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DETERMINATION OF THE DIVERSITY AND ABUNDANCE OF INSECT POLLINATORS, CASE STUDY IN WEST BUGWE CENTRAL FOREST RESERVE IN UGANDA.

BY

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RESEACH REPORT SUBMITTED TO THE DEPARTMENT OF BIOLOGY IN THE PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE AND EDUCATION OF BUSITEMA UNIVERSITY

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DECLARATION

I MATEYA COSTANT do declare that this research report on determination of the diversity and abundance of insect pollinators, case study in west Bugwe Central Forest Reserve in Uganda is my own original work.

Signature; ……………………………………………

Date; ……25/09/2024……………………………

APPROVAL

This research report has been submitted for examination with the approval of my supervisor; Ms. Namusana Hellen

Signed.......Namusanah.............................. Date........25/09/2024..........

DEDICATION

This research report is dedicated to my parents Mr. Matsatsa Thomas and Nabulwala Florence, my sisters Nabushawo Mary and Nambuya Milia and my brother Shibale Joseph for tirelessly supporting me financially, spiritually and psychologically towards the completion of my course at Busitema University

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I am grateful for the collective efforts and support of these individuals, without whom this research would not have been possible.

Table of Contents

List of Figures

List of Tables

Abstract

A field survey was carried out in West Bugwe Central Forest Reserve with the aim of determining the diversity and abundance of insect pollinators found in this forest reserve with comparison to those ones found at the forest edges. Sampling was done after two days for a period of one month using sweep nets, scan sampling and pan traps. Insects pollinators collected were sprayed with insecticides to immobilize them before pinning and dried in the cage. Representative specimen were taken to the Biology laboratory for pinning and analyzing

A total of 706 insect pollinators belonging to 11 families and 5 orders were recorded. The largest number of insect pollinators were recorded from order Lepidoptera (415), followed with order Hymenoptera (211), then order Diptera (35) followed by order Hemiptera (28) and lastly Coleoptera had the least number recorded with a total of 17 insect pollinators. Among these orders, only two orders were analyzed to family level that is Lepidoptera and Hymenoptera, under Lepidoptera, the family Nymphalidae showed the highest abundance 265(64%), followed by Pieridae 75(18%), Papilionadae 32(6%), Hesperidae 26(3%) with Rhiodinadae having the least number 5(1%). Under order Hymenoptera, family Apidae had the most abundant number 147(82%) followed by Vespidae 17(9%) Megachilidae 5(3%), Colletidae 4(2%) and Halictidae (1%) recorded the lowest relative abundance. The highest species diversity was observed in the order Lepidoptera (H' =1.1107), while orders Hemiptera and coleopteran had the least (H'=0).

However, the habitat with the highest species evenness was the forest interior (0.5658). This information shows that West Bugwe Central Forest Reserve is an ecosystem hotspot for abundance and diversity of insect pollinators and therefore it should be conserved by the stakeholders and concerned bodies for the continued ecosystem health.

CHAPTER ONE: INTRODUCTION

1.1 Background

Tropical forests are essential to maintaining biodiversity and human well-being through provision of numerous ecosystem services (Brandon, 2014). These forests contribute to global climate regulation through carbon sequestration, water cycling, and atmospheric circulation (Bonan, 2008). Together with being home to a wide variety of plant and animal species, they are also biodiversity hotspots, supporting the habitats, migratory pathways, and genetic diversity necessary for ecosystem functioning (Stork & Habel, 2014).

These tropical forests also have great abundance and diversity of insect pollinators for example on global basis, there are more than 20,000 species of bees found in the world and they are the primary pollinators in the majority of ecosystems and almost all bees are pollinators (Wojcik, 2021). Fly populations, numbering about 120,000, are the second most common visitors to most flowers and this is followed by other insect pollinators which include wasps, and butterflies (Meena, Singh, Kant, Meena, & Solanki, 2015).

Africa as a continent is also a home of abundance and diversity of insect pollinator community including Uganda as a country (Munyuli, 2011). These insect pollinators are essential to the existence of life on Earth in addition to their contributions to ecological dynamics Insect (Hagen, 2023). The passage of pollen between flowers, enabling the formation of fruit and seeds in about 88% of flowering plants worldwide (Johnstone et al., 2016). Nonetheless, the majority of pollination services provided by both wild and cultivated plants are provided by members of the Class Insecta, who are specially adapted for the transportation of pollen. Flowering plants and insects are mutually dependent on each other as pollinators. Pollinators receive food rewards in the form of nectar and pollen. Numerous insect species are recognized as pollinators of different plant species. Plants are said to be pollinated by wasps, flies, beetles, moths, butterflies, and flies (Thapa, 2006).

