects in Ankorchha forest and Sheger park in different seasons
- To investigate the frequency, abundance and distribution of insects in Ankorchha forest and Sheger park.

2. LITERATURE REVIEW

2.1. Biodiversity

Biodiversity describes the sum total variation of life forms across all levels of organization which ranges from genes to ecosystems. It includes the variety and abundance of species, their genetic composition, and the communities, ecosystems, and regions in which they occur (Burley, 2002).

Ecological processes have the totality of structural and functional relationships. Energy flows and minerals cycle through individual organisms that are members of species whose populations are assembled in to ecological communities (Kormondy, 1996). None of these

ecological processes occurs in isolation for each is manifested by particular assemblages of different species or populations in a particular physiochemical environments (Grime, 1997). Each community has a defined set of animal and plant species living in it, a set that persists year after year with only minor change. Therefore, ecological community is an interactive assemblage of species whose ecological function and dynamics are in some way interdependent (Putman, 1994).

In most of this interdependent system is found the human being and benefits a lot from the values of species diversity. Regarding the values of species diversity, ecological, economic educational and scientific, recreational and aesthetic values are the paramount ones. The ecological services of biodiversity include improvement of air and water quality, hydrological, gaseous and mineral nutrients circulation, manufacture of food by green plants to be used as food, waste disposal by organisms some of which act as decomposers, soil formation, support of parasite host, prey predator, symbiotic and other relationships among organisms (Tilman *et al.*, 1999). Economic uses of biodiversity include its uses in the management and utilization of biological resources in satisfying human needs in multi-sectoral areas including agriculture, forestry, fisheries, wildlife and other industries (Cox and Balick, 1994).

In spite of its values though, at the beginning of the 21st century scientists around the world are conscious of the increasing threat that our biodiversity is being put under. There have been many studies that have been conducted with regards to species diversity and numbers. The results suggest that the world's diversity is on the decrease (Pimm and Gittlemen, 1992).

Although naturally occurring phenomena such as fire, volcanic eruption and floods can adversely affect community structure and there by diversity, it is without question that human

activity has far greater impact on the world biodiversity, primarily through habitat destruction (Kormondy, 1996). Human activities that affect biological diversity are many and vary greatly worldwide, but may include modification of ecological processes, conversion of forest to alternate land uses, hunting and fishing, introduction of non-native species, fuel wood gathering, subsistence agriculture, and forest management practices that change habitat characteristics of the forests (FAO, 2001).

In the tropical region, the trend is not different from that of the overall world and most of this extinction is believed to be in tropical forests, which house between 50-90% of the planet's component of species (Gomes-pompa *et al.*, 1972). It is known that about 17 million hectares of tropical forests are being cleared annually and scientists therefore believe that about 60,000 of the world's 240,000 plant species and even higher proportions of vertebrate and insect species could be on the way of being wiped out from the earth forever (Levin, 1993). Regarding insects, it is well known that, anthropogenic change to tropical forest ecosystems have a large impact on native arthropod communities too (Brown 1991).

One of the countries located within tropics is Ethiopia. Because of the physical condition and variations in altitude, there is great diversity of climate, soil and vegetation in Ethiopia. The diverse climate and topography has provided with different natural environments, which support a wide variety of fauna and flora (Fekadu, 1992). Ethiopia is known worldwide as one of the global centers of biodiversity and also has a high level of endemism in its wild forest flora and fauna (NCS, 1994a). Forests are known to play an important role in the conservation of biological diversity and are believed to provide habitat to about 2/3 of all species on earth (Aldhous, 1993). As much of Ethiopia's diversity is found in its forests, the treasure of

biodiversity for which Ethiopia is still famous is being depleted rapidly as indigenous forests ecosystems disappear (Christian, 2007).

The loss of biodiversity is considered to be one of the most important of all negative effects on these forests. High diversity implies that there is a source of new species executing functions or ecosystem services for human needs (Hernandez–Stefanoni, 2006). Therefore, a reduction of biological diversity means less environmental functions and ecological processes that generate and maintain soils, convert solar energy in to plant tissue, absorb pollutants, supply clean air and water, store essential nutrients, regulate weather, and climate and so on (Levin, 1993).

2.2. Insects as biodiversity indicators

Biodiversity indicators are organisms that are used to evaluate and measure how biodiversity is changing. They aid in the determination of the degree of changes that takes place within ecosystems, populations or groups of organisms (Noss, 1990).

Bio-indicators are used instead of the direct measurements of the physio–chemical factors of an environment because it can be difficult to monitor every potentially important aspects of an ecosystem. In addition to that, using bio-indicators to estimate biodiversity is faster and less expensive than conducting comprehensive biodiversity surveys (if such surveys are even possible) (Favila and Halffter, 1997).

Insects are mostly used biodiversity indicators because of many advantages associated with them. Insects have the largest biomass of the terrestrial animals and are fundamental to studying the environment (Anderson, 1999). They also serve many functions in the ecosystem and embody the majority of links in the community food chain (McGeoch, 1998). Insects, especially butterflies, are highly sensitive to environmental instability and they respond to it very quickly

(Collinge *et al.*, 2003). Apart from these, there are standardized methods for their sampling and collection and comparative interpretation (Duelli *et al.*, 1999).

2.3. Habitat specificity of insects

As each community has a defined set of animal and plant species living in it, and this persists year after a year with only minor change, in an ecological community there is an interactive assemblage of species whose ecological functions and dynamics are in some way interdependent (Putman, 1994). Since the ability of a certain type of species to survive in a given environment depends on its being adapted to that environment, it should follow that given life forms would be more prevalent in some environments than in others (Kormondy, 1996).

Similarly, each insect species is especially adapted to live in a particular niche in a community (Ross, 1965). In a sense, the species is a prisoner in its abode because there are various environmental factors that restrict the species to its particular type of habitat (Balakrishnan and Easa, 1986).

There are many environmental factors which exert their direct and indirect impact for an insect species to exist in that particular habitat or not. Environmental factors that affect the specificity of insects for their habitat include the suitability of the climate and weather, availability of suitable host, oviposition site, a symbiont and absence of natural enemies (Majerus, 1994).

In phytophagous insects, diet suitability, especially the effects of plant chemistry, appears to be very important (Jaenike, 1990). As plants chemistry differ mainly in accordance with their species, insects prefer a particular set of plant species for their association (Hutchins, 1966). Since the type of plant species that grow in a particular habitat are affected by climate, weather,

altitude and soil type, these environmental factors indirectly affect the abundance and distribution of organisms, including insects, which are dependent on those plant species for their survival (Kormondy, 1996). Likewise, the presence of a symbiont in that particular habitat might contribute to the habitat specificity of insects. Hopkins and Thacker (1999) presented that two rare species of aphids only utilized their host plant when they grew near ant nests. For instance, the Oak feeding aphid *Stomaphis quercus* only occupied trees within 17 meter radius of a *Lasius fulinosus* nest.

In predacious insects the trend is similar. Since many of predacious insects are not generalist feeders and some are even conspicuously selective in their diet; prey abundance can determine whether a predator insect enter and remain in a habitat (Endler, 1991).

Insects show specificity in their habitat not only based on the suitability of the environment, but also because of the cost of habitat switching. Sloggett & Majerus(2000a) has suggested that dispersal might in itself be costly and that specialist ladybirds remain in the same habitat to avoid such costs. Any form of dispersal involves mortality risks, and in dispersal involving mass exodus from favorable habitats extremely heavy mortality is common (Kennedy, 1961).

2.4. Environmental factors which affect insect diversity

Given the many interactions that occur between organisms and their environment, it is reasonable to think that environment can affect the size, distribution, and other characteristics of population (Kormondy, 1996). The species characteristics and environmental influences which affect population numbers find their expression in the birth rate, the death rate, and the rates of movements in to and out of an area (Clark *et al.*,1967).

2.4.1. Weather

Long term weather, i.e. weather over periods of 30–40 years or more constitute climate. Unlike the daily and even seasonal variability of weather, climate tends to be more consistent and hence more predictable because of the long term averaging of short term variations (Kormondy, 1996). However, both climate and its short time expression which we call weather have a profound impact on the numbers of insects present at any given time (Way, 1967).

2.4.1.1. Temperature

In the lives of insects, temperature is one of the most critical factors. Insects are coldblooded animals, so that within narrow limits their body temperatures are the same as that of the surrounding medium. Within the range of ambient temperatures to which insects are naturally exposed, the rates of their physiological processes vary directly with temperature. Thus, in many places the seasonal, cyclical and other variations of temperature exert a profound influence on the rates of change of insect numbers (Clark *et al.*,1967).

Effects of temperature on insects can be shown in several ways such as effects on development, reproduction, mortality, activity, range expansion and, of course, some other indirect effects (Glen, 1954).

There is a definite low point called the threshold temperature and there is also a definite high point called lethal high temperature. Between these two points, rate of development responds to temperature changes. But, the response is not uniform throughout the insect world. Each species has its own individual rate of development. Within a species each developmental stage may have different rate of development. For instance in Japanese beetle, at identical

temperatures, the rate of development of the eggs and pupae have been found to be higher than that of the larvae (Ross, 1965).

Temperatures suitable for breeding of Queensland fruit fly occur from late spring onwards. From then on, temperatures are suitable for rapid breeding and high survival until they start to decline towards the end of March. These declining of temperatures affect speeds of development and survival rates of the immature stages of the fly (Bateman and Sonleitner, 1967).

Under the variation of natural environment, the reproductive potential shows variation. It was shown that a single female rice weevil (*Calandra oryzae*) produces 22.4 offspring per year at 23^oc, 30.6 at 29^oc and 6.2 at 33.5^o (Kormondy 1996).

The temperature range that insects can withstand varies tremendously with the species. Species that live in cool places have correspondingly lower heat tolerances, such as the mountain genus *Grylloblatta*. The optimum for this group is about 38^oF, and normal activity occurs between the approximate range of 30–60^oF (Bale *et al*, 2002).

