SPECIES COMPOSITION AND POLLINATOR EFFICIENCY OF *Ocimum Kilimandscharicum* FLOWER VISITORS ALONG KAKAMEGA FOREST ECOSYSTEM

BY

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ECLARATION

DECLARATION

I hereby declare that this thesis is my original work and has never been presented by any other research in any study for the award of a degree

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DEDICATION

I dedicate this work to my parents who have supported me throughout, Dr Amos Kutwa and Mrs. Phillisters Kutwa. To my siblings Alice, Erastus and Fred I hope this serves as a source of inspiration and reassurance that hard work and persistence pays out. My grandparents Alice, Hellen and Silvanas for their prayers and encouragement.

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LIST OF ABBREVIATIONS

NMK – National Museum of Kenya

PNV – Protected No Visit

POV – Protected One Visit

NV – Not Protected

FAO – Food and Agriculture Organization

IUCN – International Union of Conservation of Nature

KNBS – Kenya National Bureau of Statistics

KMD – Kenya Meteorological Department

ANOVA – Analysis of Variance

ABSTRACT

Pollination is an important ecosystem service in the maintenance of biodiversity and most importantly in food production as it brings about fruit formation and seed production. Pollination is, however, on the decline due to several factors including habitat loss, exotic pest invasions, pollution, overharvesting, and land use changes. The *Ocimum kilimandscharicum* plant is known for its medicinal values and has gained more attention locally and internationally for its commercial use in production of pharmaceutical products. This study analyzed the flower visitors' activity of *Ocimum kilimandscharicum* in Kakamega forest. Specifically, the study sought to: (i) assess the diversity and abundance of the flower visitors with increasing distance from the forest edge(ii) assess the effects of temperature and precipitation on flower visitors' diversity and (iii) Identify the most efficient flower visitor using seed set analysis. Data were collected through direct observations and sweep-netting for specific objective one and two. Data collection for specific objective three involved the bagging method where flowers were covered using a pollinator bag pre-anthesis and allowed a single visit from a flower visitor. The pollinator was then captured and a color tag attached to the flower. Seed sets from the flowers were collected and counted. Six study sites were identified along two transect each 2.5 km long and labeled A to F. Distance in meters from the forest edge for each site was; A=221, B=72, C=83, D=198, E=113 and F=50. Diversity indices of different flower visitors was calculated using the Shannon-Wiener diversity index. One-way analysis of variance was used to compare significant differences between sites and a two sample t – test was used to identify mean significant differences in species diversity between the closest and the furthest sites. A total of 645 individuals belonging to 35 species were captured from 4 families; Apidae, Megachilidae, Halictidae and Collectidae. The highest diversity was at Site F (H' = 2.38) which was closest to the forest edge and the lowest diversity was from Site A (H' = 1.44) which was furthest from the forest edge. Distance from the forest edge significantly influenced species diversity ($F_{(3, 20)} = 14.67$, $p = 0.024$). Distance from the forest edge also significantly influenced species abundance between the furthest sites A, D and E and the nearest sites F, B and C to the forest edge (p=0.0315) and species richness (p=0.0187). There were no significant correlations between; temperature/species richness, temperature/diversity, precipitation/species richness and precipitation/diversity. The highest number of seed set, 12,944 was collected under the *Apis mellifera* making this species, the most efficient pollinators. *Apis mellifera* also had the highest visitation frequency at 30. This study shows that *Ocimum kilimandscharicum* flower visitors play essential roles in pollination and the higher the number of visits, the higher the number of seeds set. Many of these pollinators are associated with the forest hence the need to conserve the Kakamega forest as a source pool for pollinators. This pool of pollinators has direct implications on food security to communities surrounding the forest. Further studies are required to determine the extended roles of these pollinators on the surrounding farmlands.

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Pollination is an important ecosystem service that sustains living things (Biesmeijer et al. 2006). It is the transfer of pollen grains from the stamen to the stigma of a flowering plant (Constanza et al. 1997; Ghazoul, 2005). There are two pollination types that include; self-pollination that occurs when pollen grains lands on the stigma of its own flower or another flower on the same plant (Kleijn et al. 2007) and cross pollination occurs when pollen is transferred to the stigma of a flower on another plant. Once the pollen grain reaches the stigma, it produces a pollen tube, which grows down through the style to the ovary (Kleijn et al. 2007). This enables a male pollen cell to fuse with the female cell inside the ovule. This is a process known as fertilization. This process recurs bringing about fruit formation and seeds are produced. (Faegriand Van der Pijl, 1979). Pollination has always been considered as a free service until recently when there has been a rapid decline of pollinators (Schweiger et al. 2004).

Flowering plants are dependent on pollen agents that range from wind, insects and birds to transport their pollen. Insect pollinators such as butterflies, beetles and bees have different adaptations that enhance the collection of pollen grain (Rathcke et al 1993). The extent of their activity is determined by the prevailing environmental conditions (Wilmer andStone, 2004). Pollination as the natural form of crop production is ranked more important than the fertilizer method of cultivation or even labors (Aizen M.A and Harder L.D 2009).

According to Kluser and Peduzzi (2007), the current generation is endearing towards the 6th mass extinction after the Cretaceous extension about 66 million years ago. This includes loss of biodiversity including pollinators. Per decade this ranges roughly between 1 – 10% loss mostly as a result of habitat loss and degradation (Schweiger et al. 2010), exotic pest invasions (Bjerkneset al.2007), pollution, overharvesting and land use changes such as habitat fragmentation (Aguilar et al. 2008).

Potts et al. (2010) estimatedthat the total economic value of pollination worldwide varies from between €30-€ 70 billion annually. Accordingly, any loss of biodiversity should be of concern as the decreasing pollination trends globally threaten plant reproduction and hence food supply and security (Gallai et al. 2009). In Europe there have been recent indications of a 70% drop in the United Kingdom and Netherlands of wild flowers that are insect-pollinated and a shift in pollinator community composition as of 1980's (Biesmeijer and Roberts, 2006). The pollinator decline and loss of pollination services have been linked to habitat destruction and land use intensification (Steffan-Dewenter and Westphal, 2008).

In Africa and Madagascar formation of national parks and reserves may mitigate pollinator decline and loss, but reliance on conserved areas is not sufficient enough to conserve pollinator diversity in the face of increasing land use change (Eardley et al.

2009). Moreover, the community structure of forest insect pollinators is related to their host plants (Potts et al. 2003), meaning a strategic conservation plan should focus on both the insects and their associated floral resources. Gikungu (2006) pointed out *Ocimum kilimandscharicum* as a favorite floral resource among the insect community in Kakamega forest.

This study proposes to quantify diversity and pollinator efficiency of *Ocimum kilimandscharicum* flower visitors. This study is of significance because it will expand on the knowledge of pollinators in Kakamega forest that will help in the design and implementation of conservation of plant and their pollinators in the Kakamega forest ecosystem.Emphasis on *Ocimum kilimandscharicum* will help to create a link between these plant speciesand pollinators. This efforts will help to improve pollination process and the livelihood of the local community through increased crop yields. Consequently, this will drive concerted efforts to conserve the remaining biodiversity in the Kakamega forest.

Given the roles of insect pollinators in the maintenance of native plant populations, human agricultural enterprise and commercial value, it is vital that their complex responses to ongoing global changes be studied. This is applicable particularly in the tropics where they can be investigated and understood in terms of their diversity, distribution and community composition (Brosiet al. 2008).

1.2 Statement of Problem

Ocimum kilimandscharicum is commonlyknown as thecamphor basil of the family Lamiceae. It is a perennial shrub recognised for its high medicinal value and it is dependent on insect pollinators for reproduction (Kleijn et al. 2007). While *Ocimum kilimandscharicum* has been considered as a weed in some parts of the world, its propagation has been threatened by deforestation, soil erosion and inadequate pollination (Nielsen et al. 2011). Currently Kakamega forest is undergoingdeforestation and forest succession.

The current pollination crisis is a major threat facing *Ocimum* genus all over the world (Vikrant et al. 2011). Rapidly diminishing production of *Ocimum* that may be precipitated by anthropogenic activities, forest succession and inadequate pollination possess a danger to the livelihood of farmers and the activities of research institutions that depend on *Ocimum* for phamaceutical purposes and as fertilizers especially around Kakamega Forest. Information available on *Ocimum kilimandscharicum* propagation and pollinators is not enough (Vikrant et al. 2011) whilst the future of *Ocimum kilimandscharicum* production appears grim in light of anthropogenic activities and forest succession (Gikungu, 2006).

1.3 General Objective

The general objective of this study was to determine the species composition and pollination efficiency of *Ocimum kilimandscharicum* flower visitors along the Kakamega forest edge.

1.3.1 Specific Objectives

The specific objective was to:

1. Assess the diversity and abundance of the flower visitors of *Ocimum kilimandscharicum* with increasing distance from forest edge.
2. Evaluate the effects of weather parameters; precipitation and temperature on *Ocimum kilimandscharicum* flower visitor diversity and abundance.
3. Identify the most efficient flower visitor of *Ocimum kilimandscharicum* and their effect on seed set number.