Despite the significance of tropical forests as one of them include harboring of great abundance and diversity of insect pollinators with their crucial roles they play in the ecosystems as discussed above, reports indicate that there is a great decline in the forest area due to encroachment by humans and other environmental disturbances both globally and continentally (Hansen et al., 2001). For example in Africa, there has been decline in diversity and abundance of insect pollinators due to habitat loss for example clearing of tropical forests and use of pesticides (Munyuli, 2011). In Uganda, the case is not different as reports indicate that forest area was 45% in 1980, 29% in 2010 and 11.5% in 2021 (Nandala, 2023). This indicates that there has been continuous encroachment on forest habitat area by anthropogenic activities which has affected their ecosystem service for example decline in diversity and abundance of insect pollinators (Adla, Dejan, Neira, & Dragana, 2022).

Additionally, in Uganda basically some of the central forest reserves which have undergone depreciation in the abundance and diversity of insect pollinator as per reports include; Mabira Forest Reserve as this is caused by deforestation for agriculture, urbanization and logging have caused decline in diversity and abundance of insect pollinator. Budongo Forest Reserve, as decline in abundance and diversity of insect pollinators has been caused by logging, charcoal burning and agricultural expansion on the ecosystem (Babweteera et al., 2012). Kibale National Park as decline in insect pollinators has been caused by agricultural expansion, livestock grazing and human settlement on the ecosystem (Raina, Kioko, Zethner, & Wren, 2011).

In eastern Uganda, West Bugwe Central Forest Reserve is not exceptional. This forest has undergone a lot of depreciation due to anthropogenic activities like deforestation, charcoal burning, mining timber cutting among others, these activity has an effect on the abundance and diversity of insects especially pollinators of the world flora and fauna. Studies like assessment of Forest Degradation (Mutesi, Tabuti, & Mfitumukiza, 2021), and Biodiversity and Ecological Analysis of trees , have been conducted in West Bugwe Central Forest Reserve (Wabugwa, 2022). However, there is scanty literature on the abundance and diversity of insect pollinators in West Bugwe Central Forest Reserve. This has therefore compelled the researcher to add on the body of knowledge by determining the abundance and diversity of insect pollinators in West Bugwe Central Forest Reserve, Uganda.

1.2 Problem statement

A growing body of evidence indicates that insect populations are in steep decline in both temperate sand tropical regions (Sánchez- Bayo & Wyckhuys, 2021) raising concerns about the long-term health and sustainability of both natural and anthropogenic areas. Of these declining populations are insect pollinators that play a vital role in population of leading global cash and food crop production (Nath, Singh, & Mukherjee, 2023). Insect pollinators also promote eco-tourism and foreign exchange, and with current declines, these services will be lost (Sharma & Birman, 2024).

Dramatic decline in the diversity and abundance of insect pollinators and a reduction in yield of the crops they pollinate have been also reported in many countries, including North America (Manel, Williams, & Ormerod, 2001) and Europe (Colla & Packer, 2008).

Additionally, in East Africa, reports also indicates that there has been increasing decline in the diversity and abundance of insect pollinators for example Kakamega tropical forest in Kenya as being caused by climate change and habitat degradation (Kiatoko, Raina, & Van Langevelde, 2017), Nyungwe Forest in Rwanda where pollinator diversity and abundance has decreased due to forest fragmentation and degradation and this has been the same case with Udzungwa tropical forest in Tanzania.

In Uganda, also studies have shown the decline in the diversity and abundance of insect pollinators for example in Budongo (Babweteera et al., 2012), Semiliki and Kibale tropical forest where pollinator diversity has decreased due to habitat loss, fragmentation, climate change, urbanization and agricultural expansion. This seems to be the same case with West Bugwe Central Forest Reserve, a tropical forest in Eastern Uganda as the forest is being threatened by anthropogenic activities like lumbering, charcoal burning mining among others (Mutesi et al., 2021). Therefore, the ultimate aim of this study is to identify the insect pollinators found in West Bugwe Central Forest Reserve and also to compare their abundance and diversity

1.3 Research objectives

1.3.1 General objectives

To determine the abundance and diversity of insect pollinators in West Bugwe Central Forest Reserve

1.3.2 Specific objectives

1. To identify the insect pollinators found inside West Bugwe Central Forest Reserve the forest

2. To compare the abundance and diversity of insect pollinators found inside the forest and the forest edges of West Bugwe Central Forest Reserve.

