STUDY ON INSECT DIVERSITY OF MENAGESHA FOREST AND BIHERE TSIGE PUBLIC PARK IN WET AND DRY SEASONS USING SWEEPING NET

THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, ADDIS ABABA UNIVERSITY, IN PARTIAL FULFILLMENT FOR THE REQUIREMENT OF THE DEGREE OF MASTER OF SCIENCE IN BIOLOGY

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July 2007
Addis Ababa

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② ACKNOWLEDGEMENTS

I am very much grateful to my advisor Dr Emana Getu for his initiation, great interest and his encouragement to study in not well addressed problem areas. Furthermore, I thank and appreciate him for his free and friendly approach through out the study period. I also thank Professor Balakrishnan for his provision of publications, constructive comments and sincerity.

It is my pleasure to thank Legesse Feyissa, for the material provision, encouragement and unreserved support in every kind. I also deeply thank Ato Wondwosen Aydagnhum and W/o Elleni Kebede for their moral support, guidance, and intelligence. Mulalem Roba, Tariku Tarekegn, Tsegaye W/Giorgis, W/o Elsa, Araya G/Selassie, Ato Merid Negash, W/o Bayech Wendmagegn, Ayalew-wendogenet, and Miss Sabela Getachew have to be thanked for their support at certain stage of the study. The help provided by W/t Tilki during data analysis was massive. I am also grateful to Addis Ababa University Biology Department for laboratory and other provisions.

I have no words to thank my exceptional mother W/o Negat Kebede; for helping me to bear the ups and downs of the study periods. Finally, I wish to thank all individuals who have in one way or another contributed for the success of my study.

ABSTRACT

Menagesha forest and Bihere Tsige Public Park contain diverse forms of insects. The diversity, distribution, frequency, abundance and habitat association of these insects were investigated using quadrate and transect walk methods during the wet and dry seasons.

The presence of 33 families of insects in Menagesha forest and 35 families in Bihere Tsige Public Park were recorded. In wet season more evenness and diversity were observed in the natural Menagesha forest. In the dry season, maximum insect diversity and evenness was recorded in the artificial Menagesha forest. Flowers and grass mixed vegetation of the park has the highest insect diversity and mixed vegetation of the park had the highest evenness in the wet season. Highest diversity of the park's dry season was found in grassland habitats, while high evenness was recorded in mixed vegetation. Based on Simpson's similarity index, the highest similarity was observed between natural and artificial habitats of the forest. Flower and grass mixed vegetation and grassland vegetation showed the highest similarity in the park. Grassland in the park and artificial forest in the forest showed the highest Margalefs Richness Index value.

SPSS analysis showed that the highest habitat association was recorded for grassland habitats in both seasons in the forest. In the wet season, the highest habitat association was recorded in grassland habitat of the park. In the dry season, insects showed no association to any of the habitats. T test results for insect diversity revealed no significance difference between seasons and intra-seasons in the park and the forest. Abundance of food, species of vegetation, stability of the habitats and human activities determined insect diversity at the study areas. Investment activities were determintal to the insect diversity in the forest.

1. INTRODUCTION

Borror *et al*. (1992) reported insects as the dominant group of animals on earth to date. They noted that insects by far exceed all other terrestrial animals in numbers, and they occur practically everywhere. The diversity of insects in the humid tropics has amazed biologists since the days of Bates, Wallace and the other 19 century explorer naturalists (Godfray *et al*., 1997). As can be seen from their diaries and notebooks, contemplation of how such wonderful abundance and variety might arise was instrumental in pointing Darwin and especially Wallace to the theory of natural selection. Yet as bemoaned by May (1988 and 1990) and others a century and a half later we have only a rough idea of the actual dimensions of insect species diversity and an even poorer understanding of the processes through which it is generated and maintained. Only small fractions (certainly fewer than 20%) of tropical insects have even been described by entomologists. And all the while, habitats are contracting and being destroyed at historically incomparable rate (Godfray *et al*. 1997). Insect community ecologists working in the tropics believe they have special problems compared with their colleagues studying plants or vertebrates (Kobe, 1999). He gave the explanation as for insects' field identification is impossible or very difficult except for major butterfly groups.

Biological diversity includes species diversity, richness, and genetic resources in a mutually interacting community of a given habitat (Joseph and Balakrishnan, 2005). The removal or loss of insects can cause negative effects in the ecosystem as they play a crucial role in the maintenance of ecosystem stability and diversity (Ananthakrisan, 1988). Insects and other arthropods are abundant throughout terrestrial ecosystems, probably removing about 20% of the foliage annually worldwide (Storke, 1988). But insects do not function in isolation, particularly in the soil, where in association with many other detritivore invertebrates, fungi and bacteria. In the tropical forests, ants together with the social wasps and bees constitute 80% of the biomass. Ants scavenge 90% of the dead remains of all insects and are a major element in the turnover of soil (Wilson, 1991). Insects are not uniformly distributed all over in a given habitat, but are limited to those areas, where the species-specific ecological requirements are available.

This is one of the major factors governing the distribution of animals in various types of habitats (Balakrishnan and Esa, 1986).

Ethiopia has diverse biological resources. This is reflected by altitudinal range and the diversity of climate, vegetation, and landscape. It is one of the few countries in the world that possesses unique and characteristic fauna with a high level of endemism (Shibru Tedla, 1995; Jacobs and Schloender, 2001). Over the years, the natural ecosystem in Ethiopia has been altered because of human and natural factors. Much of the highland and some parts of the lowlands have been converted into agricultural and pastoral land and the vegetation has been used for fuel wood, construction and other purposes (Hillman, 1993). Accelerating rates of biodiversity loss lead to the signing of international agreements, such as the convection on biological diversity and agenda 21, have called for the world biodiversity to be inventoried and monitored (Stork and Samways, 1995)

Insects are the most important components of an ecosystem. Their contribution interms of pollination, bicontrol agents, provision of useful products to humans can be categorized as useful aspect. On the other hand, few insect species are pests of plants, stored products, clothes, causes of fatal diseases. Basic aspects of insects in the ecosystem such as species richness, diversity, and habitat association should be studied regardless of the harmful or beneficial nature of insects for conservation purpose. Hence, the current study was initiated to know the diversity of insects in the stable ecosystems of the forest and the park.

2. OBJECTIVES

2.1. General Objective:-

- To study diversity, abundance, similarity and habitat association of insects in Menagesha forest and Bihere Tsige Public park.

2.2. Specific objectives

- To determine the diversity and abundance of insects in Menagesha forest and Bihere Tsige public park.
- To determine habitat association of insects in Menagesha forest and Bihere Tsige public park

3. LITREATURE REVIEW

3.1. Prominent features of insects

3.1.1. Seasonality

Several studies have provided evidences showing that tropical insects undergo seasonal changes in abundance at least for those parts of the tropics where wet and dry seasons alternate (Davis, 1945). Denlinger (1980) pointed out that seasonality is a conspicuous feature in the life history of many organisms. In areas with pronounced dry season, such as most of the Panama, the abundance of most insects in the season is relatively low. In areas with a very mild dry season, such as Sarkawak, insects decrease in abundance during the wetter season (Fogden, 1972). Janzen (1973) reported an area with mild dry season in Costa Rica, a sweep net sample of insects taken in the season contains more insects than such a sample from the wet season.

According to Owen (1972), in the humid tropics of West Africa adults of many species of terrestrial insects occur in all months of the year, but with seasonal peaks of abundance that are associated with the alternation of wet and dry seasons. In an area where there is a well-defined dry seasons the onset of the rains often results in an enormous increase in the numbers of species that have occurred at low frequencies thorough out the dry season. This means that a several-fold increase in total abundance of a group of insects is not necessarily the consequence of an increase in the number of species (Owen, 1969).

There is evidence which suggests that the different pattern of seasonal changes in species diversity in the tropics is determined by the tendency of tropical species to breed through out the year, whereas each temperate species tends to have a well defined restricted and predictable breeding season (Owen, 1969). This is not to suggest that in the tropics all times of the year are equally suitable for breeding: indeed, with a few exceptions, it appears that although each species can potentially breed throughout the year the probability of breeding successfully fluctuates markedly with the season (Owen, 1969).

Denlinger (1980) explained that in the tropics, temperature changes are slight and seasonal changes in rainfall exert the most dramatic effect on the environment. Rainfall patterns, however, can vary greatly from year to year, and for some organisms low rainfall is not likely to present as severe an obstacle as winter in a temperate zone. Thus, for some tropical species development appears to be Aseasonal or continue over a prolonged period (MacArthure, 1972). Yet, many other tropical species are highly seasonal, perhaps as a response to close packing of competitors and to the selection of seasons that are best suited for active development (MacArthure, 1972).