1.4. Hypothesis

1. There is no difference in species composition of *Ocimum kilimandscharicum* flower visitors in Kakamega forest with increasing distance from the forest edge.
2. Weather parameters have no effect on flower visitors of *Ocimum kilimandscharicu m*in Kakamega forest.
3. There is no efficient flower visitor of *Ocimum kilimandscharicum* that would result in a higher seed set number.

1.5 Justification

The local communities highly depend on forests for their daily needs and this exerts stress and pressure on the forest (Winfree et al. 2007). Surrounding communities in Kakamega forest area perceive *Ocimum kilimandscharicum* asa wild shrub (Joshi, 2013) that grows in the forest or in their farmlands. Some of its important uses to the locals include medicinal purposes as it is used to treat several diseases such as diarrhea and cold (Joshi, 2013). After processing, its remains are used as manure in the farms to increase crop yield. Finally it may be used for beautification of compounds.

With an existing knowledge gap on *Ocimum kilimandscharicum* the study will find out more information about its significance and it's envisaged to increase its value and awareness in supporting pollination services. This will help reduce environmental stress as it may offer an alternative source of resources to the communities and may be used to enhance pollination that will in turn increase crop yield (Navarro et al.2003). Furthermore, pollinator knowledge contributes in evaluating the possibility of pollination of further plant species along forest edges and this is helpful especially in forestry and in the breeding of commercial crops (Wright, 1953). Such knowledge also raises awareness on how human existence depends on pollinators in line with agricultural practices and food security (Brosiet al.2008).

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter reviews literature on the diversity and abundance of pollinators, effects of weather parameters on pollinator diversity and on abundance and pollinator efficiency.

2.1Diversity and Abundance of *Ocimum* flower visitors

Ocimum kilimandscharicum also known as Camphor basil is an evergreen shrub that falls under the family *Lamiaceae* (Vikrant et al. 2011). It has oblong, ovate green leaves that are oppositely arranged with pubescent leaf surface (Bhasin, 2012). It thrives in areas that have the tropical climate (Joshi et al. 2013) with warm temperatures, annual rainfall of about 1250 mm and an altitude of up to 900 mm with soils that are well drained. The leaves contain essential oils that give the plant its worth as a medicinal plant and an extract of these rich oils used to make perfume and ointments (Vikrant et al. 2011; Bhasin 2012). Other vernacular names that are common to the general public include: Kapurtulsi in Hindi and Kilimanjaro basil as the common name. Some of it local names here in Kenya include Gethereti/Makori (Meru), Lisuranza/Mwonyi (Luhya), Mbirirwa (Marakwet) and Mutei (Kikuyu) (Holm 2006)

Little information is available on the *Ocimum kilimandscharicum* plant species (Joshi et al. 2013) leaving a gap that may contribute to the importance of the genus *Ocimum.* Recent studies show that this plant is economically important and studies by Joshi (2013) have revealed that the most abundant compound of this plant is Camphor constituting 45.9 %, 1, 8-cineol at 14.6% and Limonene at 8.1 %.The genus *Ocimum* has about 200 species of both herbs and shrubs. Some of the species that are well known and studied include: *Ocimum basilicum*; also known as sweet basil. It is a culinary herb mostly used in cookery. It's also used as a remedy for several ailments including cancer, convulsion, diarrhea, epilepsy, gout, hiccup, impotency, nausea, sore throat, tooth aches, and whooping cough (Vikrant et al 2011). Basil has been reported in herbal publications as an insect repellent (Silva et al. 2010); *Ocimum americanum;* this species is characterized by whitish flowers that are used for their medicinal value. It contains flavanoids, tannins and carbohydrates. It thrives mostly in the native parts of Africa (Tanko et al. 2007); *Ocimum gratissimum;* also known as clove basil. It's known to contain antibacterial and even anticancer components that are yet to be fully exploited and studied especially in the fight against cancer (Navarro et al. 2003; Shaw et al 2006); *Ocimummicranthum;* does very well in the South American region. This region has Amazonian people and they strongly believe that this herb helps avoid bad visions and omens (Ghazoul. J. 2005; Navarro et al. 2003); *Ocimum tenuiflorum;* is a sub shrub of about 30 to 60 cm tall with leaves that are strongly scented compared to the other *Ocimum* species. It thrives well along the tropics and is commonly used as an antioxidant and also in memory improvement (Tanko.Y et al. 2007; Hoyle. M et al. 2007;Brosiet al.2008).

The genus *Ocimum* is widespread through Asia, Africa, Central and Southern America continents (Vikrant et al 2011). It has a general tropical distribution (Joshi et al.2013) with two thirds of the total 200 species being reported to originate from West Africa and the remaining one third from Asia and America (Navarro et al. 2003).

The genus *Ocimum* has so many uses especially on enhancing human health with many more health benefits that are yet to be discovered (Tanko et al. 2007). *Ocimum kilimandscharicum* extracts are used to mitigate many sicknesses in East Africa comprising remedy of coughs, colds, measles, abdominal pains, diarrhea, insect repellent, particularly against mosquitoes and storage pest control (Kokwaro1976). The essential oils obtained from this plant act as repellent against nuisance biting insects (Githinji and Kokwaro, 1995).

In Kakamega forest, *Ocimum kilimandscharicum* is a major plant for insect foraging (Gikungu 2006) and it is now being cultivated on individual farmlands for commercial purposes. It is a wild shrub (Joshi et al.2013) that grows in the forest but the transfer of this species to farmlands leaves a gap that needs to be studied and the effects identified.

Insects carry out the bigger part of pollination (Bjerknes et al. 2007). According to the Food and Agriculture Organization annual report (FAO) (2010-11) it estimates slightly more than 100 crop species that provide 90% of food supplies for over 146 countries, 71 are bee pollinated (Kleijn et al. 2007). Insect pollinators have high value and are considered as limited resources (Delaplane and Mayer, 2000).

Plant pollinators effect pollination through the transfer of pollen in and between flowers (Bauerand Wing 2010; Ashworth et al. 2009). This result in fertilization and formation of seeds and fruit (Ashworthet al.2009). Pollinators are identified by the quality of pollen they transfer (Winfree et al. 2009), the seed set and fruit set that the plant produces. A study by Kullolli (2011) in India revealed that honey bees are the major pollinators of the family *Lamiaceae* (Kulloliet al.2011).

Flower visitors do not necessarily cause pollination (Bauer et al. 2010). They visit the plant to acquire other resources such as water, nectar which consists of sucrose, fructose and glucose (Proctor and Yeo, 1995) in addition the visitor gets shade (Potts et al. 2010) and in the process may cause pollination. *Ocimum* flower visitors include a wide range of bee species (Gikungu, 2006), flies and many more that are yet to be discovered (Silva et al. 2010).

Plants have certain characteristics that attract pollinators (Balkenius, 2010). They include flower petal color, length and size of nectar tubes, flower shape and floral display (Wilmer et al. 2009), other factors include phenology and synthesis of sugar (Bertazzini et al. 2010). *Ocimum* has been found to contain essential oils (Joshi et al. 2013) that omit an attractive sweet scent. Other characters that may attract flower visitors include its purplish white colored petals (Narwal et al. 2011). Its rich flower density also contributes to its attractiveness (Joshi et al. 2013).

At the same time factors such as competition, environmental stress, chemical stress such as use of pesticides and unfavorable weather may hinder *Ocimum* flower visitors. Kasina et al. (2009) showed that more that 96% of the farmers around Kakamega forest were aware of flower visitors especially bees but half were less aware of the pollination services provided to their crops. Even those who were aware could not link flower visitation to improved productivity and family income. This may imply that the activities of these farmers are not aiming toward conservation of the flower visitors and their resources. (Kasina et al. 2009)

Another study by Chacoff et al. (2011) revealed a linear decrease of pollination with increase in distance from the forest edge. At 1000 m pollen deposition was less than at the edge and the most affected were the native pollinator species such as the *Apismellifera.* This translated into a reduction in pollen deposition but had no effect on fruit and seed set. This indicates that distance has an effect on the pollinator activity and diversity of a certain plant species as noted by Potts et al. (2010).

2.2 Effects of Weather Parameters on Flower Visitors

Currently the world is undergoing climate change (Kjohl et al. 2011) and a major indicator of this weather changes is the increase in temperature which may cause different responses in plant and pollinators (Hegland et al. 2009). *Ocimum* insect visitors and pollinators are affected depending on their physiological sensitivity to surrounding temperature change (Deutche et al. 2008). Tropical insects are relatively sensitive to temperature changes and they are currently living in an environment very close to their optimal temperature (Steffan-Dewenter et al. 2009). Deutsch et al. (2008) point out that in contrast, insect species at higher latitudes where the temperature increase is expected to be higher have broader thermal tolerance and are living in cooler climates than their physiological optima. Warming may actually enhance the performance of insects living at these latitudes (Hoyle et al. 2007).