1.4 Hypothesis

1.4.1 Null hypothesis

There is no significant difference in the abundance and diversity of insect pollinators found inside the forest and the forest edges

1.4.2 Alternative hypothesis

There is significant different in the abundance and diversity of insect pollinators found inside the forest and the forest edges

1.5 Significance of study

This study may be significant in the following ways;

Insect pollinators are important for crop production therefore knowing the diversity and abundance of insect pollinators in West Bugwe Central Forest Reserve will inform strategies for maintaining and enhancing agricultural services

Knowing the diversity and abundance of insect pollinators found in the forest can be marketed as a unique tourist destination, supporting local economies

Understanding the abundance and diversity of insect pollinators found in West Bugwe Central Forest Reserve will help to identify the areas that require protection and conservation efforts, ensuring the long-term health of ecosystems and services they provide

1.6 Justification of study

This study will provide a baseline data on the abundance and diversity of insect pollinators found in West Bugwe Central Forest Reserve.

Insect pollinator data will provide information necessary as a useful tool for biodiversity monitoring and sustainable forest habitat use.

Since the area of disturbed habitats and converted landscapes is increasing in tropical countries which contribute to climate change, the study provided base line data that can be used as a guide for conservation and management programs on areas that are being converted from natural forests

Insect pollinators are also a major tourist attraction. Therefore, knowing the diversity and abundance aided in identifying the suitable tourism sites.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Insect pollinators, comprising bees, butterflies, months, beetles, and flies, play a vital role in maintaining the ecosystem health and productivity worldwide (Dar, Lone, Parey, Hassan, & Rather, 2017). These small creatures are responsible for pollinating plants allowing them to reproduce and set seed, and are important for the production of many crops that humans depend on for food security (Peixoto et al., 2022). However, insect pollinators are facing numerous threats including habitat destruction, pesticide use, climate change and disease which can lead to their biodiversity and abundance decline (Vanbergen & Initiative, 2013).

Biodiversity in an ecosystem is paramount in in keeping ecosystem resilience and function (Singh, 2024). This is achieved as pollinators are a key components of this biodiversity, and their degeneracy can have cascading effects on ecosystem health (Nath et al., 2023). Abundance is also crucial as it impact the effectiveness of pollination services.

Despite their importance, insect pollinators are overlooked in conservation efforts, and their populations are declining at threatening rate (Vanbergen & Initiative, 2013). For example, many bee species are facing extinction due to habitat loss and fragmentation, and butterflies are experiencing significant declines due to pesticide use and habitat destruction (Goulson, Nicholls, Botías, & Rotheray, 2015).

2.2. The importance of insect pollinators

The economy of every country in the world is strongly dependent on pollination. Because they benefit humans in numerous ways, such as higher food yields and the production of honey, insects are important pollinators (Khalifa et al., 2021). Moreover, the worldwide value of pollination services is tightly linked to crop output, which has an estimated yearly value of $577 billion(Breeze, Gallai, Garibaldi, & Li, 2016).The world's food supply would decline without insect pollinators, increasing production costs for consumers. According to (Aizen, Garibaldi, Cunningham, & Klein, 2009) 35% of global crop production in terms of volume and 70% of the world's crops depend on animal pollinators.

Insect pollinators benefit adjacent towns mostly by increasing crop productivity and providing additional benefits (Tolera & Ballantyne, 2020). Pollinating insects play an important role in maintaining biodiversity and the operation of the ecosystems, but they are also vulnerable to human disturbances and rigorous management (Bongers et al., 2015).

2.3.0 Abundance of insect pollinators

Insect pollinators, such as bees, butterflies and moths, are abundant in various ecosystem worldwide. According to estimates, there are approximately 200,000 to 400,000 species of insect pollinators globally, with bees and butterflies being the most diverse groups (Tanda, 2022).

The abundance of insect pollinators varies across different regions and habitats. Tropical forests, for example, have the highest abundance of insect pollinators, with up to 1000 species per hectare (Ricketts, 2004). In contrast, agricultural landscapes have lower abundance, with up to 100 species per hectare. This variation is largely due to differences in habitat quality, availability of food resources, and exposure to environmental stressors. Despite their importance, the abundance of insect pollinators is declining and researchers have tried to observe the trends of these insect pollinators as below:

2.3.1 Global trends.

A study published in Biological Conservation estimated that 17% of insect pollinator species are threatened with extinction (Allen-Wardell et al., 1998), the Intergovernmental Science- policy Platform on Biodiversity and Ecosystem Services (IPBES) reported that 16% of pollinator species are threatened globally (Potts, Imperatriz Fonseca, et al., 2016).