According to Tanka and Tanka (1982), in addition to the broad seasonal changes in arthropod numbers and biomass, several interesting within-season fluctuation in arthropod abundance were evident. In their study of arthropods in oceanic islands, they found out that there was a lag in the response of the insects to the onset of the wet or dry season. During the early part of the dry season, arthropod biomass and abundance were comparable to the wet season’s average, and during the first weeks of the wet season, the numbers and biomass of arthropods were similar to the average for the dry season. Comparable fluctuations in abundance of tropical insects within seasons have also been found in studies where regularly taken through the wet and dry seasons (Shelly, 1988). Wolda (1977) found out that most homopterans on Barro Colorado Island in Panama started to decrease well before the end of rainy season. A mid wet – season decline of other groups of insects also occurred on Barro Colorado islands, during this decline sampling revealed fewer insects than in the dry season (Robinson and Robinson, 1970). The major problem that insects face during the dry season is the maintenance of water balance and several studies of tropical insects’ seasonality have suggested that wet season increase in insects numbers are primarily caused by increased precipitation (Bates, 1945).

The conspicuous absence of selected insect groups at certain times of the year suggests that many tropical insects like their temperate zone relatives, have developed strategies to escape a particular season. Restricted periods of abundance may be dictated by periodic food supply as well as advantages in predator avoidance and enhancement of mating success (Denlinger, 1980). Migration into more suitable environments offers a viable strategy for maintaining a continuously active population, but seasonal occurrence of a species in a particular area could also be achieved by coordinating periods of dormancy and development with appropriate environmental signals.

3.1.2. Habitat specificity

It is readily accepted that animal communities contain specialized, similar species, with narrow environmental niches. In 1967, MacArthur and Wilson explored the niche compression hypothesis, which states that as species become “packed” into a community, the habitat occupied by each species shrinks. Herbivorous insects had been seen to be associated with habitats. A number of reasons have been put forward for both higher and lower host specificity of herbivores in the tropics (Janzen, 1973: Prince, 1997). For example, the resource fragmentation hypothesis states that higher diversity leads to lower population densities for individual species and hence less host specificity, as the most specialized species are unable to maintain themselves on the most fragment resources (Godfray *et al*., 1997). Alternatively, it has been suggested that the intense biotic interactions characteristic of the humid tropics will select for greater levels and diversity of chemical defenses by plants, and this will tend to lead to greater specialization (Vane-Wright, 1978).

There have been enormous studies and illustrations of insect habitat specificity. Basset (1996) found 94 different species of herbivorous leaf chewing insects in a single tree in New Guinea, demonstrating high insect specialization, species richness and diversity. Similar studies by Marquis and Barker (1994) at La Selva, demonstrated a high specificity of butterflies and acridid grasshoppers in a wet tropical site, which allowed for diversity and species richness within a compact community. Strong (1977) found leaf hispine beetles codistribution with a large monocot, *Heliconia latishpatha*. These beetles are restricted to *Heliconia* in both larval and adult stages, and spend their entire lives on the host species. Satyamurti (1994) stated that Satyrides have preferences for shade and they frequent in bushes, grasses and dense undergrowths or in thick evergreen jungles. Sreekumar and Balakrishnan (2001a) reported the large agregation of Danaids on plants. They had also suggested the agregation of members of blue tigers and glassy tigers on *Crotalaria scabra* by sucking plant juice. Sreekumar and Balakrishnan (2001b) found out that *Idea malabarica* and *Papilio budha* species to be highly associated with evergreen forests.

Some of the researches do not support habitat association between herbivorous insects and plants. For example, Vane-Wright (1978) found that some floristically diverse islands had small butterfly fauna. Gaston (1992) extended this approach to all insects and again found no relationships between insect-to-plant ratio and plant species richness, although he stressed the problems with the available data and the preliminary nature of his analysis.

3.2. Environmental factors which affect insect diversity

According to Allan *et al.* (1973) the presence of insects at a particular habitat depends on a wide range of factors of which the availability of food and climatic conditions are the most important. Other than these, the abundance of larval food plants, conditions suitable for egg-laying and suitable flowers for feeding of adults, govern the distribution of insects. Further, the abundance of predators and parasitoids and the prevalence of disease also determine the abundance and density of insect populations (Pollard and Yates, 1993).

3.2.1. Rainfall

There is a positive relationship between arthropod abundance and rainfall (Tanka and Tanka, 1982). There is evidence that rainfall can directly influence arthropod abundance through physiological effects on reproduction, development, or activity. For example, rainfall is necessary for the initiation of breeding in diptera, such as shadflies (Chaniotis *et al*., 1971) and the emergence of the beetle *Heliocoris dilloni* from the soil in Kenya is initiated by rainfall (Kingstone and Coe, 1977).

Evidence from other studies of tropical insects suggested that rainfall might directly cause within season variations of insect activity or development. Wolda (1977) noted that the rainfall during the dry season on Barro Colorado Island initiated the activity and development of aestivating homopteran nymphs after time lags of three to five weeks. Rainfall initiated the development of the mosquito larvae *Haemagogus capricorni* during the dry season in Colombia which required two to three weeks (Bates, 1945). Rainfall provides a direct seasonal cue for mating in African termites (Leuthold and Burinsma, 1977).

Rainfall may indirectly affect insect population by its effect on food availability. Janzen (1973) suggested that herbivorous insects may cease reproduction because of a lack of suitable food. Rainfall has been shown to initiate leaf growth in lowland Neotropical forest sites with a severe dry season (Frankie *et al*., 1974). On the other hand, some insect groups are more evident during the dry season, when many tropical plants flower (Janzen, 1973; Robinson and Robinson, 1970). Chaniotis *et al.* (1971) stated that herbaceous insects such as homoptera and orthoptera may be responding to changes in vegetation affected by rainfall.

Wolda (1978a) noted that even minor variations in rainfall can cause important variations in leaf production on Barro Colorado Island and a minor leaf flush within increasing insect populations two to three weeks later. Tanka and Tanka (1982) had also noted that at the onset of rainy season, new leaf growth was not evident until two to three weeks later. The lag response between rainfall and certain groups of arthropod on Geranda to foliage was affected by rainfall patterns (Wolda, 1978a). Therefore, it is clear that seasonal fluctuations in rainfall modify the physical environment (Richards, 1952) and change resource availability for both plants and animals (Fogden, 1972), though data on the seasonal patterns of both the plant and animal portions of the tropical ecosystems are scarce (Wolda, 1978b).

It is well stated that insect abundance is closely linked to rainfall (Hillman and Hillman, 1977). But, rainfall cannot account for all the observed variability of insect abundance but it does contribute significantly. Williams (1964) suggested that seasonal distribution of many insect species maybe independent on rainfall. Denlinger (1980) in his studies of seasonal abundance of selected families of insects in Kenya stated that monitoring nine families of insects representing a diversity of life styles have been very informative. He reported that several families were consistently abundant at only one time of the year. For example, seasonality was much less consistent for grass hoppers, leafhoppers and parasitic hymenoptera. All three genera were well-represented through out the year. Their fluctuations in abundance were apparent within a single year, but the time of their peak abundance was not the same each year.

In his study of insect diversity in Kenya, among the nine taxa examined seasonal occurrence of only the Tabanidae could be partially attributed to rain fall of the previous three months. When cumulative rainfall of the previous three months was used as the independent variable, correlations were again insignificant for each taxon except the Tabanidae.

Tanka and Tanka (1982), on the other hand, suggested that the abundance of most of the groups of arthropods is significantly related to rainfall, with a time lag of three weeks. These scientists stressed that the lag response noted on a tropical oceanic island of their study area may be a general phenomenon among insects. Studies conducted in Texas supported the idea by showing significant correlation between arthropod abundance and precipitation during the preceding two weeks. But, the exact relationship between arthropod abundance and rainfall for both temperate and tropical areas is vague. Hence, it needs further investigation.

3.2.2 Food

Ross (1965) reported food as one of the most important factors influencing the distribution and abundance of insects. For many insect species it is a factor that has been changed radically by man's agriculture, travel, and transportation. According to Wolda (1978a) it seems likely that the seasonal presence of insect species is synchronized with seasonal presence of its food, if food availability varies seasonally. For foliage feeders, this means that they should usually be present when new leaves are produced. The apparent abundance of foliage in a forest does not necessarily imply an abundance of food (Feeny, 1970). Fogden (1972) found that the seasonal cycle of caterpillars and orthopteroid insects is well correlated with that of leaf production. He also found that parasitic hymenoptera increase during the caterpillar season.