Local temperatures can affect *Ocimum* pollinator behavior, altering the number of visits by a single pollinator and pollinators' behavior within *Ocimum* flowers (Silva et al. 2010). On a larger scale, changes in temperature over the entire season may alter the abundance and diversity of pollinators. For example, pollinators with a narrow temperature tolerance may be replaced by other pollinators that are less sensitive to temperature changes or have higher optimal temperatures (Hoyleet al. 2007).

2.3 Efficient Flower Visitors

Biotic factors that may affect *Ocimum* flower visitors may include competitors, predators, parasites and pathogens (Khojl et al. 2011). Competition may vary as one heads out of the forest as this depends on availability of resources (Ghiniand Morandi, 2006). Study conducted by Le Conte and Navajas (2008) indicated that natural movements of pollinator species and exchanges of domesticated bees among beekeepers brings them into contact with new pathogens. This may vary as one moves away from the forest. However, it is important to conserve the genetic variability among and within important pollinator species to decrease disease mediated mortality (Le Conte and Navajas, 2008) and maintain the diversity of insect visitors.

Anthropogenic factors (Potts et al. 2010) may also affect the *Ocimum* flower visitors' diversity, abundance and its efficient pollinators. Human settlements around forested areas, deforestation, industrial activities and urbanization have eroded many natural ecosystems (Kunin, 1997). The affected structure and spatial distribution of plant communities in turn have an effect on the number of pollinator visits and on the quality of deposited pollen (Kunin, 1997; Steffan-Dewenter and Tscharntke, 2002). For example, small populations or small patches of plants within a larger population may receive less flower visitors (Steffan-Dewenter and Tscharntke, 2002).

The destruction of nest-sites of *Ocimum* flower visitors through fragmentation and isolation affects plants and its pollinator communities and may lead to a decrease in abundance and species richness of pollinators, particularly bees that are the dominant pollinator species in Kakamega forest (Joshi et al. 2013; Gikungu, 2006, Gikungu, 2011). Studies by Winfree et al. (2009) showed that a significant, but relatively small, negative effect, of various types of disturbance on wild bee abundances and species richness. In the study habitat loss and fragmentation was the most important contributor to this significant effects.

Study on quantitative synthetic analysis of 17 crops in agricultural landscapes from around the world, highlighted habitat fragmentation as the major driver that negatively affects wild pollinator populations (Winfreeet al.2009; Steffan-Dewnter et al. 2006; Brosi et al. 2008). To date, however, there are relatively few studies on effects of fragmentation on pollinators and pollination. Similar studies have not found any effects of fragmentation on overall community richness or abundance of bee pollinators, although they detected differential responses among species, with some favored by increased native habitat, and others favored by increased (non-native) matrix area (Brosi et al. 2008; Cane et al. 2006; Donaldson et al. 2002).

There has been reports of declining species richness and abundance with decreased fragment size for bees (Steffen-Dewenteret al.2006) and butterflies (Tscahrntke et al. 2002). Similarly, studies have revealed stronger effects of fragmentation on richness and abundance for bees that were solitary (Steffan-Dewenter et al. 2006). Habitat loss mainly through deforestation and fragmentation (Potts et al.2010) are the main drivers of insect pollinator decline (Brown and Paxton 2009).

CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter contains information on the study area, research design and determination of diversity and abundance of flower visitors, analysis on the effects of weather on *Ocimum kilimandscharicum* flower visitor diversity and abundance, determination of the most efficient flower visitor of the *Ocimum kilimandscharicum* and data analysis.

3.1 Study Area

Kakamega forest is a tropical rainforest situated in Western Kenya. Its elevation is about 1500 to 1600 m above sea level with an estimated area of about 240km^2(Althof,2005). Kakamega forest is facing major anthropogenic threats because of overdependence on it by the local population (Vuyiya et al 2012). The population growth has increased from 406.4 persons per km^2 in 1999 to 521.6 persons per km^2 in 2009 (Kenya National Bureau of Statistics, 2010).

Due to its rich biodiversity and other important ecosystem services Kakamega forest has been ranked as the most sensitive forest ecosystem in Kenya by the International Union of Conservation of Nature (IUCN) 1995 (Dauber et al. 2003; Althof, 2005). The flora and fauna diversity include 380 plant species, 350 bird species, 400 butterfly species and primate and about 242 bee species (Althof, 2005; Gikungu, 2006;Gikungu, 2011).

Kakamega Forest receives an average rainfall of 1200 – 1700 mm annually that is bimodal distributed. Heavy rainfall is experienced between April and May; it gets slightly dry in June and picks up with the short rains between August and September. It’s usually dry between December and February (Kalinganireet al.2001). It is located between latitudes 00˚ 08´ 30.5̋ N and 00˚ 22´ 12.5̋ N and longitude 34˚ 46´08.0̋ E and 34˚ 57´ 26.5̋ E. Temperature is fairly constant throughout the year, ranging between 20 - 30˚C(Steinbrecher, 2004).

3.2Transect Establishment

The focus of the study was on flower visitors of *Ocimum kilimandscharicum*. The main mode of data collection was by observation and experimental where flower visitors were captured using a sweep net and control measures applied to identify the most efficient flower visitor. Two transects of 2.5 Km each were initially randomly established running along the forest edge and farmlands cutting through *Ocimum kilimandscharicum* sites (Winfree et al. 2007). *Ocimumkilimandscharicum*plots,4mx4m with rich floral patches of either naturally growing or cultivated were established along the mapped transects. Transect establishment was based on *Ocimum kilimandscharicum* availability and where there was least disturbance from livestock grazing and humans. The general surroundings of the quadrats were noted and considered for any possible external influences.

GPS coordinates of these plots were taken and labeled A to F (Appendix 1). Sampling sites were located on these transects as demonstrated in Figure 1. These selected sites were all sampled in similar order in 5 months of collection period for uniformity.

Sampling was done for a week in each month and to adequately sample the flower visitors with different diurnal patterns sampling was done within three observation times per day: 7: 00 - 11:00 am for morning, 12 noon – 1 pm and 2 – 4 pm for afternoon.

Sites were categorized as those that were furthest from the forest edge and those that were relatively close to the forest. Site A-221 m, Site D-198 m, E-113 m were the furthest and site F-50 mB-72 m and C-83 m were the closest to the forest edge. These sites were selected as *Ocimum kilimandscharicum* was fully matured and the area was least disturbed.

<u>Key; Selected sites for objective 2</u>

Kisaina Primary School- Site A

KEEP Shamba – Site B

Cecilia Point – Site C

Veros Farm – Site D

Morrises Farm – Site E

Sichakala Farm – Site F

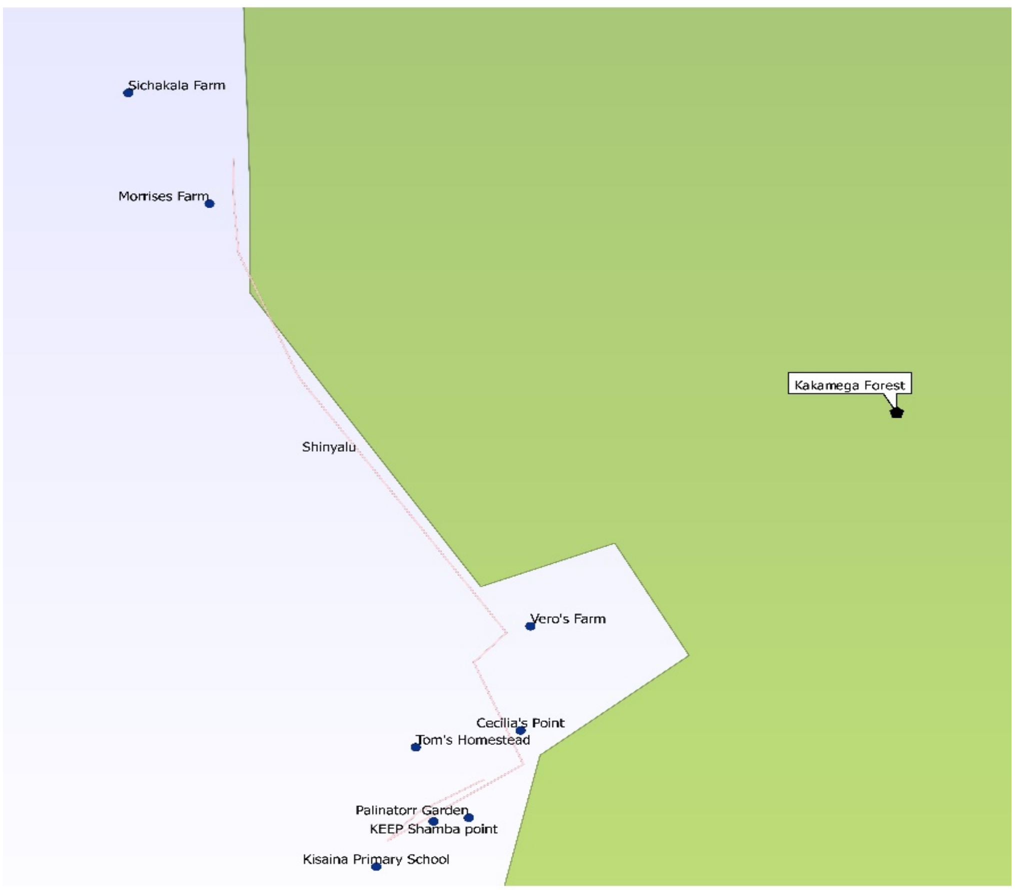

Figure 1.