2.3.2 Regional patterns

In North America, a study found that bee abundance declined by 23% between 2008 and 2013(Koh et al., 2016), in Europe, a study reported that butterfly abundance declined by 35% between 1990 and 2010 (Warren et al., 2021).

In Africa, in some countries like South Africa, a study on ecosystems found 30% decline in pollinator abundance between 2000 to 2010 (Potts et al., 2010), in Ghana a 15% decline was recorded in a year between 2010 to 2015 (Nasare, Kwapong, & Doke, 2019), in Nigeria, 10% decline in pollinator abundance was recorded (Olatoye, Ohseok, & Akinwande, 2024), while in East Africa for example in Kenya’s savannah ecosystems, a study recorded a 25% decline in pollinator abundance between 1995 to 2010 (Ochungo et al., 2021). This has been the case in

Uganda for example studies which have been carried out on forest ecosystems like Mabira forest, Budongo forest have also showed that there has been a decline in pollinator abundance (Babweteera et al., 2012).

2.4.0 Diversity of insect pollinators

Pollinating insect diversity and numbers have been decreasing globally. Studies on wild bees and butterflies in North West Europe and North America have shown a decline in regional variety and abundance. The loss of pollinators is a serious worry since they offer an essential environmental service (Potts, Imperatriz-Fonseca, et al., 2016).

The floral fidelity of other pollinators may be lowered by the extinction of a specific pollinator species, claims indicate that there are disturbing considerations about food security and the stability of ecosystem functioning due to the alarming drop of pollinators (Akter, 2021).

According to (MacInnis, Buddle, & Forrest, 2020) the diversity and number of wild bees were found to be declining in relation to their distance from natural habitats such as forests and field margins. Additionally, it has been noted that the diversity and quantity of non-bee pollinators, such as moths and butterflies, are diminishing (Requier et al., 2023). Insect pollinators, such as butterflies and bees, are highly prevalent, according to assessments of pollinators conducted at the national and regional levels (Dicks et al., 2021). For instance, it has been discovered that the populations of 37% of bees and 31% of butterflies are dropping, and that 9% of butterflies and 9% of bees are vulnerable.

2.5 Factors that affect abundance and diversity of insect pollinators

Insect pollinators are exposed to environmental pressures that are linked to their shifts in diversity, abundance and occurrence. Habitat transformation may lead for example anthropogenic activities on natural habitats like forests may lead to change in the type of land cover and may consequently lead to the disappearance of habitats for many species (Radić & Gavrilovic, 2021). It has been noted that pollinator species richness, composition, and population sizes are directly affected by degradation (Potts et al., 2010).

According to (Patrício-Roberto & Campos, 2014), insect pollinators decline significantly due to habitat conversion and loss of habitat elements like nesting and foraging sites. The loss of natural like forests habitats due to anthropogenic activities have significant negative effect on pollinator communities (López-Vázquez, Lara, Corcuera, Castillo-Guevara, & Cuautle, 2024). It acts through mechanisms that reduce reproduction and survival of insect pollinators (Frankel & Galun, 2012). These mechanisms include the loss forage and breeding habitat, population sub division and genetic drift, and interspecific interactions (Frankel & Galun, 2012). According (Gebre, 2015) indicated that the loss of floral resources and nesting sites associated with deforestation affect insect pollinator population with demonstrable economic consequences. According to (Vanbergen, 2014) also confirmed that pollination and reproduction of animal pollinated plants is negatively affected by habitat loss due to decrease in population of pollinators. Reduced diversity and numbers of pollinators' results in reduced yield of the plants they pollinate, and if this is not mitigated, it may result in extinction in both groups (Shivanna, Tandon, & Koul, 2020).

One of the consequences of natural habitat destruction like forests is the isolation of insect pollinators resulting in reduced genetic vigor, as well as increased genetic drift between isolated populations (Sen & Ravikanth, 2022).

The anthropogenic activities within natural forests may also play a role in insect pollinator population dynamics (Campbell et al., 2018). This affects species richness, abundance and community structures (Fortel et al., 2014). West Bugwe Central Forest Reserve is not exceptional as it has been encroached on by the surrounding communities. A series of activities like deforestation has destroyed the habitat of organism including insects (Mutesi et al., 2021).