Similarly, cold temperatures also cause mortality. Insects of tropical origin usually succumb as the temperatures drops near freezing. Exposure for six hours to temperatures of –4^oC would kill all adult experimental *Glossina moristans* (Southwood, 1968). The mortalities caused are often selective, because one or more of the developmental stages of many insect species have a much higher tolerance than the others. Adults and pupae of tsetse fly occurring in relatively unfavorable sites, such as places where there is little shade, are killed rapidly by temperatures during hot day periods (Edney and Barrass, 1962).

Now a days climate change is occurring and its consequences are the main environmental concerns. The elevated carbon dioxide concentrations and increasing temperatures associated with climate change will have a substantial impact on plant insect interaction (Trumble and Butler, 2009). Temperature increases already have caused change in diversity and distribution. For example, the mountain pine beetle, a major forest pest in the US and Canada, has extended its range northward approximately 186 miles with the temperature increase of approximately 3.5°F (Logan and Powell, 2001).

On the other hand higher temperatures will favor some agricultural and urban pests. Argentine ants (*Linepithema humile*), which have already expanded throughout southern and central California, are better competitors against native ant species at higher temperatures (Dukes and Mooney 1999).

Increasing temperatures favor some insects by decreasing the effectiveness of their enemies. Increasing temperatures can greatly reduce the pest suppression provided by parasites (Hance *et al.*, 2007). For example, the fly *Drosophila simulans* is a suitable host for the wasp *Leptopilina heterotoma* at temperatures between 64°F and 72°F, but becomes poor host at 79°F (Ris *et al.*, 2004).

High temperatures have also increased the geographic range of malaria parasite *Plasmodium falciparum*. This parasite generally was limited to the tropics and subtropics because it requires an average temperature above 64°F to develop. Since the 1990s, temperature increases have extended the range of malaria to elevated urban areas of Africa that has been free of the disease through recorded history (Epstein *et al.*, 1998).

2.4.1.2. Rainfall

Since the majority of an organism's mass is water, it might well be anticipated that the degree of moisture might also be a population regulator. The ecological and biological significance of water is several folds and its cyclical movement, globally and locally, has considerable influence on the distribution of ecological systems. The relative and absolute amounts, rates, and the periodicity of precipitation and evaporation strongly influence the structure, function and distribution ecosystems (Kormondy, 1996). Rainfall exerts its impact on insects directly or indirectly through its effects on humidity, soil moisture, and plant food supply.

Excessive precipitation may inflict severe physical damage to insects. An inch of rain coming as a gentle sustained rain in one area may cause no harm, but coming as a sudden pelting down pour in another area may beat in to the ground and kill most of the aphids or early stage chinch bug nymphs (Glen, 1954). A snow cover on the soil also has a marked effect on both the extremes of temperature and average temperature to which insects in the soil are subjected (Ross, 1965).

Rainfall also affects humidity (moisture in the air). In the bean weevil the larvae develop faster at high humidity, but the eggs and pupae develop more rapidly at low humidity. Humidity also affects mortality rate. Low humidity has been found to increase mortality of *Drosophila* and high humidity are recorded as interfering with hatching and molting in some species of aphids. In certain cases it has been found that high humidity apparently reduce the resistance of a species to fungus attack and act unfavorably to the insect in this manner (Glen, 1954).

In a research done on *Perga affinis affinis* it was mentioned that high rainfall in the spring and early summer of that year favored both abundant new leaf production by the host trees and successful soil penetration by the larvae. Good autumn rains permitted the adults to escape from their cocoons easily and they encountered an abundance of foliage suitable for oviposition (Carne, 1962).

The effect of rain fall (moisture) is more profound when interacted with other factors especially temperature. Moisture and temperature significantly interacting environmental factors affecting species and hence, community distribution. Thus, some organisms may be very productive or active at high temperatures in the presence of considerable moisture, but the opposite at low temperatures when considerable moisture is present. For example, the American cockroach (*Periplaneta americana*) dies at 38⁰C at high humidity but can survive up to 48⁰C in dry air. The oriental cockroach (*Blatta orientalis*) can survive 24 hours at 37-39⁰C if the air is moist but dies at the same temperature in dry air (Chapman, 1982).

Kalkat *et al.*, (1961) showed that the insecticide parathion has no effect on mortality of the red floor beetle (*Tribolium castaneum*) at a relative humidity of 90% and a temperature of 32⁰C but a 44% mortality occurred at the same relative humidity with a temperature of 43⁰C. By contrast, the insecticide malathion had a reverse effect with the same combination of humidity and temperature: mortality of 78% at a relative humidity of 55% and temperature of 32⁰C, but 32% mortality at the same relative humidity and a temperature of 43⁰C.

2.4.1.3. Light

Each ecosystem depends on factors outside of it for its existence, chiefly in the form of radiant energy from the sun because it is the insulation, or solar radiation, that produces direct

heating of the earth and is the primary agent in photosynthesis, the starting point of energy flow within ecosystems. And it is the quality (i.e. wavelength or color), intensity, and duration of insulation that are critical to biological activity (Gates, 1962).

Because of the change in inclination of the earth's axis with respect to the sun over the course of a year, the total solar radiation received at given geographical latitude varies at different times of the year (Foukal, 1990). As might be anticipated, such changes elicit a differential progression of responses by a given species to both the quality and quantity of light i.e. photoperiodism (Kormondy, 1996).

The regulatory influence of photoperiod, i.e. the differential sensitivity of species to the length of the day, is manifested through the differential response by given species to the quality and quantity of light in a given ecosystem. So that a given species have as specific a physiological response to photoperiod as it has a specific morphological adaptation to another environmental parameter (Ross, 1965).

Light plays an important role in the lives of most insects just as it does in ours. The majority of insects are especially active during the daylight hours, becoming inactive in darkness. Their lives are governed by the 24 hour cycle which is one revolution of the earth (Hutchins, 1966).

The lives of many insects are governed by the length of the day light hours too. During the summer, aphids reproduce by giving birth to living young. Most of these individuals are females and do not mate, they reproduce themselves asexually, by producing living young all summer, generation after generation. When days become shortened during autumn, generation of males and females is produced that mate and lay eggs. The aphid may thus be considered to be a

long-day insect (Ross, 1965). Research on the silk worm in Japan has revealed even better information on the way day-length influences the life cycles of insects. When the commercial silkworms (*Bombyx mori*) were reared under artificial lights so that the length of the “days” could be varied it was found that as long as they were reared under short day conditions the moths continued to lay eggs that hatched at once. If, however, the caterpillars were reared, under long-day conditions (long photoperiods) the eggs did not hatch but entered a state of suspended development or diapauses (Hutchins, 1966).

Most insects have an extremely well developed response to light, moving toward the source or away from it. Some others respond not to the light but to certain wavelength of the light. In most case this aid to find food, or in ovipositing females, for placing their eggs on correct type of foliage (Hutchins, 1966).

2.4.2. Food

The degree of availability and accessibility of food would seem to be an obvious population regulator. Food is one of the most important factors influencing the distribution and abundance of insects (Glen, 1954). It is obvious that the insect is usually present wherever a suitable food is present and is prevented from extending its range because of the food factor (Clark *et al.*,1967).

A great number of insect species including chiefly plant feeders and parasites, feed on only a small number of diverse host species, or are restricted to a group of closely related host species, or may be restricted to a single host species. These are called specific feeders. The species that have the most limited host tolerance are the ones that are most likely to have their distribution limited by food (Andrewartha and Birch, 1960).

In the case of insects feeding on a definite species of plant host it is necessary for the species to adapt a new host or to have its numbers reduced to the carrying capacity of the original host. Some species, such as the forest tent caterpillar, make the change to closely related hosts with ease and without evident ill effects. This method of shift is called host crossover. Other species will make a change from one host to a close relative with the greatest difficulty. Still other species appear to be tied permanently to a single species of host (Ross, 1965).

Amount of available food is an important factor affecting the population of a species in a given community. It is not uncommon for a species to utilize its entire available food supply with a resulting sharp reduction in population due to starvation. Although there may be considerable variation in size between different individuals of the same species, there seems to be a definite minimum amount of food required for the normal development of an individual. Housefly maggots, for instance, die during pupation if the larvae are removed permanently from their food supply. Most sawfly larva will die without further development if removed from their food only two or three feedings prior to completing their full food intake. If, therefore, an excessive number of individuals are feeding on an insufficient amount of food, those with a head start complete their normal food intake and mature, and many of the remainder run out of food and fail to develop (Clark *et al.*,1967).

Availability of food exerts its effect on insect development, mortality, fertility, reproduction, breeding or oviposition. Regarding the effect of food on development parasitic species are the best example. The size of the individual parasite is determined by the size of the respective host species. An excellent example of this is the mutillid wasp *Dasymutilla bioculata*, larvae feeding on small prey species develop in to small individuals, those feeding on large prey species develop in to large individuals (Ross, 1965).

Availability of food affects mortality also. Starvation is frequently the direct cause of death to individual insects after accidental loss of their food supply or starvation from it. Sometimes, it is the cause of decrease in population numbers. For example, during outbreaks of the psyllid *Cardiaspina albitextura* population numbers may increase to a level at which the food supply is inadequate for the number of late instar nymphs present, and some die from starvation. Many of the adults which emerge subsequently fail to find sufficient food and die without reproducing (Clark, 1962).

The effect of food availability in reproduction (breeding) is also evident. The food shortage which is usually inhibited before the adult stage is reached affects not only percentage survival but also the mean size and mean reproductive ability of adults. In *Phaulacridium vittatum* (Acrididae) the amount of food available to adults influence their sexual maturation (Ross, 1965).