Identified Ocimum kilimandscharicum Sites on GPS

3.3 Determination of Diversity and Abundance of Flower Visitors.

All foraging flower visitors in the six study sites along established transects were captured using a sweep net at 60 minutes' intervals in morning, midday and afternoon sessions. Sweeping for flower visitors was done for one week each month and to achieve randomization, each day was randomly assigned to a particular site. The number of flower visitors collected during each sampling event at a particular site were considered an estimate of the species diversity and abundance (Diego and Simberloff, 2002). Each collection was labeled with: time of collection, date and month of collection, site where it was collected and collector's name. Further analysis was done at the National Museum of Kenya (figure 2) and the collection was identified to species level supplemented by studies done by Gikungu (2002 and 2011), Njoroge et al. (2004) and Karanja (2010).

Plate 1: Identification Process of the Flower Visitors in the Laboratory.

3.4 Effects of Weather Parameters on Diversity and Abundance

Temperature and precipitation were taken as the weather parameters that were most likely to affect insect activity (Kjohl et al. 2011) in Kakamega forest. Sampling of flower visitors using a sweep net was done along established transects in the sites with the help of field assistants. Temperature and precipitation was taken as a mean on monthly basis and was acquired from the Kenya Meteorological Department.

3.5 Determination of the most Efficient Flower Visitor of the *Ocimum kilimandscharicum*

To effectively determine the most efficient flower visitor of the *Ocimum kilimandscharicum*, the bagging method (Dag et. al.2007) was applied and seed set in terms of number was used to measure the efficiency of pollinators. To accomplish this, three sites were randomly selected along the already established line transects. This was achieved by clustering the already selected sites into three groups and randomly selecting one site in each cluster as sampling points.

Morris's farm was located 113m from the forest edge at 1569 M altitude. It was surrounded by cultivated crops including maize, cassava and mangoes. The pollinator Garden was located 121m from the forest edge and was surrounded by flower shrubs and trees. Vero's farm was situated 198m from the forest edge at 1594 M altitude and surrounded by sugarcane and other cultivated crops.

In each of the three sites, simple random sampling method was used to select a total of 120 *Ocimum kilimandscharicum* flower stalks prior to anthesis (Kearns and Inouye, 1993). The selected flowers were then divided into three parts; those that were left uninterfered with were labeled NP (not protected), those that were protected using pollinator bags and left to receive one insect visitor POV (protected one visit) and finally those that were protected and received no insect visitors PNV (protected no visit) (Vaissiere et al.2011).

The main focus was on the POV samples. Once the *Ocimum kilimandscharicum* flowers opened, the pollination bags were removed and observation of the first flower visitor was made and recorded (Dag et al. 2013). Flower visitors were recorded and the flower re – bagged again to prevent further visits from other arthropods (Vaissiere et al. 2011). At this point the flower visited was tagged using a colored band (Appendix 4) giving the plant a history with its visiting agent and its efficiency in terms of seed number could easily be compared (Vaissiere et al. 1996).

The flowers were monitored until they set seeds and analysis of the seed set number was done. At the final stage seeds formed by all the selected *Ocimum kilimandscharicum* flowers on all sites and on each group respectively were collected separately to avoid mixing of results (Dag et al. 2013). Seed quantity in terms of number was recorded for comparison with other seed sets from the other sites.

3.6 Data Analysis.

Generally, input of data was done using Microsoft excel. The analysis was performed using R 2.10.0 software. Data was represented graphically. T-test and ANOVA was also applicable.

3.6.1 On Diversity and Abundance of Flower Visitors

Before input, data was analyzed at the National Museum of Kenya. Identification process of data collected for objective 1 and 2 was done and the data was classified under their family and species name. Shannon diversity profile was used to determine the diversity richness of the flower visitors and the abundance

$$H= - \sum_{i=1}^{s} (pi\,1\,npi)$$

Where;

H = the Shannon diversity index

P*i* = proportion of the population made up of species *i*

S= number of species in sample

Shannon diversity profile was preferred as it takes into account the measures of species diversity in a community based on species richness and species abundance meaning the number of individuals per species will be accounted for (Hughes et al. 1978). A habitat with diversity profile starting at a higher level than others would be considered richer. Profiles above others along their range from start to end would indicate a higher diversity or evenness of the habitat (Kindt and Coe, 2005; Chiawo, 2003).Simple linear regression was used to represent data on flower visitor diversity.

3.6.2 Effect of Precipitation and Temperature of Flower Visitor Composition

Weather data was obtained from the Kenya metrological department (Nairobi, Kenya). The data was in means (per month); precipitation (mm), temperatures (˚C).A T-test analysis was carried out to identify any significant differences between sites that were closer to the forest edge compared to those that were furthest from the forest edge. To determine the significant differences between sites ANOVA was used to compare the diversity and abundance of the flower visitors(Chiawo, 2011).

3.6.3 Most Efficient Flower Visitor

Data was first identified according to the color tag on each flower stalk attached representing the flower visitor. Referencing was done at NMK to identify the flower visitor down to the species name according to its characteristics. Simple linear regression was used to represent the seed number per group. Further descriptive and inferential analysis of data was carried out and this was summarized as mean flower visitors per site and frequency distribution that were all represented graphically.

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter contains findings of the study organized along specific objectives. It begins with the findings on diversity and abundance of *Ocimum kilimandscharicum* flower visitors, analysis of effects of weather parameters (precipitation and temperature) on the diversity of flower visitors and data on determination of the most efficient flower visitor of *Ocimum kilimandscharicum.*

The species accumulation curve below (Figure3)shows the rate at which new species were found in the study sites which provided an estimate of the species richness of the flower visitors. Sites labeled 1 to 6 correspond to sites A to F respectively. Figure 3demonstrates that there was a clear relationship between sampling effort and species richness. The higher the sampling effort the higher the number of species captured. The last site 6 corresponding to site F shows peak collection with all the species collected throughout the process being found there.

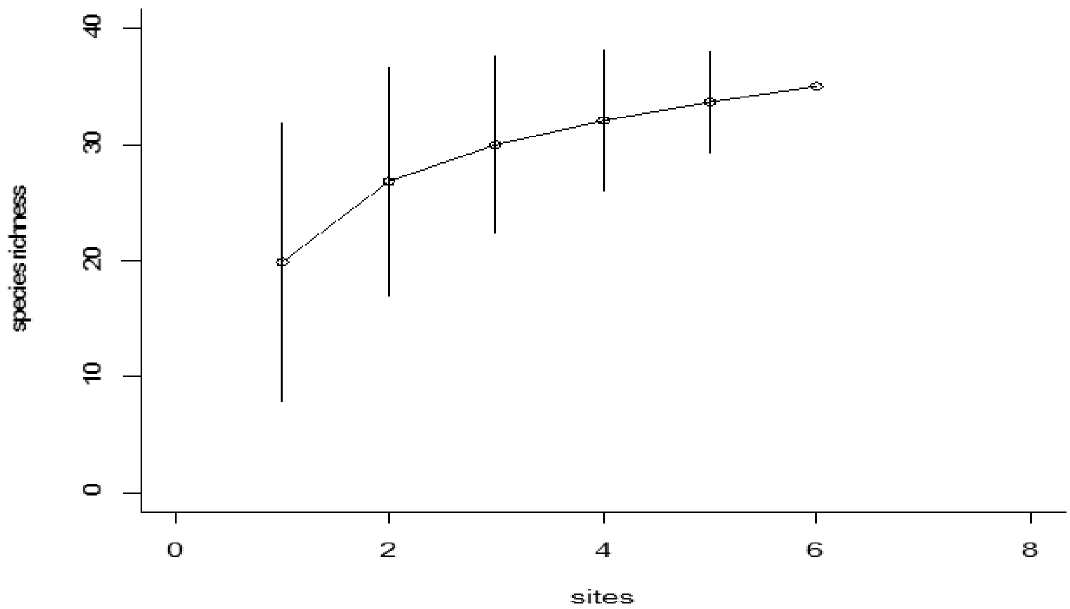

Figure 3: Species Accumulation Curve

4.2 Diversity and Abundance of *Ocimum kilimandscharicum* Flower Visitors

A total of 645 individual flower visitors belonging to four (4) families and thirty-five (35) species of bees were collected in sites located along the forest edge within a period of 5 months (table 1).