CHAPTER THREE: METHODS AND MATERIALS

3.1 Study Area

The study was conducted in West Bugwe Forest Reserve a tropical forest with medium altitude, moist and semi deciduous forest (Davenport et. al 1996). It is located in Busia District in South Eastern Uganda lying between 0030^{o}- 0033^{o}N and3096^{o} – 3096^{o}E. It covers an area of $31km^{2}$ with an altitudinal range of 1102 – 1136m (Davenport et. al 1996) (Fig.1).

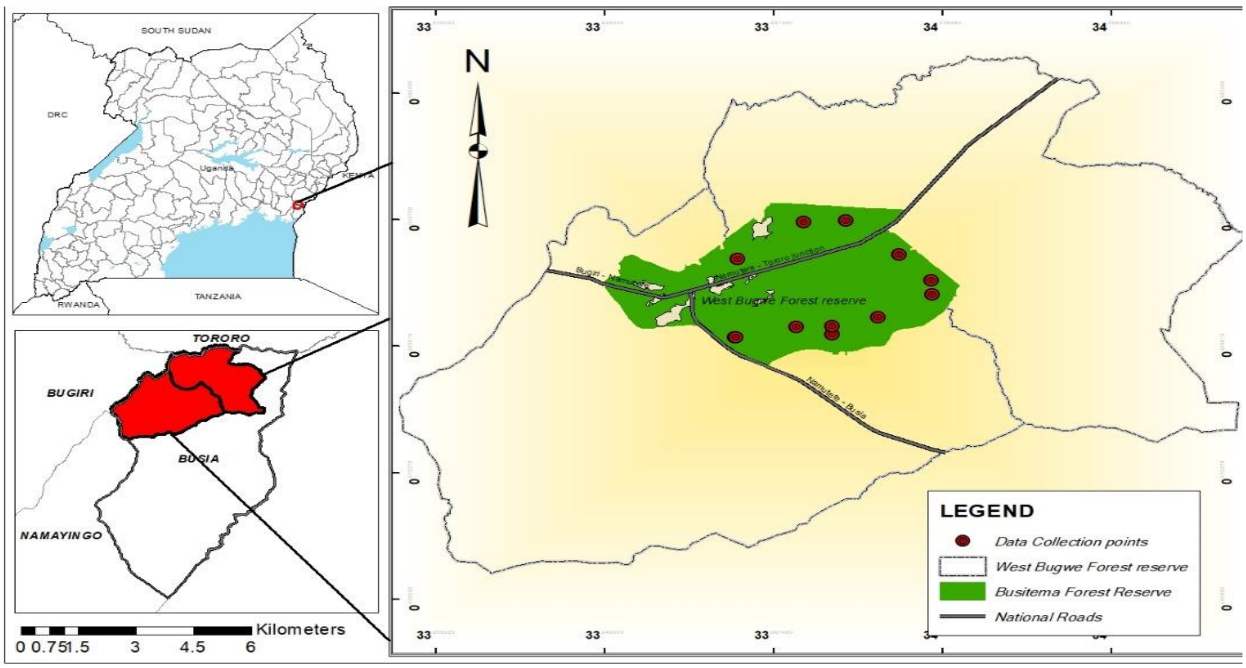

Fig 1. Map of West Bugwe Central Forest Reserve showing study site

The forest reserve is divided into three blocks namely; Sidimbire central block with 3054ha (79%), Sitambogo block with 650ha (17%) and Amonikakakenyi block with 163 ha (4%). The reserve also covers three sub-counties that is to say; Bulumbi, Buyanga and Busitema. The area receives an annual rainfall of about 1180 mm with a double maxima and minima temperature of $28.7^{0}C$and $16.2^{0}C$ respectively (Meteorological site by NEMA, 1999b). The area has ferric soils which are mainly sandy loam that favor subsistence agriculture practices (NFA, 2006).

3.2 Study sites

The forest was stratified or divided into two zones by basing on Kampala-Malaba road that bisects it. A total of ten separate sites were sampled. Each sampling site was at distance of 1-2km separate from each other. One transect (100m long and 10m wide) were established at some sites where pan traps were set, one transect (10m×10m) (Templ et al., 2019), was established at points where sweep netting was done in open places of kilns within the forest. All the sampling was done at these sites after taking a distance of 1km from the forest edge into the forest interior.

3.3 Insect pollinator sampling and collection

Insect pollinator sampling was performed after every two days for a period of one month. Three types of methods were used to collect insect pollinators that is to say sweep netting, use of pan traps and scan sampling.