Regarding fertility, food has a paramount importance. For instance, with the female tsetse flies, 3 large blood meals are required for the development of each larva to full size; and fertility will be low unless the supply of food is adequate (Glasgow, 1963). Furthermore, availability of food exerts its effect on oviposition too. Both for plant feeding and other insects the quality and quantity of the food supply may exert a marked effect on the number of eggs laid per female. There is usually a clear relationship between the size of a female insect and the number of eggs which it can develop. This size fecundity relationship operates through the size of the food store accumulated during development, and converted later to egg yolk. Shortage of food may therefore decrease fecundity (Clark *et al.*,1967).

2.4.3. Altitude

Altitude is one of the important factors which affect the distribution and abundance of organisms on the surface of the earth (Kormondy, 1996). Air pressure, radiation, temperature and the humidity regime are functions of altitude. Therefore, altitude affects insect distribution and abundance indirectly by influencing these environmental factors (Ross, 1965).

In *Zeiraphera griseana* Hubner (Tortricidae) the most favorable temperature regime for overwintering in the egg stage and the establishment of larvae in the spring occurs at altitudes of 4,000–6,000 feet, but below 4,800 ft, earlier springs and warmer summers cause many eggs to hatch in the autumn instead of during the spring, and others die after an excessively long reconditioning phase at relatively high temperatures (Baltensweiler, 1966).

2.4.4. Soil

Soil greatly affects the interactions of ecological entities. Soil is related to climate and other physical chemical, and biological factors, including vegetation and that they are dynamic systems undergoing constant and slow evolutionary changes (Bridges, 1978).

Mineral matter, organic matter, air and water are the four main constitutions of soil. Mineral matter in the soil is derived from the parent material and organic matter from the decay and decomposition of organisms or their by products (Fitzpatrick, 1980).

Important soil properties that affect insects include texture, moisture, drainage and chemical composition. Soil texture varies from hard packed clays to loose sands. Fewer insects occur in the harder packed types, because they are unable to push or dig their way through them.

The loams are probably the favorite soils for insect use. These allow digging and burrowing operations and are usually favorable in other characteristics, such as moisture content, drainage and organic content (Ross, 1965).

The moisture content of the soil is affected greatly by drainage. Impervious layers of substrata, such as clay or rock, may retard natural drainage, resulting in permanent or temporary semi marsh conditions or wet soils (Bridges, 1978). In such situations occur only those insects that are at least partially modified for aquatic existence, such as many larvae of Diptera (Ross, 1965).

More open type of subsoil, such as sand, gravel; allow free drainage, contributing to the maintenance of better aerated soils and more rapid restoration of normal moisture content after rains (Fitzpatrick, 1980).

Well aerated soil is a prerequisite of all soil insects that have no modifications for aquatic or semi aquatic existence. Drainage and texture together exert considerable influence on the distribution of insects that live part of their life in the soil (Ross, 1965).

Chemicals naturally present in the soil affect both the abundance and distribution of phytophagous insects. Deficiencies inhibit the growth of some insects but seemingly not others. Soil chemistry also determines the species of plants that grow naturally in an area. This determines the hosts available for phytophagous insects, and in this fashion the distribution of many host specific plant feeders. For instance, nitrogen deficiency lowers the productivity of some species of insects, but seems to contribute to outbreak numbers of others (Lightfoot and Whiteford, 1987).

2.5. Insect interactions

Insects are part of the complex ecosystem. These groups of organisms are incredibly diverse and their ecosystem functions are equally diverse. The ecological role of insects ranges from benefactor to killer, with the beneficial insects being the most abundant (Clark *et al.*, 1967).

2.5.1. Interaction of insects with plants

In the process of converting radiant energy in to chemical energy by photosynthesis, the green plant incorporates in to its protoplasm various inorganic elements and compounds such as CO₂, H₂O, N, P,S, and Mg and 15 more other essential nutrients. As the green plant is grazed on, the nutrients are transferred to the herbivores (Kormondy, 1996).

While a plant is alive and growing in it host to many kinds of insects and again when the tree dies it at once becomes the abode of a new insect population, chiefly boring beetles. When the tree finally falls to the earth and begins rotting there is yet another shift in population as new insects take over and hasten the processes of decomposition. A tree, living or dead, is a teeming world of that thrives in amazing diversity (Hutchins, 1966).

Insects interact with plants in many ways. Insects benefit more from plants than they contribute. Some of these benefits include using plants as a food source, housing, protection and breeding area. Some of the benefits insects give to plants include assisting in pollination, speeding up decomposition and nutrient cycling and even attacking insect pests of plants (Cranshaw, 2009).

Pollination is the process by which plants sexually reproduce. Many plants depend on insects to transfer pollen as they forage. It is estimated that 65% of all flowering plants and some seed plants (e.g. cycads and pines) require insects for pollination. This percentage is even greater for economically important crops that provide fruits, vegetables, textile-related fibers and medicinal product (McGregor, 1976). Plants attract insects in various ways, by offering pollen or nectar meals and by guiding them to the flower using scent and visual cues. This has resulted in strong relationships between plants and insects. Species of bees, beetles, flies, wasps, thrips, butterflies and moths are all successful pollinators (Cunningham *et al.*, 2002). In return insects get nectar from plants and manufacture honey from it. In addition to nectar, honeybees gather pollen from flowers and carry large quantities to their hive. Nectar contains much sugar and is high in carbohydrates. Pollen contains about 20% protein, in addition to oils and other foods (Hutchins, 1966).

Insects speed up decay and nutrient cycling in the soil and thereby facilitate the readily availability of nutrients to plant roots for absorption. Insects such as ants, termites and wood boring beetles bore in to the wood of dead trees, speeding up the invasion of wood decaying microbes. Insects such as Collmbolans, Thysanurans, beetles, and flies feed on organic matter and fungi, speeding the flow of nutrients to the soil (Lavelle *et al.*, 1994).

The number of beneficial or non-harmful insect species play many essential roles. Some predator and parasitoid insects help the plants by preying on and parasitizing insects and thereby, regarding pest insects attacking plants, control their numbers and make them less abundant and less damaging (Cranshaw, 2009).

While the majority of plant-feeding kinds of insects obtain their food by eating leaves or siphoning sap still others, for example, true harvester ants, gather fallen seeds to use it as a staple food supply of the colony (Anderson, 1991).

While most insects are content to feed up on plant tissues in the form that the plants produce them, there are many insects that secrete substances in to plants, causing them to produce special structures, called galls, within which they live. The open types of galls, which are produced by aphids, coccids etc, are formed by the insect feeding from the outside, causing the leaf to fold over and make a pocket in which it continues to feed. Closed galls are those in which a larvae lives and develops completely within the gall, only emerging as an adult insect. Galls of this type are generally produced by the larvae of beetles, wasps, moths or flies. In addition to a growth stimulating substance, the insect produces an enzyme that transforms the plant starch in to sugar (Hutchins, 1966).

Other than these, insects use plants as a housing ground too. For example, caddis larvae make use of a wide variety of building materials such as pieces of leaves, grass, bark, and twigs for building their nests (New, 1988).

There are also a number of insects that collect fiber from weathered trees and chew it in to paper which they use to make their nests. Some other insects, specially the ants belonging to the genera *Oecophylla* and *Polyrhachis* construct nests by fastening several leaves with silk. Some spiders too construct cells by bending grass blades in to the form of little boxes (Hutchins, 1966).

Another type of interaction is seen in fungus-growing ants Tribe Attini (in the family Formicidae) obligately depend on the cultivation of a fungal mutualist for their nutrition. The

higher Attine ants (the genera *Atta* and *Acromyrmex*) cultivate fungal gardens in their colony, using leaf material harvested from adjacent living plants (University of Sidney, 2004).

In addition to all of the above, some insects dwell within the tissues of plants. This type of existence affords protection from weather and enemies, and places the insect in abundant food supply. Some of these, especially the beetles, ants, and termites, tunnel through the wood of living or dead trees (Ross, 1965).

Some insects also lay their eggs on plants. Some insects of moths, beetles, flies and certain wasp like sawflies lay their eggs up on the surfaces of leaves or insert them inside, and when the eggs hatch, the larvae begin tunneling through the tissues (Clark *et al.*, 1967).

Colored insects get their distinctive color from the food they eat. Probably the most common pigments in plants are those of the carotenoid class and this contribute to the color of insects that feed on them. For instance, beets contain large amount of anothocyanin and that give a vermilion color to certain aphids (Hutchins, 1966).

Sometimes insects inflict much damage to the host plant while satisfying their needs. The greatest mortality of plants by insects results from the predation of seeds, however, some insects are capable of destroying seedlings and mature trees. Examples are spruce budworms, bark beetles and tip moths (Ross, 1965).

Sometimes insects act as parasites of the plant. Examples include phloem feeding insects, sap sucking insects, wood boring insects, gall forming insects. In addition to that insects affect certain plants seriously by disseminating disease producing organisms (plant pathogens). For example some beetles can carry and transmit cowpea mosaic virus (Southwood *et al.*, 1972).

Among the amazing interaction of plants and insects is the action of predaceous plants which trap and digest animal prey. Bladderworts (*Utricularia*) are aquatic plants that trap small organisms in bladder like pouches; sundews (*Drosera*) are plants having sticky tentacle hairs on their leaves that encompass prey; and pitcher plants (*Sarracenia*) have leaves in the shape of pitchers, partially filled with water, with stiff hairs pointing to the water; the hairs allow insects to get to bottom of the pitcher but prevent their escape (Ross, 1965).

2.5.2. Interaction of insects with other insects

Insects interact with each other too. The interactions may be among different or among the same species. Prey-predator, parasitism and competition are the main types of interactions that goes on between insects and that cause a change in insect populations.

Predatism

Among almost all animal groups the flesh eating habit has become the established way of life for certain species because a carnivorous diet has the advantage of highly essential protein content (Barryman, 1992).

Characteristically, individual insect predators need to consume a number of prey individuals in order to reach maturity. They kill and consume prey either immediately or within a short space of time. Some species feed indiscriminately up on all developmental stage of their prey, others cause selection mortalities (Radcliff *et al.*, 1996).