Table 1 below: Flower Visitors' Species Composition Collected

Family	Species Identified
Apidae	*Apismellifera*
	Allodape sp.
	Amegillasp. I
	Amegillasp. II
	Amegillasp. III
	Braunsapis
	Ceratinasp. I
	Ceratinasp. II
	Meliponula
	Thyreussp.
	Xylocopacalens
	Xylocopaflavorufa
	Xylocopaincostans
	Xylocopatorridium
	Xylocopa (xylomellisosp. I)
	Xylocopa (xylomellisosp. II)
	Xylocopasp. III
Megachilidae	*Coelioxys sp.*
	Felinae sp.
	Heriade sp.
	Ithanoptera
	Megachilesp. II
	Megachilesp. III
	Megachilesp. VI
	Megachilesp. V
	Pseudoanthidium sp.
Halictidae	*Halictinaesp VIII*
	Lipotrichessp.
	Nomiasp.
	Patellapissp.
	Pseudapissp.
	Seladoniasp.
	Systrophasp.
	Thrinchostomasp.
Colletidae	*Collete sp.*

The family *Apidae* had the highest number of species (17) and individuals (516) followed by *Megachilidae* with nine (9) species with 60 individuals, *Halictidae* with eight (8) species with sixty-eight (68) individuals and the family *Colletidae* with one (1) individual belonging to a single species (Appendix 5).

Plate 2: Flower Visitors Arranged According to the Family Category in an Insect Box

In the family Apidae, A*pismellifera* was the most dominant with 329 individuals followed by *Meliponula* species with 44 individuals and the least dominant was the *Flavoruf*a, Family Collectidae had one individual of the genus *collett*e (appendix 5). Under family Halictidae the most dominant was genus *Lipotriches* with 18 individuals, followed by *Nomia*sp with 16 individuals and the least dominant was the *Thrinchostoma*sp and the *Pseudapissp*each with one (1) individual. The most dominant species under family

Megachilidae was the *Megachilesp II* with 18individuals, followed by *Heriadias* with 11 individuals. Least dominant species was the *Ithanoplectra* with one (1) individual.

4.2.1: Effect of Distance from the Forest Edge on Flower Visitor Diversity and Abundance

Table 2 below provides further information on effect of distance from the forest edge on the flower visitors diversity and abundance. Site F had the highest species richness (n=30) and was located some 50 M from the forest edge. It was followed by site B and C with 23 and 21species respectively. These were the most diverse sites save for site F and were also located closest to the forest at 72 M and 83 M respectively. The site with the least number of species collected was site A with 11 and was the furthest from the forest edge at 221 M. (Table 2).

Table 2: Distance of Sites from Forest Edge, Total Abundance and Species Richness of Flower Visitors on Selected Sites

Site	Distance from the forest edge (m)	Total abundance	Species richness	Shannon-Weiner Diversity Index
A	221	64	11	1.44
B	72	77	23	2.29
C	83	147	21	2.05
D	198	135	15	1.54
E	113	102	19	1.94
F	50	120	30	2.38

The site with most abundant species was C with 147at 83 M and least species abundant site associated with *Ocimum kilimandscharicum* flower visitors was A with 64 at 221 M which was the furthest from the forest edge.

Determination of the effect of distance from the forest edge on species diversity and abundance was tested using a two-sample t-test, after clustering the sites according to distance from the forest edge, sites F, B, C being the closest and those furthest to the forest edge; A, D and E respectively. With a significant level of 0.05, distance had a significant effect on species abundance (t=4.177) p value = 0.0312. In addition, distance significantly influence species richness (t=3.2893) p value= 0.0187

ANOVA on the differences in the variation in flower visitor composition among the study sites differences resulted as; $F_{(3, 20}$ = 14.47, p= 0.024indicating that between sites A to site F,F>F critical hence the null hypothesis that distance doesn't affect the flower visitors' composition can be rejected.

Figure 3 shows the monthly species richness of the flower visitors by month from August to December 2015. Flower visitor species increased steadily from August to December then leveled off. Showing that the ore time spent sampling for flower visitors the higher the species discovered.

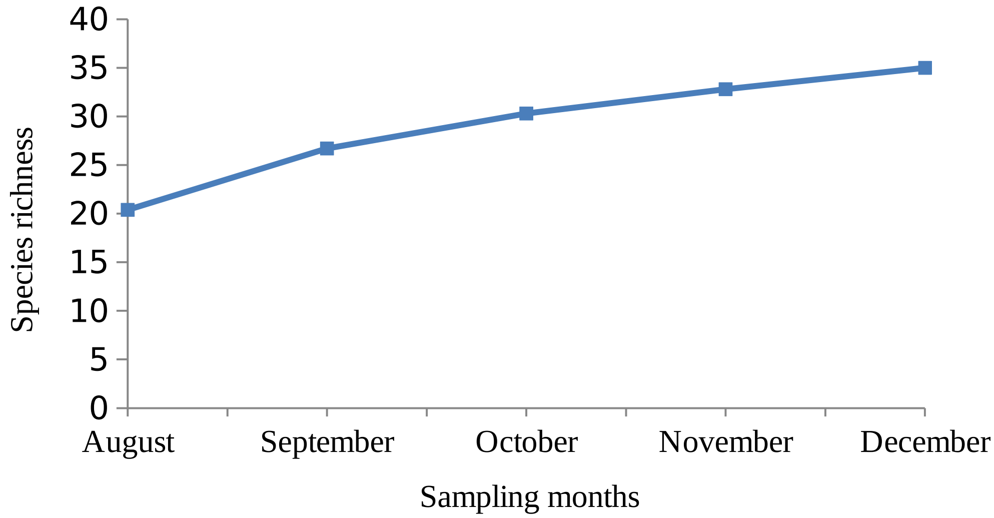

Figure3: Monthly Species Richness Curve (August to December 2015).

Figure4below shows the species rank abundance curve of bee flower visitors associated with *Ocimum kilimandscharicum*.The species rank abundance conforms to Log-normal distribution.

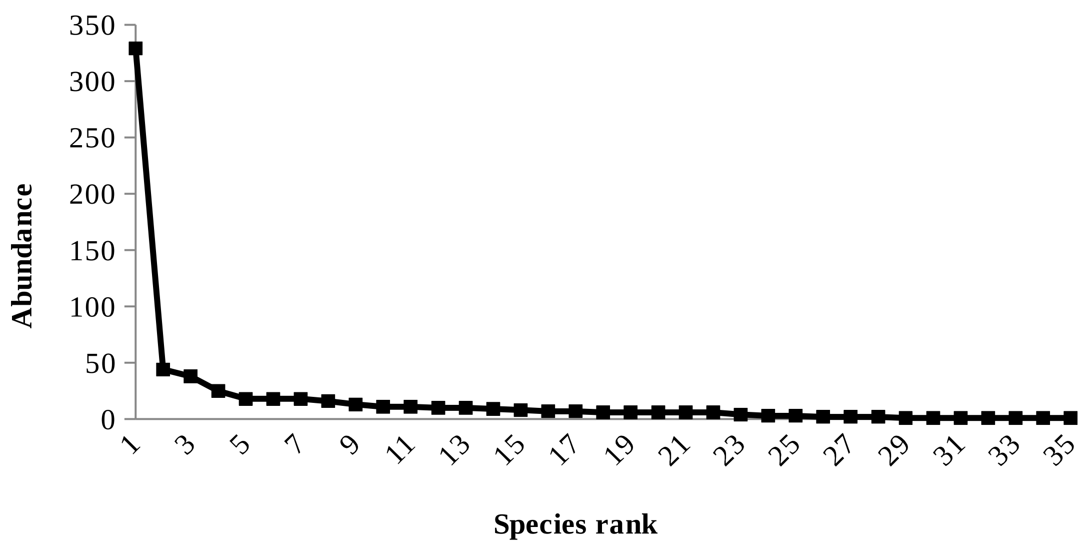

Figure 4: Species Rank Abundance of bee Flower Visitors on Ocimum kilimandscharicum.

4.3 Effects of Weather Parameters on *Ocimum kilimandscharicum* Flower Visitors' Diversity and Abundance.

Analysis on the effects of weather parameters precipitation and temperature on the flower visitors' abundance and diversity revealed that there was no significant correlation between most of the variables. There were no significant correlations between temperature and diversity($r = -0.509$, $p= 0.3810$), precipitation and diversity ($r=0.377$; $p=0.531$), temperature and species abundance ($r=-0.00618$; $p=0.9921$), species abundance and precipitation ($r=-0.248$; $p=0.688$), temperature and the species richness of flower visiting insects ($r=-0.729$ $p=0.1623$) and between precipitation and species richness($r=0.824$; $p=0.08592$).Precipitation and rainfall data are shown in Appendix 8.

4.4 Identification of the Most Efficient Pollinator by Seed Set Analysis

Out of the 120 selected individual flowers at each of the three sites, 95successfully developed on Morris' farm, 76 successfully developed on the Pollinator Garden and 104 developed to set seeds on Vero farm. A number of the flowers dried up prematurely ($n=43$), or were destroyed by termites ($n=28$) while others were destroyed by interference from a tractor ($n=14$). A total of 42,499 seeds were collected from all sites in total. Of these 19,436 seeds were collected from flowers that were protected with one visit (POV), 103 seeds from flowers that were protected with no visit (PNV) and 22,960seeds were collected from flowers that were not protected (NP) (Appendix 4 and 5).