Janzen and Schoener (1968) found a difference between areas in the abundance of insects associated with difference in the production of leaves and shoots in the dry season. During the season when most leaves are mature, the insects may depend entirely on the few new leaves available (Rockwood, 1974). And one might expect slight changes in leaf production especially during the off - season, to have a major effect on the demography of insects. Owen and Chanter (1972) noted the association of the larvae of *A. lycola* on *Poozotzia guineensis*, abundant plant which disappears in the dry season, and which is only readily abundant towards the end of the wet season. As a result, *A. lycola* is relatively common only at the end of the season, the time when the larval food plant is available. This clearly demonstrated the impact of food on insect abundance.

3.2.3. Elevation

Janzen (1973) in his study of the structure of tropical insect communities pronounced that the beetle bug and other insect components in sweep samples display definite changes in increasing elevation. Taking some insects as an example, Janzen (1973) found 122 species of ants between 750 and 2,200 mts elevation and only 3 species above 2,200 mts (none at 3,200 mts). In his world survey of high elevation ants, he listed 4 from Costa Rica, with all of them taken at 2,000 mts. On the other hand, ants are common at high elevations in temperate zones. Janzen (1973) listed 92 species of ants in 20 genera from above 2,130 mts in the Colorado Rocky Mountains. He further listed 30 species from 2,400 mts or more from the Himalayas and other temperate Asiatic localities. Mani (1962) also listed 12 common ant species in the Himalayas between 3,000 mts and 6,500 mts of equal interest, local inhabitants pointed out that there are no termites at the Vara Balnca and Cerro sites of Costa Rica (Janzen, 1973). Janzen (1973) also noted that termites were “very rare” in “cloud forests” at 1,100 mts in Venzuela. Elevation is a factor that limpidly affects insect abundance.

3.2.4. Temperature

Ross (1965) noted that in the lives of insects’ temperature is one of the most critical factors. Denlinger (1980) stated seasonal changes in temperature are important for tropical insects. Though in the tropics temperature changes are slight and seasonal changes exert the most dramatic effect on the environment. Bierne (1955), in analysis of the relationship between weather and the abundance of Lepidoptera suggested that warm, dry seasons were generally beneficial. Pollard (1988) noted in his study of butterflies that many species, such as *Maniola jurtina*, *Lycaen phalaeas*, *Polyommatus Icarus*, *Aricia agestis* and *Coenonyampha pamphilus,* may increase if summer temperature increases. Species such as *Aricia hyperantus* may not benefit from increased temperature, and indeed may decline in number, unless also rainfall increases. Matthee (1978) reported that high temperature induces egg diapause in the locust *Locusta paradalina*. Low temperature, on the other hand, triggers pupal diapause in flesh flies (Denlinger, 1974 and 1979). *P. malvae* and *E. tages* showed egg-laying tendency and larval survival in the warm season (Pollard, 1988). The difficulty of determining the effect of temperature was expressed by Pollard (1988) as the overall effect of weather on population trends will be complex and difficult to predict, let alone temperature.

3.2.5. Time of day

Contrast of day and night has also big impact on insect's diversity. In tropical zones, the most significant temperature fluctuations are not seasonal, but rather diurnal and nocturnal. The differences in temperature between day and night could also explain the diversity and species richness between diurnal and nocturnal insects, as the insects must expend more energy in order to adapt to the lower nocturnal temperatures (Huffaker and Gutierrez, 1999). Metabolic activities essential for development, feeding, dispersal, reproduction, and survival may all are impeded by the decrease in nocturnal temperature, which likely results in greater diurnal diversity, species richness, and abundance. Diurnal insects become more active when the sun heats their bodies, while nocturnal insects rely on stored body energy. Morris (1967) demonstrated that during colder seasonal temperatures, the webworm, *Hypahntria cunea's* development is retarded and the larvae must feed on older foliage, which forces a late emergence from the larval stage and a decreaseinnumbers.

Nocturnal foraging may also influence diversity and species richness. The "cost" of nocturnal foraging is greater in terms of calories used for flying, so the "rewards" must be higher (Prince, 1997). Heinrich (1979) illustrated the importance of maintaining sufficiently high body temperature to allow efficient flight. For example, a bumblebee cannot fly if its muscle temperature drops below 30 degrees Celsius. Foraging at night during cooler temperatures is usually performed by larger insects capable of temperature regulation (Prince, 1997), which has implications for nocturnal insects that do not benefit from solar radiation. Williams (1941) has also suggested that most insect's dry weight samples increase at night. This might be due to the capture of large insects at night.

There are also many factors that contribute to the diversity of insects. Photoperiod, an environmental token widely used in temperate zones, is not an obvious seasonal signal in the tropics, but is successfully utilized near the equator by the red locust *Nomadacris septempfasciata* as a signal for induction of adult diapause (Norris, 1965). Chemical changes in host plants provide triggers for larval diapause in the Lepidopteran, stem borers *Busseola fusca* (Usua, 1973) and *Chilo partellus* (Scheletes, 1978) and provide the cue for adult diapause termination in the desert locust *Schistocerca gregaria* (Carlisle *et al.*, 1965).

3.3. Insect Interactions

3.3.1. Insects and Plants

About half the species of insects feed on living plant substance and another one fourth eat decaying plant material and are usually put in a separate category of "saprophagous" insects (Lanham, 1964). Borror *et al*. (1992) supported the idea as insects that feed on plants probably outnumber those feeding on other things. They also recommended that there are very few terrestrial or freshwater plants that are not fed upon by some insects,and these insects feed in different ways and on different parts of the plants. Elzinga (1978) estimated that 50% of the insect species, especially during the immature stages, use living plant material for food.

The relationship between insects and plants is a curiously close one (Lanham, 1964). Based on Godfray *et al*. (1997) it has long been known that insect species richness correlates with plant species richness both at local and regional levels. Global diversity estimations for these insects have been made using plant species numbers as the predictor, assuming high degrees of host plant specificity (Erwin, 1982). Recent studies indicated that levels of host specificity may be lower than thought previously (Novotny *et al*. 2002). Most of the high values reported for plant species correlation at medium and large spatial scales are owing to similar response to environmental factors in the two groups and not to direct, casual relationships (Hawkins and Porter, 2003). Owen (1972) pointed out that there is an evolutionary aspect of the seasonality of insects and plants.

There is some direct and much indirect evidence that ecological differences between species minimize competition for resources that are in limited supply (Shannon, 1963). Ecological differences are, therefore, thought to reduce to some extent, competition between species. However, there are exceptions for example Vane Wright (1978) found that some floristically diverse islands had small butterfly faunas. Gaston (1992) extended this approach to all insects and again found no relationships between insect to plant ratio and plant species richness, although he stressed the problems with available data and the preliminary nature of his analysis. If anything, there was a tendency for the ratio to be lower in the tropics. Lanham (1964) emphasized the other aspect of plant-insect relationship. The aspect in which the mutually helpful, or symbiotic one; insects carry pollen, thus cross-fertilizing the plants, with the plants on their side contributing nectar and some of the pollen to insects. Lanham (1964) stressed that half or more of the species of plants depend on insects for sexual reproduction. More than 65% of the flowering plants are pollinated by animals such as insects, birds, snails and bats, but insects play the dominant role.

3.3.2. Insects and other animals

The relationship between insects and other amimals is predacious in both ways: insects feed on other animals, and other animals prey on them (Lanham, 1964). He underlined that insects come out second best, providing much more food for the rest of the animal world than they get back in return.

Borror *et al*. (1992) stated that a great many animals utilize insects as food. Whole groups of vertebrate animals base their economy on insects (Lanham, 1964). Janzen (1973) recommended the rainy season increase in insects resulted in qualitative changes in insectivore feeding behaviore. Borror *et al*. (1992) evidenced that many freshwater fish feed to a large extent on insects, particularly on such aquatic forms as mayflies, stoneflies, caddisflies, mosqutio larvae, midge larvae, and larvae of aquatic beetles. Stream fishes depend not only on the abundant aquatic insect life, but also on the insects that fall into the water from streamside vegetation (Lanham, 1964). Janzen (1973), on his side, reported the great abundance of small fish in Panamanian streams was due to washing of insects into the streams and large aquatic insect community. Most abundant amphibians, the frogs and toads are mainly insect eaters (Lanham, 1964). The realization that birds were predaceous on insects is ancient and 50 to 60% of the food of birds are insects (Elzinga, 1978). Borror *et al*. (1992) underlined that birds that feed largely or entirely upon insects have an aesthetic value because of their interesting habits, and they often have a practical value because they act as important predators of insect pests. *Ctenosaura* lizards, the large adults of which are vegetarian, oviposit at such a time that the insectivouros young are first found in the habitat shortly after the rains begin (Janzen, 1973). Borror *et al*. (1992) generalized the relationship as toads, frogs, lizards, bats, skunks, moles, and shrews feed largely or entirely on insects. This has big value in devising control methods. Elzinga (1978) recommended the treatment of the soil for beetle grubs to control moles, the reasoning being that once the primary source of food is eliminated these insectivores either starve or migrate to other areas.