Predatory habits are found in many orders of insects and in all these either the mouth parts or the legs are specially modified for catching their prey. Dragonflies, Dytiscid Beetles and Neuroptera have powerful jaws which in some cases have serrated edges. The nymph of the

dragonfly has a powerful prehensile labium. Bugs such as Pentatomids use their sharp proboscis to stab their prey. The praying mantis has its front legs modified so that the tarsus can be folded back against the tibia like a jack-knife, the edges of both being toothed; it also has powerful jaws and a very flexible neck. Robber flies (Asilidae) have all their legs powerful and hairy for catching small insects in flight. Some scorpion flies and Hunting wasps support themselves with their front legs and catch their prey with the enlarged hind legs (Doutt, 1964).

Insect hunters are usually well suited to their trade, for they are active, alert and keen of vision. Some of predacious insects do use venom to paralyze and kill their prey. In others, they inject large quantities of venom in the body of the prey. The venom has the power to digest and liquefy the inner tissues of the prey so that the dissolved material is then sucked (Hutchins, 1966).

Carabidae and Staphylinidae are two very large beetle families that feed on both adult and larval stages almost exclusively. Many families of wasps are predaceous, as are larvae of Tabanidae, Dolichopodidae, and some other large families of Diptera. Odonata (damselflies and dragonflies) are predaceous as both nymphs and adults. The same is true of certain families of Hemiptera such as Phymatidae (ambush bugs), in some other families of Hemiptera, such as the Miridae (plant bugs), most genera are phytophagous, but some are predaceous (Ross, 1965).

A number of field experiments have shown that changes in the densities of predatory (and other) species affect the structure of their ecological communities (Power *et al.*, 1992).

Among the many predators which attack tsetse flies are web-spinning spiders the effect of which have been estimated quantitatively. Glasgow (1963) reported that *Hersilia* species caused 17% mortality per week in a population of *Glossina swynnertoni*.

Unlike well adapted parasites, predators tend to kill their prey; this can result in oscillation of both predator and prey. The numerical response of predator to prey density may have three basic aspects, a rather immediate response by concentration, a delayed reproductive response and a rather immediate numerical response through improved survival of immature predators (where the immature stages are also predators) (Hagen, 1987).

Cannibalism has frequently been observed in insect species especially at times of overcrowding or when food is in short supply. One of the best known insect in which cannibalism occurs is the codling moth (Geier, 1963).

Parasites and parasitoids

A parasite is an organism that lives at the expense of the host. A parasitoid is an organism that has young that develop on or within another organism (the host), eventually killing it. Parasitoids have characteristics of both predators and parasites (Cranshaw, 2009).

The larvae of many families of Hymenoptera (Ichneumonidae, Chalcididae, Scelionidae, and many others) and a few families of Diptera (Pyrgotidae, Tachinidae) are entirely endoparasitic on insects or closely allied arthropods. A few Lepidoptera and several Coleoptera including the entire small series Stylopoidea have endoparasitic larvae (Ross, 1965).

Most parasitoid insects lay their eggs on the larvae, nymph or adults of other insects, so that when the larvae comes out of the eggs it feeds on them. Insect parasites that live in the bodies of other insects are usually the larvae of small Hymenoptera such as chalcid wasps and ichneumon flies and some 25equeste, mainly Tachinidae (Cranshaw, 2009).

Parasitoids vary in size and habits. There are wasps so tiny that they can lay their eggs in the eggs of larger insects where their larvae mature. Other wasps deposit their eggs within the bodies of caterpillars. The pyrgota fly lay its egg in may beetles body. The larva eats and grows within her body, slowly destroying her stored food. Eventually, the beetle dies and the larvae change in to pupa (Hutchins, 1966).

Insects have few ectoparasites of the type of the lice or fleas, in which the adult stage or both immature and adult stage use the body of the host as a home. An unusual ectoparasite is the bee louse *Braula caeca* a curious minute fly that is ectoparasitic in the adult stage on honeybees (Ross, 1965).

In the Hymenoptera, some families whose larvae are mostly endoparasites, such as the Braconidae, contain genera whose larvae are attached externally to their host larvae. These parasites have the same host relation as their endoparasitic allies, in that normally only one parasite individual lives on one host individual, the latter almost always dying when or before the parasite is mature (Ross, 1965).

Parasitoids, like predators, result in a change in the population of insects. It was mentioned that the effects of parasitism by *Habrocytus 2bequester* (Walker) on *Bruchidus ater* (Marsham) larva caused 80% death, and in *Leucoptera spartifoliella* 58% of the late larvae and pupae of were destroyed by Eulophids (Price, 1973).

Parasites also are a major contributor to many ecological interactions and especially to mortality in numerous species is well recognized (price *et al.*, 1986). Characteristically, parasitic insects cause age specific mortalities (Clark *et al.*,1967) and parasitism is more effective as a regulatory phenomenon (Kormondy 1996).

Competition

Competition is the simultaneous demand by two or more organisms for a common resource. There are two types of competition namely intraspecific competition and interspecific competition. Intraspecific competition occurs among individuals within a single species. Interspecific competition occurs between individuals of different species (Kormondy 1996).

Insects compete for food source, oviposition sites and space for a living. Among insects competition is chiefly for food. This competition may be between either individuals of the same species or different species (Ross, 1965).

Competition in insects may result in reduction in multiplication rate, reproduction rate, survival, or fecundity. It was mentioned that in *Arytaina spartil* the adult numbers dropped from about 8,000 per bush to 1,000 during the period of dispersal and yet fecundity was still abnormally low. This is due to lack of oviposition site and intraspecific competition for oviposition sites (Southwood, 1968).

Averill and prokopy (1987) showed that intraspecific competition in the fruitfly *Rhagoletis pomonella* takes at least two forms. If more than one larva develops in fruits of hawthorn (*Crataegus mollis*), survivorship drops sharply, the result of competition for food. In addition, multiple infestation cause a decreased pupa size which, in turn, results in prolonged maturation of females and lower fecundity. The second form of competition is territorial. The female marks its oviposition site with a pheromone that is sufficient to deter most other females from laying more eggs in the fruit. Bateman and Sonleitner (1967) mentioned that there is evidence that competition between larvae of fruit fly in fruit led to reduced larval survival.

In some instances insects may make the food inaccessible to others. *Brevicoryne brassicae* can reverse not only the outward flow of sucrose that would normally occur from such a leaf also draw nutrients from other, uncolonized leaves, as well as stopping nutrients from leaving the colonized leaf (Southwood, 1968).

2.5.3. Interaction of insects with the human being

From the beginning of human history man has been in almost constant battle with the insects. Insects have destroyed his food and as parasites, have sucked his blood and have transmitted some of his most serious diseases.

In contrast to that, some insects have a lot to contribute to the life of human being. Manufacturing honey from flower nectar is an ancient profession practiced by several species of insects. Of all the world's nectar gatherers the domestic honeybees (*Apis mellifera*) is the best known. It has been kept under domestication for thousands of years and is now a common "domesticated" animal in almost every land. Some insects produce silk. Sericulture or the commercial culture of silkworms is an ancient craft that began in china about 1800 B.C. silk is now produced commercially in all parts of the world (Hutchins, 1966).

Some insects also benefit man by preying up on the pest insects of his crop. For example, Ground beetles (family Carabida) feed on cutworms and other pests, and, thus, are definitely beneficial to man (Cranshaw, 2009).

Insects, especially honey bees, are very important to the farmers and fruit growers. Many kinds of clover and fruit trees will not set seed or produce fruit abundantly unless sufficient bees are present to assist them in pollination (McGregor, 1976).

In contrast to their advantage, insects also cause direct and indirect harmful effect to man. Insects act as vectors of pathogens that cause diseases such as typhoid fever, bubonic plague, malaria, yellow fever, dengue, sleeping sickness, elephantiasis on human beings (Ross, 1965).

The venoms injected by stinging insects are complete organic substances when introduced in to animal bodies they cause various reactions. The venom may affect the red blood cells, act on the nervous system, cause swelling of tissues or produce anaphylactic (or allergic reaction). Some peoples are especially sensitive to bee or other insect stings and may be made very ill or even die as a result (Hutchins, 1966).

Insects also attack man's agricultural crops, domestic animals, stored products and household materials (Ross, 1965). All the major field crops suffer high losses from insect that feed on the wood, suck the plant sap, inject toxin in to the plant body, cause injury by oviposition, or transmit plant pathogens (Ainsworth, 1981).

Ectoparasites and pests of stored foods are of prime importance in human habitations. Grain, meat, flour, grain meals, and other highly nutritious food stuffs are eaten by many insects. When in storage, those commodities suffer a heavy loss from insect damage. It is estimated that about 20% of stored products get lost by arthropods world wide. In addition, larvae of clothes, mats and carpet beetles feed on at anything containing animal fibers, such as woolen garments and carpets. Silverfish and cockroaches are general feeders that eat starchy food such as book bindings. Termites and carpenter ants excavate in woods and sometimes tunnel in the timbers of houses (Ross, 1965).

Man, to protect himself and his properties from insect attack use insecticides and other control measure such as biological, cultural and managmental, mechanical, physical and other control measure to keep insect numbers down.

2.5.4. Interaction of insects with microorganisms

Insects not only interact with multicultural organisms but to unicellular organisms too.

Fungi, bacteria, and viruses attack insects in various stages and at times are destructive to their hosts. Among common fungus diseases of insects is *Empusa muscae*- the house fly fungus. A famous fungus disease is *Beauveria globulifera*, often referred to as *Sporotichum globulifera*, the white fungus of chinch bug. During warm and humid seasons this fungus kills large numbers of chinch bugs and other insects (Ross, 1965).