Figure 5, 6 and 7 below indicate that A*pismellifera* visited flowers produced the highest numbers of seed at 4574, 3333 and 5037 seeds respectively giving a total of 12,944 seeds out of the total 19,436 seeds collected from the POV.

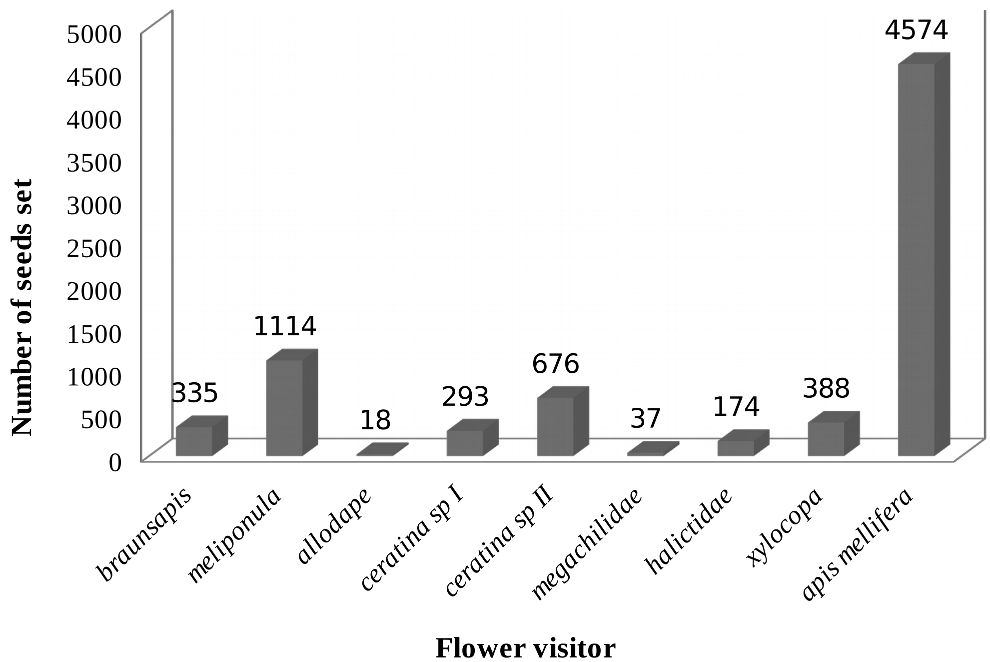

Figure 5: Graph above represents the Number of Seeds Set against the Flower Visitor Identified by Color Tags From Morris's Farm Site

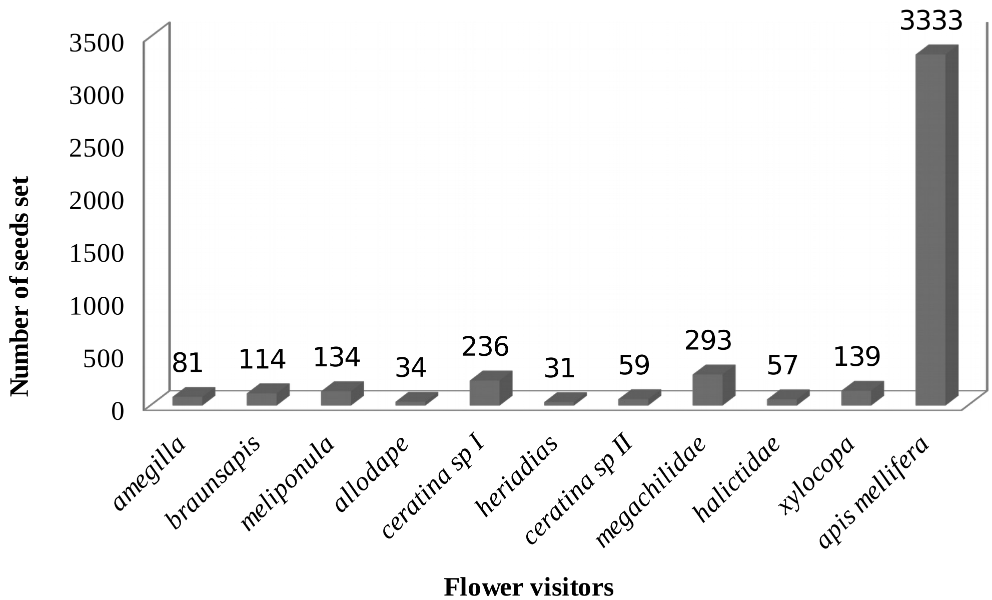

Figure 6: Graph above shows the Number of Seeds Set against the Flower Visitor Identified by Color Tags From Pollinator Garden Site

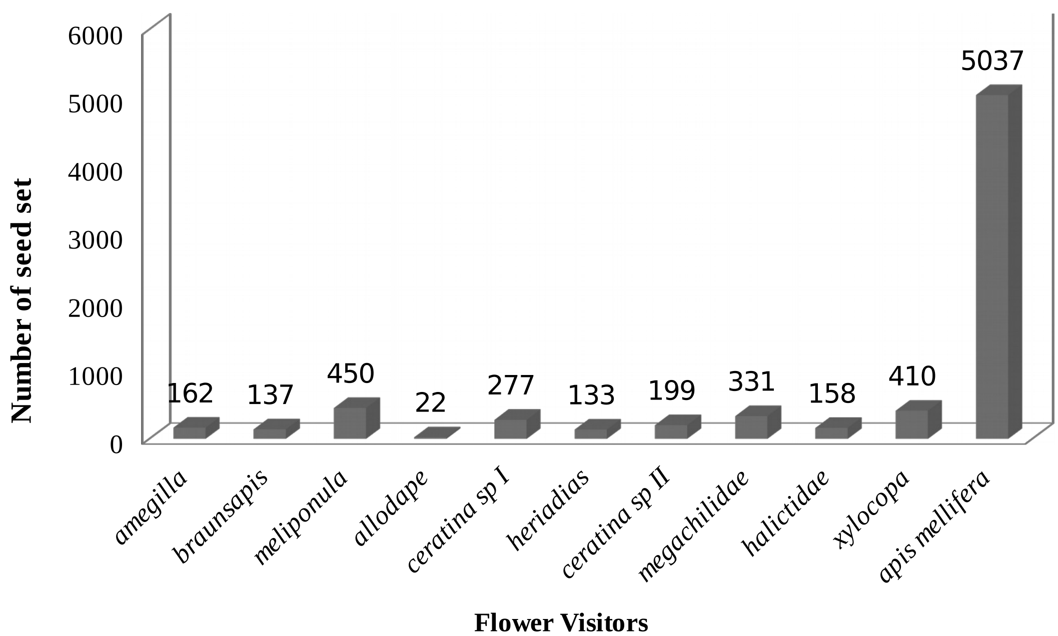

Figure 7: Graph above Shows the Number of Seeds Set against the Flower Visitor Identified by Color Tag For Vero's Farm Site.

4.4.1: Frequency Distribution of Individual Flower Visitor Family/Species in Selected Sites

Results show that the rate at which all flower visitors foraged in the selected *Ocimum* plant differed. *Apismellifera*was the most frequent visitor of flowers in all the three sites with a frequency of 30 at the Pollinator garden, 45at Vero farm and 50 at Morrises farm. This could account for the highest number of seed set produced from *Apismellifera*in all the three sites. This was followed by *Meliponulasp*, *Ceratinasp 1* and M*egachilidae* with a frequency of 7while the lowest frequency was recorded from *Allodape, Amegilla, CeratinaspII andHeriadias*with a frequency of 3 (Figure 8)