3.3.3. Insects and Humans

People benfit from insects in many ways; without them, human society could not exist in its present form (Borror *et al.*, 1992). Insects provide humans many useful products, such as honey, bees-wax, silk (Matheson, 1960; Borror *et al.*, 1992; Elzinga, 1978). For centuries people have used insects or their products as medicinal agents (Borror *et al.*, 1992). Scientific research and aesthetic value of insects are also significant (Borror *et al*., 1992; Matheson, 1960). Insects are also the great scavangers of the land (Matheson, 1960). Such insects assist in converting decomposing plants, animals and dungs into simpler substances that are returned to the soil, where they are available to plants, they also serve to remove unhealthful and obnoxious materials from our surroundings (Borror *et al*., 1992). Although largely ignored by the “civilized” western world, insects are good source of food for humans (Elzinga, 1978). The Arabs eat locusts (Borror *et al*., 1992). In certain parts of Africa ants, termites, bettle grubs, caterpillars, and grasshoppers are eaten (Elzinga, 1978). Elzinga (1978) stressed that a change in our thinking is needed in order to use insects to feed a portion of the growing human population, but this change is not anticipated in the near future. On the other hand, there are a few thousand species of insects that are injurious to humans (Matheson, 1960; Borror *et al.*, 1992; Elzinga, 1978; Horn, 1978). Most of the major diseases caused by insects have had a profound effect upon human civilization (Elzinga, 1978). He evidenced the plague which has killed 25% of all Europeans in 1348 A.D.. Insects are also the cause of damage of humans stored products, fabrics, crops (Matheson, 1960; Borror *et al.*, 1992; Elzinga, 1978; Horn, 1978).

3.3.4. Insects and Insects

Insects worst enemies are themselves (Lanham, 1964). He further noted that of the nearly one quarter of a million known species that eat animals instead of plants, most feed on other insects. Borror *et al.* (1992) classified entomophagous insects into two general groups: predators and parasitoids. The larvae of many famillies of Hymenoptera (Inchenumonidae, Chalcididae, Scelionidae, and many others) and a few families of Dipteran (Pyrgotidae, Tachinidae) are entirely endoparasite on insects or closely related allied arthropods (Ross, 1965). A great many insects are predaceous on other insects (Borror *et al.*, 1992). Carabidae and Staphylinidae are two very large beetle families that feed in both adult and larval stages almost exclusively as predators on other insects (Ross, 1965). Borror *et al.* (1992) coined the term insect hyperparasites-insects that parasitize another insect. Lanham (1964) generalized the relationship among insects as probably every species of insect in existence has one or more enemies.

4. MATERIAL AND METHODS

4.1. DESCRIPTION OF THE STUDY AREA

4.1.1. Menagesha forest

The study areas were Menagesha forest and Bihere Tsige Public Park. Menagesha forest is found at immediate outskirt of Menagesha town. Menagesha is located at 18 kms North West of Addis Ababa and 7 km from Holeta town between 38˚33’59 E latitude and 9˚03’00 N longitude (Fig 1). To the south, Mount Wechecha and Mount Medehanialem border the forest. Wellmera and Sademo form the border to the west. To the East, the forest is bordered by Gefersa. The northern part of the forest is bordered by Kolobo village. The nearest town to Menagesha forest is Holeta.

4.1.1.1. Climate

The climate of Menagesha forest experiences a regime of two rainy seasons, the short rains occur between March and May, and the long rains from June to September. However, unexpected showers may occur in all months of the year with a mean annual rainfall of about 1150 mm. Temperature of the forest area ranges from 11 to 22˚C. The hottest months are May and June, while the coldest months are December and January. Because of differences in altitudes, variation in precipitation and temperature is noted from place to place in the forested area.

4.1.1.2. Topography

The forest area has an altitude of 2,500 m.a.s.l. The parts of the forest are majorlly composed of flat lands inhibited by forests. But, some part of the forest is composed of steeper gradients, especially the one inhibited by bushes and big trees. The forest is also characterized by a single river which goes through much of the forest area. The river is seasonal.

4.1.1.3. **Vegetation**

The major plant species of the forest includes: *Juniperus procera*, *Acacia abyssinica*, *Croton macrstachyus, Euclaptus globules,Olea africana ,Prunus africanus, Sagertiathea, Casaurina spp.*, *Schinnus molle, Cordia africana, Hagenia abyssinica Iris germanica, Osyris quadripartita, Hyparrhenia spp., Cyndon spp., Rubus spp., Mytenus spp., Carduus pychocephalus* (Friis, 1995).

4.1.2. Bihere Tsige Public Park

Bihere Tsige Public Park is located in south eastern part of Addis Ababa. It is located between 38˚45'12 E latitude and 8˚57'14 N longitude (Fig. 2). The park is a part of the Nifas-Silk-Lafto sub-city. Akaki-Kaliti sub-city borders it in the east. Lideta and Kirkos sub cities border it to the south. Bole sub city shares border in the north.

4.1.2.1. **Vegetation**

The park is characterized by various types of vegetation. The vegetation of the park has great value interms of fulfilling the recreational objective of the site. It is composed of large trees, grasses and herbaceous plants. The most commonly occurring plants were: *Ficus ovata, Podocarpus falcatus, Gravillea robusta, Mimosa pigra, Phoenix reclinata, Eribotrya japonica, Spathodea nilotica, Rosa sinensis, Jacaranda mimsofolia, Ficus vasta, Cactus spp., Sedum spp., Rosa abyssinica, Allophylus abyssinicus, Iri germanica, Dracaena stunderi, Cestrium auranticum ,Juniperus procera, Acacia abyssinca, Croton marcostachycus, Euclaptus globulus, Olea africana, Prunus africanus, Casaurina spp., Schinnus molle*, *Cordia africana, Hagenia abyssinica* (Friis, 1995).

4.1.2.2. Topography

The public park understudy is relatively flat with an altitude of 2,202 m.a.s.l. There is only one major river that crosses the park. The River is highly polluted and cannot be a good source of water for the park. Since the main purpose of the park is recreation, most part of the area is leveled manually.

4.1.2.3. Climate

The park shares the same climatic characteristics as that of Addis Ababa. The climate is categorized as Warm Temperate Climate I which has a distinct dry month in winter. The mean temperature of the coldest month is below 18˚C, and for more than four months the site could have mean temperature of greater than 10˚C. Rainfall distribution and amount varies considerably from area to area. In areas of heavy rainfall, forests predominate while grass covers the areas of moderate rainfall. The hottest month is May with an annual temperature of 17.9˚C, while the coldest month is December with an annual average temperature of 14.8˚C.

4.2. Materials

Materials used during the study include Camera, notebooks, rulers, data sheetes, binocular microscope, topographic maps, insect sweeping nets, wooden insect collection boxes, pins, collecting jars and chloroform.

4.3. Methods

4.3.1. Selection of the study area

Wet season study was carried out from 7 July 2006 to September 28, 2006. While dry season study was carried out from 18 November 2006 to 27 January 2007. Following Balakrishnan and Esa (1986), Sreekumaar and Balakrishnan (2001), Denlinger (1980), and Tanka and Tanka (1982), the study areas were divided into six categories (Three in the park and the other three in the forest area) based on the habitat types. The forest study area was divided into: artificial forest (entirely dominated by eucalyptus tree), grassland and natural forest. The park study area, on the other hand, was categorized into: Grassland, flowers and grass mixed vegetation and mixed vegetation.