Among bacteria diseases Flacherie, an infectious and highly fatal disease of silkworms, is caused by a bacterium. Grasshoppers and chinch bugs are attacked by similar bacteria. A bacterium called *Bacillus popilliae* is also very destructive to the Japanese beetle larvae. *Bacillus thuringiensis* is also a well known bacterial disease of insects. Virus diseases are extremely toxic to susceptible insect species. Polyhedrosis viruses in particular have proved sufficiently virulent against certain sawfly and lepidoptreous larvae (Ross, 1965).

Insects interact with pathogenic microorganisms by being their transmitters (vectors).

Some insects also grow fungus. The ambrosia beetles of the genus *xyleborus* cultivate moulds and the spore bearing conidia and both the larvae and adults of these insects feed on the tender shoots of the fungus (Hutchins, 1966).

2.5.5. Interaction of insects with other animals

Insects interact with the animals around. Insects inflict an attack on the animals and animals also prey on insects too.

Vertebrates contain many groups that are insectivores. Among the fish, perch, sunfish, crappies, bass, and sheepshead use insects for a large share of their diet. Reptiles and amphibians are largely insectivorous, as are bats and moles; other mammals such as mice, skunks, shrews, and raccoons eat large numbers of insects (Hutchins, 1966). Birds are the outstanding vertebrate insect eaters. Swifts, nighthawks, and flycatchers feed entirely on insects caught on the wing. During insect outbreaks many birds of omnivorous food habits switch temporarily to an insect diet. Crows, blackbirds, gulls, owls, and small hawks are in this group and have been noted especially feeding on grasshoppers during periods of abundance. All these animals are abundant and being comparatively large individuals, eat proportionately large numbers of insects. In doing so they exert an ecological force against insect populations (Ross, 1965).

There is a bird in Africa, called honey guides, that appears to subsist on a diet of wax and bee larvae. These birds can digest and assimilate the wax (Hutchins, 1966).

Insects, in turn, inflict their attack on these animals mainly being parasites or by transmitting some of their diseases. Domestic animals have a variety of specific ectoparasites including Anoplura (sucking lice), Mallophaga (chewing lice) and fleas. In addition to that all warm blooded vertebrates are attacked by a great number of blood sucking flies such as mosquitoes, horseflies, blackflies, stable flies and horn flies. Several vertebrates are attacked internally by larvae of botflies and warble flies which are endoparasites. Some insects transmit

disease causing pathogens to animals. For example, trypanosomiasis is transmitted by tsetse flies (Ross, 1965).

3. MATERIALS AND METHODS

3.1. Description of the study sites

3.1.1. Ankorcha forest

Ankorcha forest is found in Northern part of Addis Ababa and has coordinates of 09° 05.31.6' N 038° 44.44' E/ 09° 00.29' N 038° 48.09' E. To the south Yeka Sub City, to the north Oromia region, to the west Entoto forest, and to the east Kotebe and Karra borders the forest.

Ankorcha forest experiences two rainy seasons. The main rainy season is from June to September. The other short rainy season is from January to March. The mean annual rainfall is 1089 mm. The mean annual temperature is 15–22°C, the hottest month being May and the coldest month is October.

Ankorcha forest is found at 2490–2902 m.a.s.l. The topography is mostly steepy, but in some places there are flat lands. Kebena is the main river which goes through the forest year round. But in addition to that there are seasonal streams which get dry during the dry seasons.

The major plant species that are found in the forest are *Casuarina equisetifolia*, *Pinus radiata*, *Pinus patula*, *Eucalyptus camaldulensis*, *Rubus steudneri*, *Buddleja davidii*, *Brucea antidysenterica*, *Acacia melanoxylone*, *Juniperus procera*, *Acacia abyssinica*, *Hagenia abyssinica*, *Eucalyptus globulus*, *Acacia decurrens*, *Croton macrostachyus*, *Cordia Africana*, *Erythrina brucei*, *Olea europaea*, *Dovyalis abyssinica*, *Rosa abyssinica*, *Thymus schimperi*,

Solanum anguivi, *Maytenus addat*, *Clusia abyssinica*, *Sida schimperiana*, *Lippia adoensis*, *Kalanchoe petitiiana*, *Erica arborea*, *Hagenia abyssinica* and *Justicia schimperi*.

3.1.2. Sheger public park

Sheger public park is located in central part of Addis Ababa in Gulele Subcity. It has coordinates of 09° 03.479' N 038° 44. 325' E / 09° 03.391' N 038° 44. 454' E. Since the park is located in the central part of Addis Ababa, its climatic conditions are the same to that of the city. The annual rainfall is 1089 mm. The annual mean temperature is 15–25°C the hottest month being May and the coldest month being October. Sheger park is found at the altitude of 2436 m.a.s.l. The inland area of the park is almost leveled.

The major plant species that are found in the park are *Euphorbia cactus*, *Acacia melanoxylone*, *Ficus sur*, *Juniperus procera*, *Schinus molle*, *Olea europaea*, *Cupressus lusitanica*, *Phoenix reclinata*, *Allophylus abyssinicus*, *Mellittia ferruginea*, *Dracaena steuldneri*, *Amaranthus caudatus*, *Pelargonium multibracteatum*, *Dovyalis caffra*, *Eucalyptus globulus*, *Acacia decurrens*, *Justicia schimperi*, *Acacia abyssinica*, *Rosa richardii*, *Hibiscus rosa-sinensis*, *Hagenia abyssinica*, *Podocarpus falcatus*, *Prunus Africana* and *Callistemon rigidus*.

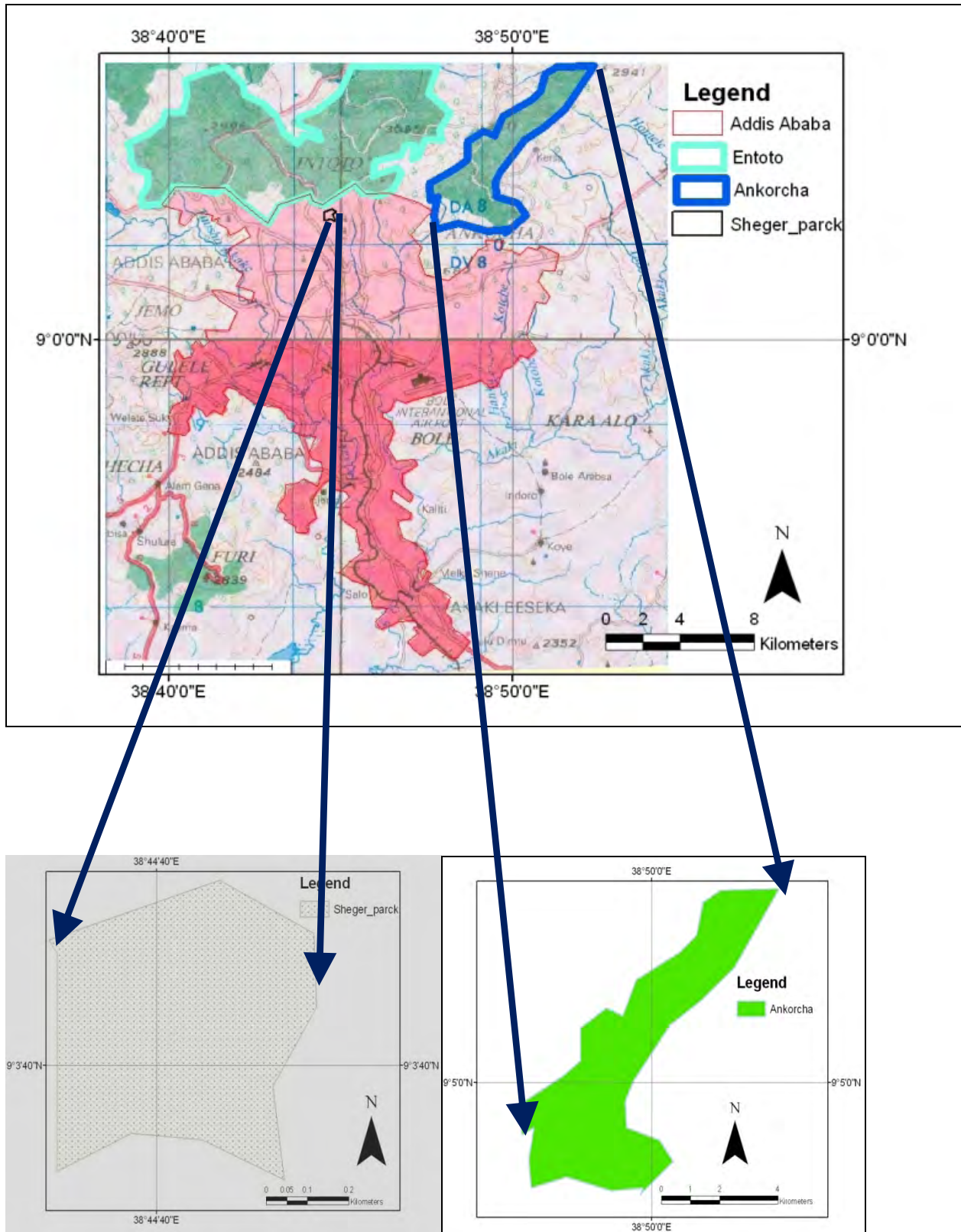


Figure 1. Topographic map of Ankorchha Forest and Sheger Public Park

3.2. Materials

The materials used in the study are topographic map, insect sweeping nets, insect collection jars and boxes, chloroform, binocular microscope, pins and data sheets.

3.3. Methods

3.3.1. Selection of the sample spots and time duration

Each of the study areas were divided into three categories based on the habitat types of each area. The forest study area was divided into artificial forest (Eucalyptus dominated) habitat, natural (mixed) forest habitat and grassland habitat. The park study area was divided in to grassland habitat, flowers and grass mixed habitat and mixed vegetation habitat.