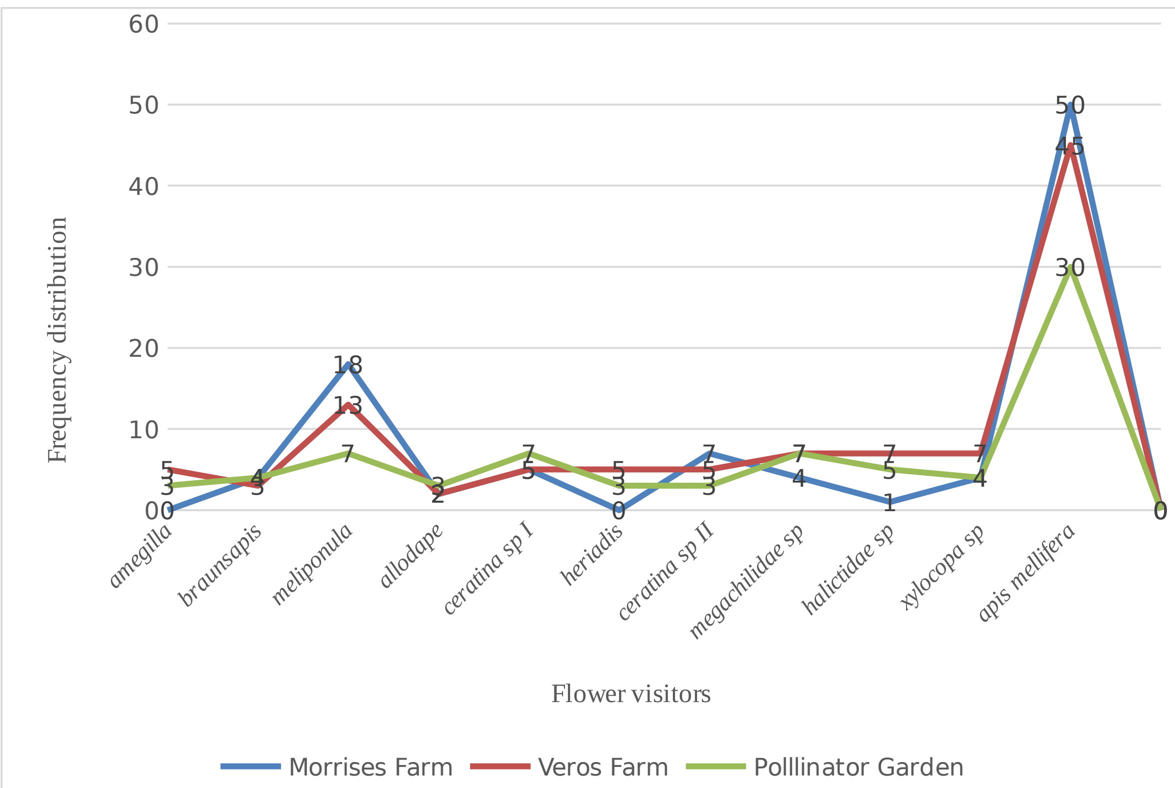

Figure 8: above: The Frequency of Distribution of Flower Visitors at the three Selected Study Sites; Morris Farm, Vero's Farm and Pollinator Garden.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATION

5.0 Introduction

This chapter is divided into three categories. It begins with the discussion of the most important findings for each objective. Followed by the conclusions and finally recommendations.

5.1 Discussion

This study has demonstrated that *Ocimum kilimandscharicum* flower visitors play essential roles in pollination. Many of these pollinators are associated with the forest, which add to reasons as to why Kakamega forest needs to be conserved. In addition, the study has also shown that the number of visits by flower visitors has implications on the number of seeds realized by the plant. The study also demonstrated that prevailing temperature tends to not have significant impacts on the flower visitors' activity.

5.1.1 Flower Visitor Composition and the Effect of Distance

The study has shown that the most common flower visitors are members of the bee families *Apidae*, *Megachilidae*, *Halictidae*and *Collectidae*.*Apidae* was the dominant bee family throughout the whole study period and at all the study sites. These finding are in line with the findings of Chiawo (2011) whereby the family *Apidae* dominated most of the composition of his findings around the fallow farmland. In a study by Potts et al. (2003) on pollinator decline, *Apidae* was also the most dominant family and consequently, experienced the highest decline in abundance from extraneous factors.

Of the six study sites, site F had the highest abundance and diversity of *Ocimum kilimandscharicum* flowers visitors followed by site B and C respectively. This may be explained on the basis of their close proximity to the forest edge. Site F demonstrated the foraging range of forest flower visitors and their ability to forage on plants on the forest edge. These findings are in agreement with those of Potts et al. (2003) in Mt Carmel in which it was reported that the most dominant pollinator species were collected in grass and shrub like areas near the forest. Steffan-Dewenter and Westphal (2008) demonstrated that habitats undergoing ecological successions were more effective in enhancing pollinator diversity and abundance. These findings support the importance and value of Kakamega forest and identifies the forest as a key habitat that supports pollinator communities,especially bee species.

Overall abundance of flower visitors was high in site C. The site was located in an open farmland where there were various farming activities that enhanced the growth of different kinds of plants. These findings support studies by Gikungu et al. 2011and Steffan-Dewenter and Westphal (2008) where it was shown that bee abundance was high in open farmlands. The rank abundance curve conformed to Log-normal distribution whereby the species abundance follows a normal distribution. This indicated that an increase in the number of sites visited, increased the probability of collecting different flower visitor species.

Distance had significant effects on the composition of flower visitors; with sites closest to the forest being more diverse and with higher abundance than those sites located far. These findings conform to those of Zurbuchen (2010), who reported that whenever distance between nesting stands and experimental sites was increased, the duration of foraging bouts consistently increased and bee species composition deferred too.

Graph of species richness against sampling duration (months)indicates that increase in sampling duration increases the likelihood of collecting rare species hence causes an increase in their abundance and the normal distribution becomes more visible. The pattern indicates that as more time was spent in this study, more flower visitor species were captured and identified. The abundance also increased and so the normal distribution became more evident as sample duration increased.

5.1.2 Effects of Weather Parameters

Temperature did not significantly affect flower visitor diversity and abundance. This is in line with a study by Pereboom and Biesmeijer, (2003) who reported that despite different bee species facing high solar radiation and high temperatures there seemed to be no major difference in composition between the bees in different biographical area with different weather patterns. Most bee activity was recorded during the mid-mornings (10 - 11 AM).Pollinators and plants have different climatic requirements, and may therefore respond differently to changes in ambient temperature. Temperature can induce different responses in plants and pollinators. Even if plants and pollinators do respond to the same temperature cue, the strength of the response might differ (Hegland *et al.* 2009).

5.1.3: The Most Efficient Flower Visitor

The large number of seeds (22,960) collected under NP demonstrates effective pollination of the *Ocimum kilimandscharicum* that occurred with diverse flower visitors. However, under the protected with no visit (PNV) the small number of seeds (103) collected indicates that pollination may have occurred despite the control measures to prevent it. This may have occurred through other forms of pollination, like self-pollination, leaving a knowledge gap that requires further studies.

The complete and actual role of the flower visitors in effective pollination studies is usually dependent on the frequency and relative number of visits to the flowers. According to Freitas (2002), however, results obtained under the single-visit study are equally important in providing an estimate or a foundation for carrying out further studies. It may also indicate a rough estimate of the importance of a flower visitor in pollination and crop production.

Apidaestood out in this study as the most effective pollinators. The study conforms to that of Cruz et al. (2002) on cashew where it was found that A*pismellifera* under family Apidae were most efficient pollinator as they helped produce the highest number of seeds in each of the three sites. Morris' Farm Site was the closest to the forest cover at 50 m.

This may add to the explanation for the high number of seeds (7609) produced from the site as bees did not have to cover a long distance to get to their foraging sites.

5.2 Conclusion

In conclusion, fragmentation and habitat alteration in Kakamega forest will have irreversible effect on the fauna including a wide range of bee flower visitors that play a major role in pollination and are attracted by the *Ocimum kilimandscharicum* plants.These flower visitors as shown in this study are diverse and are dependent on the forest as they forage along the forest for resources.

Consequently, by planting *Ocimum* which attracts many diversified pollinators, local communities can benefit from their pollination services to increase their crop yields. While the findings of this study may be inconclusive, because of its short duration, the information obtained forms a foundation and offer baseline data for future studies on pollinators of the *Ocimum* family.

5.3 Recommendation

1. The diversity and abundance of pollinators observed on *Ocimum kilimandscharicum* flowers shows that this plant species can be used to attract pollinators in larger farmlands that carry out commercial farming.
2. There is need for further studies to be carried out to identify the significance of *Ocimum kilimandscharicum* flower visitors in the crop yields of the surrounding communities.

3. Carry out more detailed studies on effects of precipitation, temperature and other weather parameters on *Ocimum kilimandscharicum* flower visitors with longer study period in Kakamega forest, be thoroughly investigated in view of the anticipated climate change.
4. Those who domesticate bee for honey production can plant *Ocimum kilimandscharicum*as the study has shown that it is a favorite forage plant among bees including the stingless bees.
5. Researchers and local communities should increase public awareness of *Ocimum kilimandscharicum* as it will help more people benefit from its use.

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APPENDICES

Appendix 1: Site Name, GPS Coordinates Altitude and Surrounding Environment of Selected Sites.

SITE	GPS READINGS	ALTITUDE	SURROUNDING
SICHAKALA'S FARM **SITE F**	N 00.25755 E 034.84508	1538 M	Homestead surrounded by blue gum tree, sugarcane, cassava, maize
Road co – ordinate	N 00.25485 E 034.84866		Ishereno River flowing 50 m from this point to blue gum trees
MORRIS'S FARM **SITE E** **RED**	N 00.25302 E 034.84786	1569 M	Huts, sukuma wiki, sugarcane, maize,
Road co – ordinate	N 00.25304 E 034.84870	1551 M	Sugarcane plantation, homesteads
Road co-ordinate	N 00.25101 E 034.84885	1562M	
Road co – ordinate	N 00.24590 E 034.85093	1569 M	
VERO'S FARM **SITE D**	N 00.23575 E 034.85886	1594 M	Sugarcane, cassava, maize, homestead
Road co – ordinate	N 00.23548 E 034.85804	1585	
Chepsonoi to Kakamega via	N 00.23427 034.85692	1585 M	Main road connecting transects to murram road.