4.3.2 Data Collection

Transect walk and quadrant methods were used for sampling. Six transects, each of 0.1 km lengths with three quadrates on each of them were marked through different habitats in the study areas. Three of the transects were laid in the three categorized habitats of the forest. The other three transects were marked in the different habitats of the park. Eighteen quadrates in the park and the forest, each having a size of 10 x 10 m^2 in six transect lines were sampled at random. All actual sampling was done each month once from July to January. Time of sampling was relatively evenly distributed between 16:00-17:00 hrs. Sampling could not be restricted to sunny weather because in some months sunshine was rare, but no sampling was done in the rain. Samples were taken from one of the three quadrants of each transect line in each vegetation type in every month from the study areas. Insect samples were collected with 0.38 diameter sweep net constructed of muslin with finmesh net at the tip. Each sweep represented a horizontal swing with an arc of approximately 135 degrees and height between 0.5-2.00 mts above the ground. Then, the contents of the net were emptied into one liter killing jar with chloroform soaked sponge in it after series of three sweeps. The insects collected were taken to Addis Ababa University, Entomology laboratory to be sorted, counted and placed into various taxa with the help of binocular microscope. All insects were identified to family level using the identification key of Borror *et al.* (1992). Besides, the books, different drawings of insects, specimens of insects in museums were used as means of identification of insects collected in the field.

4.3.3. Data analysis

The diversity of insects was determined by Shannon-Weaver index and Simpson's diversity index. High number of Shannon Weaver index indicates high diversity whereas low value of Sampson's diversity index indicates high diversity.

H'/H max = Evenness

Where, H'= Shannon-weaver value

H max = ln S (S = family number examined)

Simpson's diversity index (Simpson, 1949) was used to determine the diversity among insects and their habitats.

Simpson's Index (D) = ∑ (n/N) 2

Where, n = the total number of organisms of a particular family

N = the total number of organisms of all family.

Insect family richness was calculated by Margalefs richness index (MRI). Large numbers indicate high diversity.

Margalefs Richness Index (**MRI) = S-1/lnN**,

Where, S = Total number of families observed and

N= Total number of individuals observed in all quadrates.

The similarity of insects in different habitats were determined by

Jaccard index (Cj) = j / (a+b-j)

Where, j = the number of families found in both sites

a = the number of families in site A

b = the number of families in site B.

SPSS computer programme was used for Chi-square analysis to test the association of insects and their habitats. Variation in abundance of insects in wet and dry seasons of the study areas was computed by t test. Family abundance (the ratio between total number or individuals of a family in all study plots and total number of sample units in which the family observed), Frequency (the ratio of quadrates of occurrence and total number of quadrates studied), Distribution (the ratio between abundance and frequency) was computed to analyze the diversity of insects in the forest and the park.

5. RESULTS

5.1. Diversity of insects in Menagesha forest and Bihere Tsige Public Park.

Insect diversity in Menagesha forest is shown in Table 1. The highest diversity of insects in Menagesha forest was observed in the natural forest in wet season. On the other hand, artificial forest holds the largest diversity in the dry season of Menagesha forest. Artificial forest habitat has the highest diversity of insects in both seasons in Menagesha forest. The most even distribution of insects in both seasons was that of the natural forest habitat.

Table 1. Insect diversity in Menagesha forest in 2006/07.

Seasons	Habitat types	Number of individuals	H'	H'/Hmax	D
Wet season	Grassland	119	1.79	0.63	0.23
	Artificial forest	55	1.89	0.78	0.15
	Natural forest	54	2.02	0.84	0.15
Dry season	Grassland	81	1.73	0.75	0.21
	Artificial forest	50	2.25	0.89	0.10
	Natural forest	71	1.88	0.81	0.13
Both seasons	Grassland	200	1.98	0.66	0.21
	Artificial forest	105	2.14	0.72	0.096
	Natural forest	125	2.10	0.74	0.12

Note: - H'= Shannon Wiener Index of diversity

H'/H max = Evenness.

D = Simpson's diversity index

Insect diversity in Bihere Tsige Public Park is shown in Table 2. Flowers and grass mixed vegetation has the most diverse insect family in the wet season. In the dry season of the park, the highest diversity of insects was recorded in grassland habitat. Taking both seasons into consideration, diversity of the flower and grass mixed vegetation stood first. In terms of evenness, mixed vegetation habitat has been proved to be the first. Sampson's diversity index supported Shannon weaver index in indicating diversity of insects.

Table 2. Insect diversity in Bihere Tsige Public Park in 2006/07.

Seasons	Habitat types	Number of individuals	H'	H'/Hmax	D
Wet season	Grassland	117	1.62	0.65	0.25
	Flowers and grass mixed	112	2.16	0.76	0.14
	Mixed vegetation	55	2.06	0.80	0.11
Dry season	Grassland	86	2.02	0.81	0.13
	Flowers and grass mixed	116	1.88	0.78	0.14
	Mixed vegetation	39	1.78	0.91	0.15
Both seasons	Grassland	203	1.77	0.62	0.19
	Flowers and grass mixed	228	2.28	0.75	0.13
	Mixed vegetation	94	2.18	0.78	0.11

Note: - H'= Shannon Wiener Index of diversity

H'/H max = Evenness.

D = Simpson's diversity index

5.2. Similarity and Species richness of insects in Menagesha forest and Bihere Tsige Public Park.

Similarity in distribution of insects in Menagesha forest is shown in Table 3. In the wet season the most similar habitats of Menagesha forest were artificial forest and grassland vegetation. In the dry season, however, natural forest and grassland vegetation shared the highest similarity. In both seasons, the most similar families were recorded between natural and artificial forest. The least similar habitats in both seasons were observed between artificial forest and grassland vegetation.

Table 3. Similarity in distribution of insects in Menagesha forest in 2006/07.

			Habitat types	
Seasons		Natural	Grassland	Artificial
Wet season	Grassland	0.21		0.57
	Artificial	0.36	0.57	
	Natural		0.21	0.36
Dry season	Grassland	0.64		0.54
	Artificial	0.50	0.54	
	Natural		0.64	0.50
Both seasons	Grassland	0.45		0.43
	Artificial	0.55	0.43	
	Natural		0.45	0.55

High values indicate high similarity in distribution of insects.

Similarity in distribution of insects in Bihere Tsige Public Park is shown in Table 4. The most similar habitats of the wet season of Bihere Tsige Public Park were flower and grass mixed vegetation and mixed vegetation. In the dry season, the highest similarity of families was recorded between flowers and grass mixed and grassland habitats. In both seasons, the highest similarity was recorded between flower and grass mixed vegetation and grassland. Grassland and mixed vegetation share the lowest similarity index in both seasons.

Table 4. Similarity in distribution of insects in both seasons in Bihere Tsige Public Park.

		Habitat types		
Seasons		Grassland	Flowers and grass mixed	Mixed vegetation
Dry season	Grassland		0.48	0.36
	Flowers and grass mixed	0.48		0.60
	Mixed vegetation	0.36	0.60	
Wet season	Grassland		0.69	0.31
	Flowers and grass mixed	0.69		0.22
	Mixed vegetation	0.31	0.22	
Both seasons	Grassland		0.47	0.36
	Flowers and grass mixed	0.47		0.37
	Mixed vegetation	0.36	0.37	

High values indicate high similarity in distribution of insects.

Table 5 demonstrates the MRI values of insects in various habitats of Menagesha forest. The most preferred habitat by the order Orthoptera was grassland. Artificial and natural forests were devoid of Orthoptera. Hymenopterans were observed in all habitats with MRI value ranging from 0.28 in grassland vegetation to 0.85 in artificial and natural forest. The only habitat where the order Odonata were recorded was the grassland vegetation.The order Lepdoptera was recorded in artificial habitat with low MRI value of 0.57. In the grassland, the MRI value of Lepidoptera was 1.71. Coleopterans were seen in grassland vegetation with a MRI of 1.14 and in artificial forest with a MRI value of 0.85.

Table 5. Margalef´s richness index of insects in various habitats in Menagesha forest.

	Habitat types		
Insect orders	Grassland	Artificial forest	Natural forest
Orthoptera	0.28	0	0
Hymenoptera	0.28	0.85	0.85
Odonata	0.28	0	0
Lepidoptera	1.71	0.57	1.42
Coleoptera	1.14	0.85	0
Diptera	0	0.25	1.14

High values indicate high richness of insects.

The MRI values of the insect orders recorded in Bihere Tsige Public Park are shown in Table 6. The order Orthoptera was seen only in grassland habitats. Flowers and grass mixed vegetation and Mixed vegetation were devoid of Orthopterans.The order Hymenoptera was observed in all the three habitats with MRI values of 0.56 in grassland, 0.54 in mixed vegetation and 0.84 in Flowers and grass mixed vegetation. Flowers and grass mixed vegetation was the only preferable habitat for the order Coleoptera. The MRI value of Lepidoptera in grassland and Mixed vegetation is 0.56. Flowers and grass mixed vegetation was highly dominated by the order Lepidoptera. The MRI values of Diptera ranges from 0.56 to 1.40. The maximum MRI value of Diptera was recorded in a mixed vegetation habitat whereas it had a minimum MRI value in the grassland habitat.