The study was conducted in the wet and dry season. The wet season study was carried out from 12th of July 2008 to 17th of September 2008, and the dry season study was undertaken from 15th of November 2008 to 20th of January 2009.

3.3.2. Sampling methods and Data collection

The sampling methods used were transect walk and quadrant methods. Six transects, three on each of the park and the forest were laid based on the habitat difference. Each transect covers an area of approximately 2,500 sq. m. On each of the transect three quadrants having 5m length and width were marked. Therefore, six transect lines were sampled at random in each of the park and the forest at different habitats and totally 18 quadrants were marked in those transects.

Samples were taken from all of the three quadrants of each transect line in each habitat type in every month of the wet and dry seasons between 4:00–5:00 p.m. Insect samples were

collected by sweeping net. Sweeping was done in the range of 135-180 degrees and a height of 0.5–2 meters above the ground. The contents of the net were then put in a jar that contains chloroform. The jars were put in the boxes and taken to Addis Ababa University, Entomology laboratory for identification. The insects were identified to a family level using a binocular microscope and identification key of Borror *et al* (1992).

3.3.3. Data analysis

A diversity index is a mathematical measure of species diversity. In this study the diversity of the insects was determined by using the most commonly used indices namely Shannon–Wiener index of diversity and Simpson’s diversity index.

-The first index calculated was Shannon-Wiener diversity index (Shannon and Wiener, 1963). Higher value of Shannon-Wiener diversity index indicates higher diversity.

Shannon-Wiener Formula

Evenness= H'/H_{max}

Evenness is a measure of the relative abundance of the different families making up the richness of that habitat.

$H' = \text{Shannon-Wiener value} = -\sum p_i \ln p_i$

Where, p_i = the proportion of the number of insects in the i th family to the total number of families in that particular site

$\ln p_i = \log$ of p_i to the base 10

$H_{\max} = \ln S$ (S = number of families examined)

– In addition to this, Simpson's Diversity Index (Simpson, 1949) was used to quantify the insect diversity each habitats. Lower value of Simpson's Diversity index indicates higher diversity.

Simpson's Diversity Index D (Domance) = $\sum (n / N)^2$

Where, n = the number of organisms of a particular family
 N = the total number of organisms of all families in that particular habitat

– The number of species per sample is a measure of richness. So richness was calculated by Margalef's Richness Index (MRI) (Margalef, 1968).

Margalef's Richness Index (MRI)= $S-1 / \ln N$

Where, S = Total number of families observed

N =Total number of individuals of all families observed in the habitat.

– The similarity of insects in different habitats was quantified by Jaccard's index of similarity.

Jaccard's index (C_j)= $j / (a + b - j)$

Where, j =number of families found in both sites

a =the number of families in site A

b =the number of families in site B

Frequency, abundance and distribution of insects were also observed. The frequency was noted as the proportion of the sampling plots in which the insect found to the total number of sample plots examined. Abundance was taken as the total number of individuals of a family per sample plots in which it occurs. Distribution was calculated by dividing abundance by frequency (Brown, 1984).

Chi-square analysis for testing the association of insects and their habitats was done by using the 2005 version of SPSS computer program and t-test was used to compare the means.

4. RESULTS

In Ankorchha forest the presence of eighteen families of insects which belong to six families was revealed during the investigation. The dominant insect order was Diptera with six families followed by Hymenoptera with five families. Odonata, Coleoptera and Lepidoptera were all represented by two families each. Hemiptera was represented by only one family .

In Sheger park, twenty-five families of insects which belong to seven orders were observed. Here too the dominant insect order was Diptera with eleven families followed by Hymenoptera with six families. Order Lepidoptera was represented by three families and Hemiptera was represented by two families. Odonata, Cloeoptera and Thysanoptera were represented by one family each.

4.1. Diversity of insects in Ankorcha forest and Sheger park

Insect diversity in Ankorcha forest is shown in Table 1. The highest diversity of insects was observed in the natural forest in wet season. The same holds true for the dry season too, i.e. it is the natural forest that possesses the highest diversity. Considering both seasons together, here too, the natural forest is the habitat where in the highest diversity was observed.

In the wet season the best even distribution of insects was observed in the grass land habitat. But in the dry season insects were best evenly distributed in the artificial forest. Considering both seasons together, the grass land was the habitat where the highest evenness was seen.

Table 1. Insect diversity in Ankorch forest in 2008/2009.

Seasons	Habitat	Number of insects	H'	Hmax	Evenness	Simpson's D
Wet season	Natural forest	77	2.83	4.34	0.65	0.06
	Artificial forest	22	1.85	3.43	0.54	0.19
	Grass land	49	2.61	3.89	0.67	0.08
Dry season	Natural forest	48	2.71	3.87	0.69	0.07
	Artificial forest	7	1.55	1.94	0.79	0.22
	Grass land	14	2.06	2.64	0.25	0.14
Both seasons	Natural forest	125	2.85	4.8	0.59	0.06
	Artificial forest	29	1.93	3.36	0.57	0.16
	Grass land	63	2.57	4.14	0.62	0.08

Insect diversity in Sheger park is shown in Table 2. In all seasons, the highest diversity of insects was observed in the mixed vegetation habitat.

Insects were best evenly distributed in the flowers and grass mixed habitat in the wet season. But in the dry season, grassland habitat is the best habitat regarding even distribution of insects. The same was true when both seasons were considered together i.e. the best even distribution was observed in grassland in both seasons.

Table 2. Insect diversity in Sheger park in 2008/2009.

Seasons	Habitat	Number of insects	H'	Hmax	Evenness	Simpson's D
Wet season	Mixed vegetation	84	2.89	4.43	0.65	0.06
	Flowers and grass mixed	64	2.85	4.15	0.68	0.07
	Grass land	23	2.12	3.13	0.67	0.14
Dry season	Mixed vegetation	55	2.8	4.00	0.7	0.06
	Flowers and grass mixed	45	2.58	3.81	0.67	0.09
	Grass land	8	1.55	2.07	0.75	0.22
Both seasons	Mixed vegetation	139	2.89	4.93	0.58	0.22
	Flowers and grass mixed	109	2.62	4.69	0.55	0.07
	Grass land	31	2.03	3.43	0.59	0.14

4.2. Insects family richness in Ankorchha forest and Sheger park

Margalef's richness index (MRI) value of insects of Ankorchha forest is shown in Table 3. In Ankorchha forest natural forest habitat was the most preferred habitat by insects found in order Coleoptera with MRI value of 0.45. Artificial forest was the richest habitat in insects of order Diptera with MRI value of 0.51. The MRI value of 1.31 was the highest value of insects which belong to order Hymenoptera in the natural forest. But insects in order Lepidoptera preferred most the grassland habitat with the MRI value of 0.51. Similarly, insects of order Odonata recorded the highest value of MRI value of 0.51 in the grassland habitat.

Table 3. Margalef's richness index values of Insects in Ankorchha forest in 2008/2009.

Insect orders	H A B I T A T		
	Natural forest	Artificial forest	Grassland
Coleoptera	0.43	0	0
Diptera	1.35	0.51	1.36
Hemiptera	0	0	0
Hymenoptera	1.13	0.8	1
Lepidoptera	0.39	0	0.51
Odonata	0.35	0	0.51

Margalef's richness index (MRI) value of insects of Sheger park is shown in Table 4. In Shger park there was no difference in the preference of the habitat by insects of order Coleoptera, Odonata and Thysanoptera. Flowers and grass habitat was the best preferred habitat by insects which belong to order Diptera and order Hemiptera with the MRI value of 2.36 and 0.28 respectively. Similarly, both insects belonging in order Hymenoptera preferred the grassland habitat with MRI value of 1.67. On the other hand, mixed vegetation habitat was the best preferred habitat for insects of order Lepidoptera with the MRI value of 0.72.

Table 4. Margalef's richness index values of Insects in Sheger park in 2008/2009.

Insect orders	H A B I T A T		
	Mixed vegetation	Flowers and grass	Grassland
Coleoptera	0	0	0
Diptera	1.98	2.36	1.56
Hemiptera	0	0.28	0
Hymenoptera	1.29	1.13	1.67
Lepidoptera	0.72	0.55	0
Odonata	0	0	0
Thysanoptera	0	0	0

4.3. Similarity of insects among different habitats of Ankorcha forest and Sheger park

The values of Jaccard's index of similarity among different habitats of Ankorcha forest is shown in Table 5. In Ankorcha forest the most similar habitats in both wet and dry season were natural forest and grassland habitats. The least similar habitats in wet season and in dry season were artificial forest and natural forest. Considering both seasons together, the result was similar, i.e. natural forest and grassland habitats show the highest similarity in insects.

Table 5. Values of Jaccard's index of similarity in Ankorcha forest in 2008/2009.

Habitat	S E A S O N S		
	Wet season	Dry season	Both seasons
Artificial And Natural	0.38	0.29	0.23
Artificial And Grassland	0.46	0.4	0.3
Natural And Grassland	0.83	0.44	0.44

The values of Jaccard's index of similarity among different habitats of Sheger park is shown in Table 6. In Sheger park the highest similarity of insects was seen in flowers and grass mixed habitat and mixed vegetation habitat in all the wet season, dry season and also in both seasons together. The least similarity was seen in grassland and mixed vegetation in all seasons.

Table 6. Values of Jaccard's index of similarity in Sheger park in 2008/2009.

Habitat	S E A S O N S		
	Wet season	Dry season	Both seasons
Grassland And Flowers & Grass	0.52	0.29	0.29
Grassland And Mixed vegetation	0.39	0.21	0.21
Flowers & Grass And Mixed vegetation	0.68	0.45	0.45

4.4. Frequency, abundance and distribution of insects

Frequency, abundance and distribution of insects in Ankorch forest are shown in Table 7. In Ankorch forest eighteen families of insects were recorded. The most frequently found families of insects in Ankorch forest were Aphididae, Formicidae, and Muscidae. Regarding their abundance, Formicidae stood first. Scolytidae was the highly distributed family in the forest.