Shinyalu road			Transect closed.
Road co – ordinate from barracks into MFCG.	N 00.23011 E 034.85862	1597 M	
CECILIA POINT **SITE C** **BLUE**	N 23.149 E 034.85862	1606 M	
KISAINA PRIMARY SCHOOL **SITE A**	N 00.22592 E 034.85358	1588 M	
Road co – ordinate into Kisaina.	N 00.22698 E 034.85395	1596 M	
Road co – ordinate into Keep shamba.	N 00.22816 E 034.85503	1597 M	
KEEP SHAMBA **SITE B**	N 00.22777 E 034.85554	1598 M	Naturally growing *Ocimum*, homestead, maize, sugarcane
Road co – ordinate	N 00.22947 E 034.85725	1595 M	
TOMS HOME	N 00.23080 E 034.85493	1579 M	River Khasiya, trees, bananas and maize

POLLINATOR GARDEN **YELLOW**	N 00.22792 E 034.85675	1585 M	

Appendix 2: Composition of Flower Visitors Captured and the Numbers

Species	**Number**
Apismellifera	329
Allodape	6
Amegillasp. I	1
Amegillasp. II	6
Amegillasp. III	3

Braunsapis	9
Ceratinasp. I	25
Ceratinasp. II	7
Meliponula	44
Thyreussp	2
Xylocopacalens	38
Xylocopa*flavorufa*	6
Xylocopaincostans	11
Xylocopatorridium	2
Xylocopaxylomellisosp. I	8
Xylocopaxylomellisosp. II	18
Xylocopasp. III	1
Coelioxy	3
Feline sp.	6
Heriadias sp.	11
Ithanoplectra	1
Megachilesp. II	18
Megachilesp. III	6
Megachilesp. VI	10
Megachilesp. V	1
Pseudoanthidiumsp.	4
Halictinaesp VIII	13
Lipotrichessp.	18
Nomiasp.	16
Patellapissp.	7
Pseudapissp.	1
Seladoniasp.	10
Systrophasp.	2
Thrinchostomasp.	1
Collete sp.	1

Appendix 3: Table Representing the Color Tag and Number of Seeds for SITE MORRIS

COLOR TAG	**SEED NUMBER**
blue	37
blue	126
blue	15
blue	157
TOTAL	**335**
green	14
green	12

green	2	green	103

green	188	green	14

green	14
green	41
green	8
green	35
green	58
green	143
green	101
green	76
green	18
green	194
green	76
green	17
TOTAL	**1114**
N. blue	7
N. blue	11
TOTAL	**18**
N. pink	11
N. pink	36
N. pink	123
N. pink	106
N. pink	17
TOTAL	**293**
pink	82
pink	78
pink	63
pink	18
pink	177
pink	146
pink	112
TOTAL	**676**
purple	6
purple	3
purple	5
purple	23
TOTAL	**37**
red	174
TOTAL	**174**

white	51
white	66
white	199
white	72
TOTAL	**388**
yellow	44
yellow	56
yellow	18
yellow	112
yellow	64
yellow	110
yellow	92
yellow	29
yellow	94
yellow	10
yellow	123
yellow	221
yellow	162
yellow	121
yellow	137
yellow	67
yellow	96
yellow	106
yellow	133
yellow	162
yellow	86
yellow	11
yellow	114
yellow	132
yellow	56
yellow	46
yellow	34
yellow	186
yellow	128
yellow	83
yellow	18
yellow	138
yellow	51
yellow	102
yellow	93
yellow	49
yellow	6

yellow	20	yellow	168
yellow	101	yellow	189
yellow	23	yellow	97
yellow	72	yellow	51
yellow	9	**TOTAL**	**4574**
yellow	143		
yellow	206	**GRAND**	
yellow	159	**TOTAL**	**7609**
yellow	46		

Appendix 4: Table Representing the Color Tag and Number of Seeds for SITE VERO

COLOR TAG	SEED NUMBER
black	34
black	21
black	17
black	49
black	41
TOTAL	**162**
blue	12
blue	39
blue	86
TOTAL	**137**
green	56
green	27
green	33
green	3
green	9
green	35
green	23
green	6
green	53
green	69
green	54
green	33
green	49
TOTAL	**450**
N. blue	18
N. blue	4
TOTAL	**22**
N. pink	109
N. pink	64
N. pink	55
N. pink	27
N. pink	22
TOTAL	**277**
Orange	29
orange	18
orange	41
orange	29
orange	16
TOTAL	**133**
pink	56
pink	43
pink	6
pink	48
pink	46
TOTAL	**199**
purple	11
purple	67
purple	72
purple	12
purple	64
purple	83
purple	22
TOTAL	**331**
red	13
red	6
red	28
red	16
red	31
red	33
red	31
TOTAL	**158**
white	56
white	43
white	73
white	30
white	23
white	94

white	91
TOTAL	**410**
yellow	167
yellow	67
yellow	89
yellow	31
yellow	98
yellow	88
yellow	116
yellow	193
yellow	148
yellow	67
yellow	104
yellow	178
yellow	17
yellow	104
yellow	37
yellow	93
yellow	179
yellow	177
yellow	158
yellow	93
yellow	183
yellow	138
yellow	21
yellow	93
yellow	212
yellow	94
yellow	37
yellow	74
yellow	90
yellow	58
yellow	116
yellow	79
yellow	153
yellow	174
yellow	94
yellow	182
yellow	95
yellow	184
yellow	112
yellow	69
yellow	138
yellow	102
yellow	95
yellow	173
yellow	67
TOTAL	**5037**
GRAND TOTAL	**7316**

Appendix 5: Table Representing the Color Tag and Number of Seeds for SITE POLLINATOR GARDEN

COLOR TAG	SEED NUMBER
black	32
black	31
black	18
TOTAL	**81**
blue	53
blue	11
blue	13
blue	37
TOTAL	**114**
green	14
green	21
green	3
green	16
green	25
green	18
green	37
TOTAL	**134**

N. blue	7
N. blue	3
N. blue	24
TOTAL	**34**
N. pink	13
N. pink	31
N. pink	34
N. pink	28
N. pink	28
N. pink	65
N. pink	37
TOTAL	**236**
orange	11
orange	4
orange	16
TOTAL	**31**
pink	24
pink	16
pink	19
TOTAL	**59**
purple	48
purple	7
purple	48
purple	37
purple	4
purple	83
purple	66
TOTAL	**293**
red	21
red	13
red	9
red	9
red	5
TOTAL	**57**
white	29
white	18
white	74
white	18
TOTAL	**139**
yellow	124
yellow	19
yellow	178
yellow	94
yellow	78
yellow	73
yellow	109
yellow	186
yellow	59
yellow	82

yellow	193	yellow	201
yellow	178	yellow	183
yellow	75	yellow	85
yellow	59	yellow	149
yellow	83	yellow	64
yellow	104	yellow	93
yellow	94	yellow	170
yellow	99	yellow	132
yellow	148	**TOTAL**	**3333**
yellow	94		
yellow	79	**GRAND TOTAL**	**4511**
yellow	48		

Appendix 6: Color Tags Representing Individual Bee Species are as indicated

Color	Species represented
Yellow	*Apismellifera*
White	*Xylocopa*
Green	*Meliponula*
Neon Blue	*allodape*
Blue	*braunsapis*
Red	*halictidae*

Neon Pink	*ceratinaspi*
Pink	*ceratinasp ii*
Orange	*heriadias*
Black	*amegilla*
Purple	*megachilidae*

Appendix 7: Number of Seeds set from Sites MORRIS, VERO and POLLINATOR GARDEN

MORRIS		**VERO**		**POLLINATOR GARDEN**		
94 flowers set seeds	**SEED NUMBER**	104 flowers set seeds	**SEED NUMBER**	76 flowers set seeds	**SEED NUMBER**	**SEED TOTALS**
POV	7609	**POV**	7316	**POV**	4511	**19,436**
NP	7911	**NP**	8198	**NP**	6851	**22,960**
PNV	36	**PNV**	43	**PNV**	24	**103**
TOTALS	**12,751**		**12,231**		**8413**	**33,395**

Appendix 8: Temperature (◦C) and Precipitation (mm) Data for the period of Jan 2014 – July 2015

Elements	**Year**	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Precipitation (daily total)	2014	**47.9**	**48.3**	**54.4**	**132.1**	**242.6**	**265.2**	**113.8**	**308.5**	**172.0**	**218.0**	**162.8**	**67.8**
Precipitation (daily total)	2015	**3.4**	**52.2**	**210.6**	**368.3**	**293.9**	**229.8**	**146.0**					
Temperature (daily max)	2014	**27.5**	**29.2**	**29.6**	**28.7**	**27.5**	**27.5**	**27.6**	**27.9**	**27.9**	**27.8**	**28.2**	**29.2**
Temperature (daily max)	2015	**31.0**	**32.4**	**32.7**	**28.0**	**32.4**	**26.9**	**28.1**					