Table 6. Margalef´s richness index of insects in various habitats in Bihere Tsige Public Park.

		Habitat types	
Insect orders	Grassland	Flowers and grass mixed vegetation	Mixed vegetation
Orthoptera	0.28	0	0
Homoptera	0	0	0
Hymenoptera	0.56	0.84	0.54
Coleoptera	0	0.84	0
Lepidoptera	0.56	1.68	0.56
Diptera	0.56	0.84	1.40
Odonata	0	0	0

High values indicate high similarity in distribution of insects.

5.3. Frequency and abundance of insects in Menagesha forest and Bihere Tsige Public Park.

Thirty three families of insects in Menagesha forest and thirty five families in Bihere Tsige Public Park were recorded. Frequency, abundance and distribution of these insects are shown in Tables 7 and 8. The most dominant family in Menagesha forest was Acrididae. Acrididae was also the most frequently found family in the forest. The highest distribution in the forest was recorded for the family Gryllarcrididae. Acrididae was the most abundant family in Menagesha forest. Acrididae and Cixiidae were the two most dominant insect families in Bihere Tsige Public Park. In the park, frequent occurrence of Lycaenidae was observed. Acrididae was highly abundant in the park. The widest distribution was recorded for the family Danaidae. In terms of order, the highest number of insects was recorded for the order Orthoptera in Bihere Tsige Public Park wet season and Menagesha forest wet season. On the other hand, Lepidoptera was the order with the highest number of insects in the dry season of both Menagesha forest and Bihere Tsige Public Park (Fig. 3).

Table 7. Frequency, Abundance and Distribution of insects in Menagesha forest.

Family name	Number of insects	Frequency	Abundance	Distribution
Acrididae	143	0.98	23.8	23.9
Aeshnidae	3	0.16	3	18.75
Apidae	8	0.16	8	5
Andrenidae	6	0.33	3	9.09
Apoidae	14	0.33	7	21.2
Bombinae	4	0.16	4	25
Bombyliidae	4	0.16	4	25
Cephidae	2	0.16	1	1.60
Coenagrionidae	13	0.66	3.25	4.90
Carabidae	9	0.66	2.25	3.40
Chalcididae	1	0.16	1	6.25
Danaidae	4	0.60	6.25	10.4
Endomychidae	1	0.33	2.50	7.57
Gelechiidae	1	0.16	1	6.25
Gryllacrididae	17	0.16	17	106.25
Gracillariidae	4	0.16	4	25
Gomphidae	1	0.16	1	6.25
Hesperiidae	6	0.50	2	4
Muscidae	29	0.66	7.25	10.9
Oestridae	4	0.16	4	25
Pieridae	28	0.50	9.30	18.6
Pyralidae	4	0.50	1.33	2.66
Nymphalidae	16	0.33	8	24.2
Scolyitdae	1	0.16	1	6.25
Scarabaeidae	9	0.50	3	6
Syrphidae	21	0.50	7	14
Sciomyzidae	2	0.16	2	12.50
Sessidae	4	0.16	4	25
Tenobrionidae	4	0.16	4	25
Tephritidae	2	0.16	2	12.50
Lycaenidae	25	0.60	6.25	10.40
Formacidae	34	0.66	8.50	12.80

Table 8. Frequency, Abundance and Distribution of insects in Bihere Tsige Public Park

Family name	Number of Insects	Frequency	Abundance	Distribution
Acrididae	138	0.83	27.6	33.2
Braconidae	4	0.16	4	25
Coenagronidae	14	0.50	4.6	9.2
Lycaenidae	22	0.98	22	22
Carabidae	25	0.66	1.25	1.89
Challiphoridae	16	0.50	5.3	10.6
Oestridae	1	0.16	1	6.25
Cixiidae	77	0.66	19.25	29.1
Pieridae	44	0.66	11	16.6
Apidae	42	0.66	10.5	15.9
Sphecidae	11	0.66	2.75	4.16
Bruchidae	1	0.16	1	6.25
Inchenumonidae	1	0.16	1	6.25
Eupelmidae	1	0.16	1	6.25
Scarabaeidae	6	0.16	6	37.5
Endomychidae	1	0.16	1	6.25
Pyralidae	8	0.33	4	12.1
Syrphidae	6	0.33	3	9
Scathophagidae	2	0.16	2	12.5
Psychidae	2	0.16	2	12.5
Tortricdae	2	0.16	2	12.5
Hesperiidae	15	0.33	7.5	22.7
Tettigoniidae	3	0.16	3	18.75
Anthophoridae	4	0.16	4	25
Tachinidae	1	0.16	1	6.25
Sarcophagidae	1	0.16	1	6.25
Rhagionidae	1	0.16	1	6.25
Muscidae	31	0.66	7.75	11.7
Paccnnodae	3	0.16	3	18.75
Margarodidae	1	0.16	1	6.25
Tipulidae	1	0.16	1	6.25
Danaidae	32	0.33	16	48.4
Apoidae	6	0.33	3	9
Saturniidae	1	0.16	1	6.25
Nymphalidae	1	0.16	1	6.25

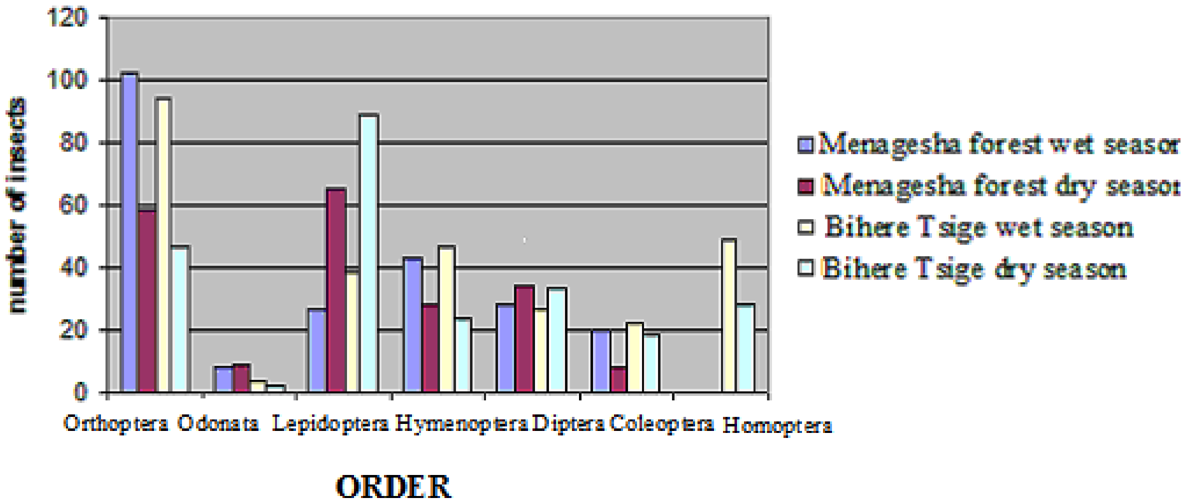

Figure 3. Diversity of insects in Menagesha forest and Bihere Tsige Public Park in wet and dry seasons.

5.4. Habitat association of insects in Menagesha forest and Bihere Tsige Public Park.

Habitat association of insects in Menagesha forest is shown in Table 9. Wet season result of Menagesha forest indicated high significance difference showing the existence of interaction between insects and the vegetation use. The total habitat association value of the wet season was $x^2 = 467.27$, $P < 0.01$. In this season the highest habitat association was obtained in the Grassland habitat. Significance difference between the insects and habitat usage $x^2 = 178.82$, $P < 0.02$ was obtained in dry season in Menagesha forest. Grassland was again the preferred habitat in this season. In both seasons of the forest, high significance difference was observed with $x^2 = 999.12$ and $P < 0.01$ values. Grassland vegetation was preferred by insects in both seasons.

Table 9. Habitat association of insects in Menagesha forest.