Table 7. Frequency, abundance and distribution of insects in Ankorch forest in 2008/2009.

Order of Insects found	Family of insects found	Total number of insects	Frequency	Abundance	Distribution
Coleoptera	Endomychidae	6	0.22	3	13.64
	Scolytidae	4	0.11	4	36.36
Diptera	Bombyliidae	3	0.11	3	27.27
	Muscidae	23	0.67	3.83	5.72
	Oestridae	8	0.33	2.67	8.09
	Sciomyzidae	9	0.44	2.25	5.11
	Syrphidae	12	0.44	3	6.82
	Tephritidae	11	0.56	2.2	3.93
Hemiptera	Aphididae	24	0.67	4	5.97
Hymenoptera	Andrenidae	12	0.56	2.2	3.93
	Bombinae	10	0.44	2.5	5.68
	Cephidae	9	0.33	3	9.09

	Chalcididae	8	0.33	2.67	8.09
	Formicidae	29	0.67	4.83	7.21
Lepidoptera	Gracillariidae	12	0.44	3	6.82
	Sesiidae	10	0.33	3.33	10.09
Odonata	Aeshnidae	9	0.33	3	9.09
	Coenagrionidae	18	0.56	3.6	6.43

Frequency, abundance and distribution of insects in Sheger park are shown in Table 8.

In Sheger park twenty five families of insects were collected. Among these the most frequently found families were Aphididae, Chalcididae, Muscidae, Sphicidae, Tipulidae and Thripidae. The most abundantly found family was Aphididae. Formicidae was the most highly distribute family in Sheger park.

Table 8. Frequency, abundance and distribution of insects in Sheger park in 2008/2009.

Order of Insects found	Family of Insects found	Total number of insects	Frequency	Abundance	Distribution
Coleoptera	Endomychidae	8	0.44	2	4.54
Diptera	Anthomyiidae	11	0.56	2.2	3.93
	Bombyliidae	5	0.22	2.5	11.36
	Chalcididae	12	0.67	2	2.98
	Culicidae	15	0.44	3.75	8.52

	Muscidae	25	0.67	4.17	6.22
	Rhagionidae	7	0.44	1.75	3.97
	Sarcophagidae	9	0.44	2.25	5.11
	Schatophagidae	6	0.22	3	13.64
	Syrphidae	9	0.44	2.25	5.11
	Tachinidae	6	0.44	1.5	3.41
	Tipulidae	8	0.67	1.33	1.98
Hemiptera	Aphididae	43	0.67	7.17	10.70
	Cicadellidae	12	0.33	4	12.12
Hymenoptera	Anthophoridae	8	0.44	2	4.54
	Brachonidae	6	0.22	3	13.64
	Eupelmidae	8	0.56	1.6	2.85
	Formicidae	5	0.11	5	45.45
	Ichneumonidae	5	0.33	1.67	5.06
	Sphecidae	15	0.67	2.5	3.73
Lepidoptera	Noctuidae	5	0.22	2.5	11.36
	Psychidae	9	0.33	3	9.09
	Tortricidae	6	0.22	3	13.64
Odonata	Coenagrionidae	9	0.44	2.25	5.11
Thysanoptera	Thripidae	26	0.67	4.33	6.46

4.5. Habitat association of insect in Ankorcha forest and Sheger park

Habitat association of insects in Ankorcha forest is shown in Table 9. In Ankorcha forest insect-habitat association showed no significant difference in all seasons. The total habitat association value of the wet season was $\chi^2=37.333$, $P<0.5$. In this season the highest habitat association was observed in the artificial forest habitat. During the dry season the total habitat association value was $\chi^2=29.111$, $P<0.2$. In this season too the highest habitat association was observed in the artificial forest habitat. When both seasons were considered together a total habitat association value of $\chi^2=42.445$, $P<0.5$ was found and the highest habitat association was observed in the artificial forest habitat.

Table 9. Habitat association of insects in Ankorcha forest.

Seasons		Habitat		
		Artificial forest	Natural/Mixed forest	Grassland
Wet season	Chi-square	26.000	4.000	7.333
	df.	5	5	5
	Assym.significance	0.000	0.549	0.194
Dry season	Chi-square	12.333	7.667	9.111
	df.	2	6	3
	Assym.significance	0.002	0.264	0.028
Both seasons	Chi-square	25.556	8.889	8.000
	df.	6	10	8
	Assym.significance	0.000	0.543	0.433

Habitat association of insects Sheger park is shown in Table 10. In Sheger park insect habitat association showed no significant difference in all seasons. In Sheger park the total habitat association value of the wet season was $\chi^2=55.8$, $P<0.06$. In this season the highest habitat association was observed in the grassland habitat. During the dry season habitat association value of $\chi^2=49.04$, $P<0.08$ was obtained. Here too the grassland habitat was the habitat which showed the highest habitat association. Considering both seasons together, a habitat association value of $\chi^2=55.4$, $P<0.6$ was obtained the grass land habitat being the habitat which showed the highest habitat association.

Table 10. Habitat association of insects in Sheger park.

Seasons		Habitat		
		Grassland	Flower and grass mixed	Mixed
Wet season	Chi-square	25.200	15.640	14.960
	df.	4	7	8
	Assym.significance	0.000	0.029	0.060
Dry season	Chi-square	24.560	13.360	11.120
	df.	2	6	6
	Assym.significance	0.000	0.038	0.085
Both seasons	Chi-square	32.360	8.000	15.040
	df.	5	10	10
	Assym.significance	0.000	0.629	0.131

The t-test result of the comparison of insect abundance of Ankorchha forest in wet and dry seasons showed significant difference with $t=7.518$ and $P=0.000$. In Sheger park too insect abundance in wet and dry seasons showed significant difference with $t=5.734$ and $P=0.000$. But when insect abundance of Sheger park and Ankorchha forest were compared during the wet season no significant difference were observed with $t=-0.809$ and $P=0.430$. Similarly when insect abundance of Sheger park and Ankorchha forest were compared during the dry season no significant difference were observed with $t=0.573$ and $P=0.574$.

1. DISCUSSION

The findings of this study may be affected by the sampling method. Sweep netting collects mostly low flying insects from vegetation. While there are many different types of insects, our most common insects were found in dipteran order in both Ankorcha forest and Sheger park. For instance, in Sheger park, 40% of the insects collected and studied belong to the order Diptera. One of the reasons for domination of order Diptera in both the forest and the park may be because of their high mobility. This allows them to inhabit a wider range of places in a range of climates.

In Ankorcha forest the most species rich habitat was mixed forest habitat. Insect populations in this habitat were relatively high when compared to the artificial (Eucalyptus dominated) forest and the grassland habitat. It was found to comprise 57% of the insects collected in Ankorcha forest.

In Sheger park insect population were found to be high in the mixed vegetation than that of the flowers and grass mixed habitat and the grass land habitat. This habitat was found to comprise 50% of the insects collected in Sheger Park. Heterogeneity of habitats is the main reason for species richness (Sanjayan, 1993). Among the present study habitats in Ankorcha forest, heterogeneity is high in the mixed forest when compared to the artificial forest and the grassland. In Sheger Park too heterogeneity is high in the mixed vegetation when compared to the flower and grass mixed vegetation and grass land habitats.

Among the three selected habitats of Ankorcha forest, in all seasons, highest diversity of insects was observed in the mixed forest. Similarly, in Sheger Park, the mixed vegetation habitat

was found to have the highest diversity of insects. One explanation for this may be that as the mixed forest habitat contains a wider variety of plant species, this may have created a wider variety of niches for wider diverse species. Diversity of insects in an area depends primarily on the availability of mixed plant species, which constitute their major food resources (Mathew and Rahamatthulla, 1993). Therefore, heterogeneity of the mixed forest habitat in Ankorchha forest and mixed vegetation habitat in Sheger Park is the main reason for highest insect diversity, as homogenous conditions yield lower diversity whilst heterogeneous conditions yield higher diversity (Alatolo, 1981).

In Ankorchha forest the grassland stood second in insect diversity in spite of less heterogeneity. One of the reasons for this is associated with the faster growth of the grass. The annual growth rate of grasses is generally much faster than any other plant, which could explain the species richness being greater than that of the forest. This implies that there is a shelter or food in the grassland.

In Sheger Park, the flower and grass mixed vegetation stood second in insect diversity because this habitat comprised a better heterogeneity than the grass land habitat. The grass land habitat showed the lowest diversity not only due to homogeneity but also because it is the most frequently disturbed habitat by the visitors of the park. The disturbance of the habitat affected the diversity of insects because their homes get destroyed. Still the other reason may be associated with the grass being cut frequently to make the park attractive to visitors. So, due to the exportation of nutrients from the area might have contributed to the loss of insect diversity.

In Ankorchha forest the lowest diversity of insects was recorded in the artificial forest in all seasons. Since the artificial forest is mainly dominated by eucalyptus, its homogeneity may

be one of the factors for low diversity record in there. The other reason may be associated with the Eucalyptus trees. Eucalyptus is known to discourage undergrowth. In the study it was observed that there was almost no undergrowth under the Eucalyptus trees. Due to this lower ground cover, insect diversity became low, because this condition increases ground temperature in hot seasons and decreases it in cold seasons (i.e. increase exposure), decreases available moisture and effective humidity, removes shelter, hibernation, and egg-laying sites. In the artificial forest people come now and then to collect the shaded leaves of the Eucalyptus trees. As Ananthkrishnan (1988) concluded that richness and abundance of insect species in an ecosystem are closely related to the physical stability of the habitat. As human activities change habitats a lot, that is how the disturbed habitat affects insect diversity and makes the area to have fewer insects. Undisturbed sites have more insects than disturbed sites because there are more places for them to live.