		Habitat types		
Seasons		Grassland	Artificial forest	Natural forest
Wet season	Chi-square	373.00	45.60	48.67
	df	16.00	10.00	10.00
	Significance Value.	0.00	0.00	0.00
Dry season	Chi-square	104.55	23.44	50.83
	df	9.00	11.00	9.00
	.Significance Value.	0.00	0.01	0.00
Both seasons	Chi-square	685.80	150.32	163.00
	df	19.00	18.00	16.00
	Significance Value.	0.00	0.00	0.00

Habitat association of insects in Bihere Tsige Public Park is shown in Table 10. In the wet season in Bihere Tsige Public Park, significance difference between habitat usage and insect families with $x^2 = 490.75$ and $P < 0.01$ was obtained. Most insects in this season were positively associated with Grassland habitat. In the dry season of Bihere Tsige Public Park, insects habitat association showed no significance difference with $x^2 = 171.99$ and $P < 0.2$. In both seasons of the Public Park, High significance difference was evident between insects and habitat usage with $x^2 = 1000.34$ and $P < 0.01$ values. Grassland was the most preferred habitat in both seasons.

Table 10. Habitat association of insects in Bihere Tsige Public Park in all seasons.

Seasons		Habitat types Grassland	Flowers mixed with grass	Mixed vegetation
Wet season	Chi-square	261.15	187.93	41.67
	df	11.00	16.00	12.00
	Significance Value.	0.00	0.00	0.00
Dry season	Chi-square	66.93	96.60	8.46
	df	11.00	10.00	6.00
	Significance Value.	0.00	0.00	0.20
Both seasons	Chi-square	494.34	413.79	92.21
	df	16.00	20.00	15.00
	Significance Value.	0.00	0.00	0.00

T-test result of the comparison of Menagesha forest wet and dry seasons insect abundance was not significant with $t = 4.91$ and $p = 0.128$ values. Wet and dry season abundance variation in Bihere Tsige Public Park was not also significant with $t = 7.26$ and $p = 0.087$ values. Wet season of Menagesha forest and wet season of Bihere Tsige Public Park had non-significant variation of insect abundance with $t = 7.89$ and $p = 0.08$. The dry seasons of Menagesha forest and Bihere Tsige Public Park are significant in terms of insect abundance with $t = 16.84$ and $p = 0.038$ values.

6. DISCUSSION

Sweeping alone can not sample the entire insect community but only the sub community active in the vegetation in the height zone can be sampled (Janzen and Schoener, 1968). Among the insects that live on the upper parts of the plants, the highly mobile species, such as the butterflies, larger diptera and hymenoptera, are likely to have escaped collection (Porches and Cowling, 2006). It could also be argued that sweeping is not consistently efficient across different vegetation types (Janzen, 1973). Further differences could result from the levels of insect activity at the various collection periods, which can be minimized by collecting under similar weather conditions. In addition, the general thinning of the foliage during the dry season makes sweeping relatively easy because of reduced entanglement in Vines and dense patches of leaves (Janzen and Schoener, 1968). Some species of insects, especially those in the Chrysomelidae (Coleoptera), and Membracidae and Cicallidae (Homoptera), are occasionally clustered on a single plant host; if the net hits this plant, the species becomes common in the sample, but if the net misses, the species is likely to be rare or absent (Janzen and Schoener, 1968). Nevertheless, these limitations cannot seriously affect the insect patterns observed (Proches and Cowling, 2006). This is because the errors are roughly proportional in each area (Janzen and Schoener, 1968).

Fluctuation of insect abundance was evident both in Menagesha forest and Bihere Tsige Public Park in wet and dry seasons. The causes of fluctuations in insect abundance and the differences among species are still not completely understood. There are probably both biotic and abiotic factors responsible for the phenomenon (Pinheiro *et al*., 2002). However, Wolda (1980) gave some reasons for insect seasonality. The reasons include macroclimatic and microclimatic changes, and variation in the availability of food resources. Wolda (1978a) proposed two general hypotheses to explain the variability in abundance of tropical insects: climatic predictability and seasonal variation of food resources. The former suggests that populations should fluctuate less in areas where the climate is more predictable. The latter hypothesis implies that insect numbers should be directly related to seasonal variations in the abundance of food resources. Previous studies conducted in tropical areas have shown a similar increase in insect abundance in the wet season as seen in this study for certain orders of insects. Many tropical insects have their highest abundance in the wet season; for example, *Drosophila* in Brazil (Dobzhansky & Pavan, 1950), tree insects in Costa Rica (Boinski & Scott, 1988; Boinski & Fowler, 1989), several groups of insects in Panama (Ricklefs, 1975; Wolda 1978a and b; Shelly, 1988), Granada (Tanaka & Tanaka, 1982), Australia (Frith & Frith, 1990) and Kenya (Denlinger, 1980). As it is also evident in this study, Tanaka and Tanaka (1982) in the study of arthropods in oceanic islands found out that the arthropod fauna in Granada appear to be generalists, with the same communnity compostion between the wet and dry seasons. The reason behind the conspicous absence of selected insect groups at certain times of the year was explained by Tanaka and Tanaka (1982) as many tropical insects, like their temprate-zone relatives, have developed strategies for escape during particular seasons. Restricted periods of abundance may be dictated by periodic food supply as well as advantages in predator avoidance and enhancement of mating success. Denlinger (1980) evidenced the most important factor for insect flactuation in wet and dry seasons is rainflall. Rainfall may directly affect insect populations (Janzen, 1973). It has also an indirect effect (Chaniotis *et al*., 1971). Even minor varitaions of rainfall can cause important crucial variation in leaf variations (Wolda, 1978a). Though rainfall contribute for insect abundance and flactuations significantly, it can not be responsible for all of the observed flactuations (Tanaka & Tanaka, 1982). Each taxon could respond differently relative to the seasons, so that the effects of the wet or the dry season could be reflected in numeric responses in arthropod populations (Pinheiro *et al*., 2002). Studies conducted in temperate areas, such as Texas, USA, demonstrated a positive correlation between the abundance of arthropods and the precipitation levels during the 2 weeks that preceded the insect peak (Dunham, 1978). In the savannas of Kenya, the relationship between the rains and insect abundance was shown to be quite clear for some species, but for many other species, abundance was independently distributed relative to the rains (Denlinger, 1980). This paper is also an evidence for the relative increament of insect richness in the wet season. Supporting the previous findings by others,however, the current study did not generate sufficient data to see the association of climatic factors and insect flactuation since the study was conducted for the short period of time.

6.1. Insect diversity in Menagesha forest

In the wet season of Menagesha forest high diversity and eveness were observed in natural forest due to stability and easy availability of larval food. This result is in agreement with that of Sreekumar and Balakrishnan (2001a) where the prevalence of butterfly species at a particular habitat depends on a wide range of factors, of which the availability food is the most important. In this same wet season, grassland vegetation was found to be the least diverse habitat. Plant diversity and structure affect the viability of many species of terrestrial invertebrate populations (Warren *et al*., 1997). The grassland in this season was dominated by phytophagous grasshoppers and leafhoppers. In the dry season of Menagesha forest, artificial forest was evident to have high diversity of insects. This is due to less exposure of the artificial forest to cattle grazing in comparison to grassland vegetation. Sreekumar and Balakrishnan (2001a) suggested that the disturbances in the form of cattle grazing may cause a decline in the abundance of insects in certain habitats. Moreover, Kunte (1997) pointed out that grazing and forest fire have serious impacts on butterfly populations as cattle overgraze palatable species which would be the larval food plants of some butterflies. Artificial forest of the study area was highly exposed to fuel wood collection which affected insect diversity. But, the local people collected fuel wood in the form of shed leaves from the ground which had minimal effect on flying insects.

The most similar vegetations of Menagesha forest in the wet season were artificial forest and grassland vegetation. This is because they had more or less similar structure of the vegetation with stratification and canopy cover (Sreekumar and Balakrishnan, 2001b). In the wet season of the forest there was higher precipitation, which in turn could have caused quite important variation in leaf production, hence, food for herbivores (Wolda, 1978a). The precipitation has, therfore, intitiated enormous amount of grass in both habitats. This as a result increased phytophagous insects in grassland vegetation and artificial forest. In the dry season, however, the most similar habitats were natural forest and grassland vegetation. Human activities in natural and artificial habitats are known to cause depletion of animal diversity (Joseph and Balakrishnan, 2005). Artificial forest in the dry season was exposed to human activities. Local people searching for fuel wood had almost removed the grass cover in the artificial forest. On the other hand, the natural forest was far from human activities which helped it to retain its grass cover. Grassland vegetation and natural forest had, therfore, shared the same vegetation (grass) and thus shared phytophagus insects in the dry season.

Both in the dry and wet season Menagesha forest grassland vegetation was preffered to other habitats. Diversity of insects in an area depends primarily on the availability of mixed plant species, which constitute their major food resources (Mathew and Rahmathulla, 1993). Heterogeneity of the habitat is the main reason for species richness (Sanjayan, 1993). Thomas (1995) reported that as habitat specificity of butterflies can be directly related to the availability of food plants. Each habitat has a specific set of micro environment suitable for a species (Sreekumar and Balakrishanan, 2001a). In grassland vegetation, most habitat specific insects had to be phytophagous insects which made them suitable in utilizing the grass nutriton. Some insects might not be habitat specific at all. Such general occurrence would help them to have a wider distribution and to maintain larger population size. Many of such kinds of non-specific insects are polyphagous which would help them to live in all habitats and in different elevation gredients (Sreekumar and Balakrishanan, 2001b).

6.2. Insect diversity in Bihere Tsige Public Park

In the wet season of the public park, flowers and grass mixed vegetation had the highest diversity of insects. Since the purpose of the park is to creat recreational place for people, most of the vegetations are highly stable. Richness and abundance of insect species in an ecosystem are closely related to the physical stability of the habitat (Ananthakrishnan, 1988). Different species of herbivorous insects peak in abundance depending upon the time that the resource they exploit is most abundant (Pinheiro *et al*., 2002). The grassland had also surplus amount of nutrition quality in the wet season due to high precipitation. Flower and grass mixed vegetation, on the other hand, had the opportunity to attract both nectar-loving and phytophagous insects at the same time. Moreover, the flower and grass mixed vegetation had wide access of protection which helped it to become stable. As Murphy *et al.* (1990) noted the holometabolus life cycle of butterflies exposes them to a wide range of environmental influences including disturbances. Butterflies are sensetive to disturbances (Sreekumar and Balakrishnan, 2001b). This can also be true for insects in the Park study area. Insects prefer undisturbed, stable, habitats.

In the dry season, the most diverse insect habitat was seen in grassland habitat. Flowers and grass mixed vegetation had shown decreament in diversity. The reason for the decreament might be man-made activities in these habitats. To keep the beauty of the flowers, the habitat was subjected to repeated disturbances. The grasses under the flowers were cleared which highly minimized the diversity of phytophagous insects. On the other hand, the grassland was allowed to grow for the beginning months of the dry season before it was cleared. This might have helped the grassland vegetation to possess higher diversity than the other habitats. This result is in agreement with Owen and Chanter (1972) where repeated vegetation cutting, burning and clearing resulted in the irregular flactuation of the diversity of insects due to instability of the garden as a habitat for butterflies.

The most similar habitats in the wet season of Bihere Tsige Public Park were mixed vegetation and flowers mixed with grass. The reason might be the overlapping of flowering seasons of plants in both habitats. Certain flower –visiting insects might have dominated these habitats. When the similartiy of floral season ended, the similariy of insects in the habitats also ceased. This idea was well-supported by Owen and Chanter (1972). Almost all the foodplants exhibit a seasonal cycle of growth and some of them are not available at all in the dry season. In their study, *A.lycoa* feed on *Pouzlolzia guineensis*, a plant which disappears in the dry season. *A.lycoa* parallely diminishes in the dry season.

Grassland vegetation and flowers mixed with grass vegetation shared the highest similarity in the dry season of the public park. As stated in this text, the type of vegetation or canopy cover has the biggest impact on insect diversity (Sreekumar and Balakrishnan, 2001a). Although the grass in the flower habitat was cleared, it does not necessarily mean that it woud not regenerate. This regeneration of the grass had created common vegetation for phytophagous insects in the habitats. The other alternative could be the less simillar structure of vegetation in these habitats might be due to the clearing of grasses which might have created simillar insect fauna.

In the wet season of the Park the highest habitat association was observed in grassland habitat. The reason is again the type of vegetation. In this case, the vegetation is entirely dominated by grass which attracted grasshoppers and leaf hoppers that are herbivorous. Polyphogous insects were not seen to be habitat specific since they had variety of nutrition alternatives.

In the dry season, there was no habitat association. This means the insects were spending their time moving and searching for food in all the three habitats. The clearance of grass minimized herbivorus insects associated with it. Unstabitlity initiated non-specificity of insects. Owen and Chanter (1972) explained that the irregular flactuations of butterflies is due to the instability of their study garden as a habitat for butterflies. Generally, rainfall, human activities, and food played great roles in the distribution, abundance and habitat association of insects in Bihere Tsige Public Park and Menagesha Forest.

7. CONCLUSIONS AND RECOMMENDATIONS

The presence of 32 families in Menagesha forest and 35 families in Bihere Tsige Public Park revealed the importance of these areas as good habitats of insects.

High diversity and evenness of insects in artificial forest and natural forest implied the importance of Menagesha forest. This was due to less exposure of these habitats to human activity and availability of food. Artificial forest and natural forest showed high similarity with grassland vegetation in the wet season in Menagesha forest. The reason behind the similarity was the presence of grass in these sites which is the main food stuff of phytophagous insects. The most preferred habitat in Menagesha forest was the grassland vegetation. Most of the associated insects in this habitat are herbivores that mainly depend on the grass as food source. In the artificial and natural forests, on the other hand, most insects were polyphagous which would help them to live in all habitats and in different elevation gradients.

High diversity of insects in Bihere Tsige Public Park was observed in flowers and grass mixed vegetation and grassland vegetation. This was due to high and surplus amount of food in these habitats. Moreover, these habitats were relatively the most stable part of the park. The stability rose from the continuous care and observation of the park. Flowers mixed with grass vegetation showed similarity with mixed vegetation in the wet season and with grassland vegetation in the dry season. This might be due to the overlapping of floral seasons and commonality of food for adults and larvae, respectively. In the wet season of the park, the highest habitat association of insects was with that of grassland habitat. Leafhoppers and grasshoppers were the ones that were associated with this habitat. In the dry season of the park, on the other hand, there was no habitat association. The insects were spending their time moving and searching for food in all habitats.

The study revealed the preferred habitats and food for the major insects. In the forest study area for instance artificial forest and natural forest were seen to be homes for diverse forms of insects. These habitats are exposed to deforestation at the highest rate. This is because of fuel wood collection and most importantly the escalation of investment activities in the forest. If the present disturbances and investment continues at this rate, most insect families will totally be endangered. The Park area, on the other hand, has an appreciable diversity of insects. But, it would have very big diversity of insects, had it been kept properly. The administration and local people have to give due attention to the purposeful use of the park.

Based on the results of the present study, the following recommendations can be made:-

1. In the forest area, the most diverse insects were located in artificial and natural forests, which are highly exposed to human activities. These habitats should be protected from high human interferences.
2. Different families of insects confirm different habitat association. Therefore the different vegetation types should be protected from being devastated.
3. This study identified 32 families of insects in the forest and 35 families of insects in the park. This does not mean that these families are the only ones in the study areas. Further, study should be conducted to fill the gap.
4. Both the park and the forest habitats are rich in other vertebrate species such as mammals, amphibians, reptiles, birds and invertebrates like nematodes. The habitats have also got appreciable diversity of plants. Therefore, a multidisciplinary approach in needed to conserve this biota.
5. As any organism, insects distribute themselves in areas of suitable climatic conditions, when sufficient food for survival and reproduction is available. Critical action should be taken to stabilize disturbed habitats especially in the forest study area.

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Appendix 1. Scientific names of common plants in Bihere Tsige Public Park

Ficus ovata

Podocarpus falcatus

Gravillea robusta

Mimosa pigra

Phoenix reclinata

Eribotrya japonica

Spathodea nilotica

Rosa sinensis

Jacaranda mimsofolia

Ficus vasta

Cactus spp.

Sedum spp.

Rosa abyssinica

Allophylus abyssinicus

Iri germanica

Dracaena stunderi

Cestrium auranticum

Juniperus procera

Acacia abyssinca

Croton marcostachycus

Eucalyptus globules

Olea africana

Prunus africanus

Casaurina spp.

Schinnus molle

Cordia africana

Hagenia abyssinica

Appendix 2. Scientific names of common plants in Menagesha forest

Juniperus procera

Acacia abyssinica

Croton macrstachyus

Eucalyptus globules

Olea africana

Prunus africanus

Sagertiathea

Casaurina spp

.

Schinnus molle

Cordia africana

Hagenia abyssinica

Iris germanica

Osyris quadripartite

Hyparrhenia spp

Cyndon spp

Rubus spp

Mytenus spp

Carduus pychocephalus

Appendix 3. Figures of different habitats (A=Flower and grass mixed vegetation, B=Grass and flower mixed vegetation, C = grassland vegetation in Bihere Tsige Public Park, D=Artificial forest, E=Natural forest, F=Deforestation in the forest) in the study areas.

A

B

C

D

E

F