In this study the mixed forest and the grassland habitats of Ankoscha forest were found to be the most similar habitats in all seasons were found to be the most similar habitats in all seasons. One of the reasons for this may be due to the location of the grassland and natural forest. The grassland habitats selected for the study were near or in between the mixed vegetation because near and in between the eucalyptus dominated forest habitats there were no grounds covered by enough area of grass to get enough sample spots. Therefore, due to their being located adjacent to each other flying insects might have been caught while wondering here and there. The least similar habitats were the mixed forest and the artificial forest habitats. The reasons for this might be their difference in homogeneity and diversity.

In Sheger park the highest similarity of insects was seen in flowers and grass mixed habitat and mixed vegetation habitat in all seasons. Some of the reasons for this might be due to the

heterogeneity of the plants in both habitats, or/and the lower number and diversity of insects in the habitat might have made the grassland habitat to be relatively less similar to the other habitats in the park. The least similar habitats were the grassland and mixed vegetation habitats. The reason for this might be due to their difference in type and diversity of plants they possess.

In Ankorcha forest the highest insect-habitat association was observed in the artificial forest. This might be due to specificity of insects to this habitat having a particular type of plant which is Eucalyptus, and unlike the grassland habitat, which also has a particular type of plant species, stay relatively greener during the dry period because of deep root system of the plants.

In Sheger Park the highest insect-habitat association was observed in the grassland habitat. The reason for this might be due to specificity of insects to this habitat having a particular type of plant species and availability of the grass for the insects because it gets watered during the dry season.

Significant difference was observed when the dry and the wet seasons of the means of abundance of insects of the respective sites were tested. The main reason for this might be the difference in weather specially rainfall in the wet and dry seasons. But no significant difference was observed in abundance of insects when the respective season of the forest was compared to that of the park. The main reason behind this might be due to the forest and the park located in the same region and so have similar weather condition. The other reason might be associated with the type of plant species grow in these areas. Most of the main plant species growing in these areas were found to be the similar.

2. CONCLUSIONS AND RECOMMENDATIONS

It is evident that the insect diversity in both Ankorcha and Sheger Park is dependant mainly on the heterogeneity of the vegetations of the habitat and the extent of the disturbance in the habitat. In Ankorcha forest, in the artificial forest habitat, less of insect diversity was observed mainly due to homogeneity of the vegetation and human disturbance of the habitat. As insects are good indicators of biological diversity, it is evident that there has to be less biological diversity in the artificial forest habitat. Therefore, the government body that is in charge of the Ankorcha forest should take some measures to increase the heterogeneity of this habitat by reforesting it with different types of tree species, and should take some measures to keep peoples and some domestic animals off the forest.

In Sheger Park the same holds true that less number of insects were observed in the grass land habitat mainly because of its homogeneity and disturbance of the habitat by human beings. The government body that is in charge of this park should take some measures to protect the grassland habitat, and thereby the park, from being damaged. Similarly, people who go there should also take care of the park while recreating themselves there. These should be done mainly because parks and green areas are vital constituents of the urban environment. Also, they are the breathing, recreational and interaction spaces of the city that is becoming overpopulated, congested and polluted.

Generally, when the two areas were compared, Sheger Park showed a better number and diversity of insects in spite of its very small area of land and being located in the center of the city and a more disturbed environment. From this it can be concluded that if more and more

green areas are established and being taken care of, it is possible to counterbalance the damaging effects caused by man through degradation, modification and simplification of the natural environment.

The following recommendations can be made from the current investigation:-

1. Further investigation should be made by using different insect sampling methods
2. Further studies should also address different environmental factors that may influence the insect populations in the different habitats of Ankorcha forest and Sheger Park.
3. In Ethiopia there is limited baseline data and little accurate information with regards to trends in biological diversity and activities or processes that threaten the biodiversity. This means that more of these types of surveys will have to be done on going basis over the years in order to determine the diversity of these and other different areas, to asses the extent of the disturbance to the environment and also to fill the information gap that currently exists.
4. Within landscapes dominated by the forest, conservation considerations may include maintaining or restoring a mosaic of forest species and the diversity of native tree species in order to provide adequate habitats for insects and other organisms which are dependant on the forest for their living.
5. It is utmost importance that the wider population should be educated about the issues of biodiversity, conservation, and the importance of balancing human needs and conservation of the environment.

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Appendices

Annex 1: T-test results of the comparison of means in wet and dry seasons in Ankorcha forest.

	Paired differences					t	df.	Sig. (2-tailed)
	Mean	St. dev.	St. error mean	95% conf. int. of the difference				
				lower	upper			
Pair - wet& dry	4.3889	2.47669	0.58376	3.15726	5.62052	7.518	17	0.000

Annex 2: T-test results of the comparison of means in wet and dry seasons in Sheger park.

	Paired differences					t	df.	Sig. (2-tailed)
	Mean	St. dev.	St. error mean	95% conf. int. of the difference				
				lower	upper			
Pair - wet& dry	2.4800	2.16256	0.43251	1.58734	3.37266	5.734	24	0.000

Annex 3: T-test results of the comparison of means of Ankorchha forest and Sheger Park in wet season.

	Paired differences					t	df.	Sig. (2-tailed)
	Mean	St. dev.	St. error mean	95% conf. int. of the difference				
				lower	upper			
Pair - Wet1 & wet 2	-1.444	7.57878	1.78634	-5.2132	2.32439	-0.809	17	0.430

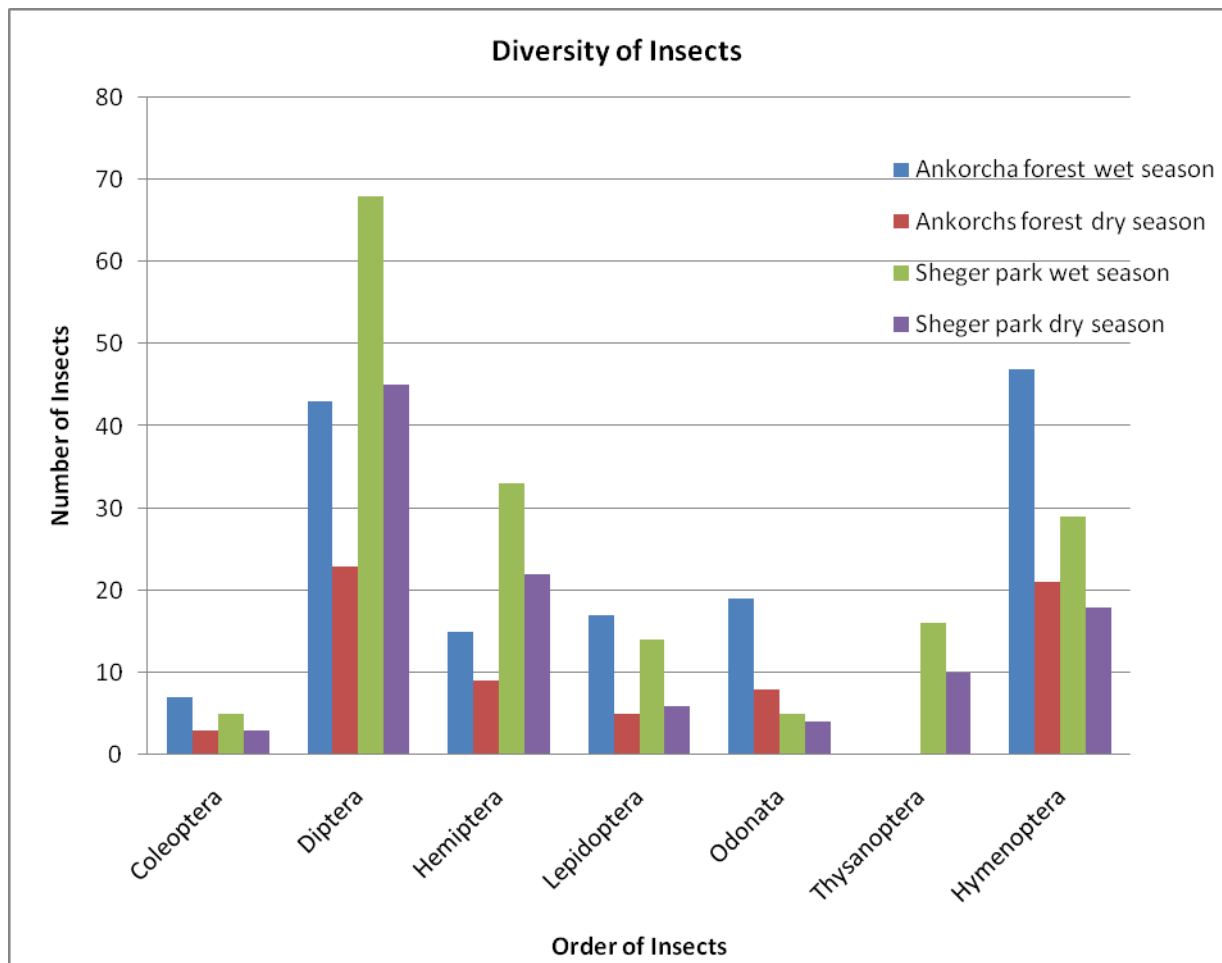
Annex 4: T-test results of the comparison of means of Ankorchha forest and Sheger Park in dry season.

	Paired differences					t	df.	Sig. (2-tailed)
	Mean	St. dev.	St. error mean	95% conf. int. of the difference				
				lower	upper			
Pair - Dry1 & dry 2	0.6667	4.93487	1.16316	-1.7873	3.12072	0.573	17	0.574

Annex 5: Photo of insects collected



Annex 6: Diversity of insects in Ankorcha forest and Sheger park in wet and dry seasons.



Annex 7: Figures of different habitats.

The forest study area:

1. Artificial forest (Eucalyptus dominated) habitat



2. Natural (mixed) forest habitat



3. Grassland habitat



The park study area:

4. Grassland habitat



5. Flowers and grass mixed habitat



6. Mixed vegetation habitat.