3.3.1 Sweep netting

Sweep net was used to collect insect pollinators inside the forest in areas surrounding kilns where charcoal had been removed and a total of five kilns were sampled using this method. This sweep netting was done within a distance of 10m×10 m that is to say from the kiln to the surrounding area where there was vegetation cover. The insect pollinators was recorded from 8:00AM to 4:00PM. The insect pollinators collected were sprayed using insecticide to immobilize them sorted, identified and pinned in a cage.

Fig 2a. Sweep netting of insect pollinators in kiln recovering with plant species after charcoal burning

From (Fig 2a.) insect pollinators were collected an open area surrounding a forest kiln which was surrounded with herbaceous plants after charcoal burning in West Bugwe Central Forest Reserve.

Fig 2b. Sweep netting of insect pollinators in a forest kiln where mining had taken place

From (Fig 2b) above, the insect pollinators were collected from an area surrounding forest kiln recovering with grass after mining had taken place in West Bugwe Central Forest Reserve.

Fig 2c. Sweep netting of insect pollinators around a kiln where charcoal burning had taken place.

From (Fig 2c) above, insect pollinators were collected from the vegetation around a fresh kiln where charcoal burning had taken pace in West Bugwe Central Forest Reserve

Fig 2d. Sweep netting of insect pollinators around a recovering kiln after charcoal burning

From (Fig 2d) above, insect pollinators were collected in kiln revering with herbaceous vegetation more especially Amarathus after charcoal burning had taken place in West Bugwe Central Forest Reserve

3.3.2 Use of pan traps

Pan traps of different colours mainly white, yellow green and red were used at sampling sites identified with scattered shrubs and grasses within the forest (Krahner, Dietzsch, Jütte, Pistorius, & Everaars, 2024). A bundle of three pan traps were placed after every 10m from each other along a line transect of 100m long. These pan traps were placed at a height of 1m above the ground and were filled with 300ml of water and odorless soap less detergent (Jaques, Jofré-Pérez, Murúa, Vieli, & Fontúrbel, 2023). Then they were left for 24hours after which the insect were collected after immobilizing them with an insecticide, sorted, identified using identification keys and pinned in a cage.

Fig 3a.

From (Fig 3a) , the pantraps were set to capture the insect pollinators within the interior of West Bugwe Central Forest Reserve

Fig 3b.

From Fig 3b pantraps were checked after 2 days of setting them and any insect pollinator found caught was picked

Fig 3c

From Fig 3c, pan traps were having some insect pollinators which they had captured after two days of setting them

3.3.3 Scan sampling

Scan sampling was done along the treks after every distance of 100m for 1000m from the forest edge (Peterson, 2022). Scan sampling was done in two different periods that is say in the morning from (8:00am to 10:00am) and afternoon from (2:00am to 4:00pm).

Fig 4a. Coleoptera scan sampled pollinating the flower

From (Fig 4a) above, the Minotaur beetle (order Coleoptera) as one the insect pollinators was scan sampled while pollinating a flower of a Lantana camara along the forest trek of West Bugwe Central Forest Reserve

Fig 4b. Lepidoptera scan sampled pollinating the flower

From (Fig 4b) above a butterfly (order Lepidoptera) as one insect pollinators was scan sampled pollinating a flower in a forest canopy in West Bugwe Central Forest Reserve

Fig 4c. Apidae scan sampled pollinating a flower

From(Fig 4c) above, a bee (Oder Apidae) one of the insect pollinators was scan sampled pollinating a flower on one of the plant species which had grown around the kiln in West Bugwe Central Forest Reserve

3.4. Data analysis

In this study, two traits of pollinator assemblage were analyzed that is, abundance (total number of insect pollinators in an area) and diversity. Assessment of diversity was calculated by species evenness and dominance. Diversity was calculated using the Shannon-Weiner diversity index (H

'= - Σ pi ln pi) where **p** is the proportion n/N of one particular species (**n**) and **N** is the total number of species

The abundance of insect pollinators was calculated using the Simpson index ($D = \Sigma (ni/N)^2$) where **N** is number of individuals of all species and **ni** is number of individuals of species i.

T-test and Analysis of Variance (ANOVA) was used to compare the diversity and relative abundance of insect pollinators between the forest interior the forest edges.

CHAPTER FOUR: RESULTS

4.1 Diversity of Insect pollinators

A total of 706 insect pollinators belonging to 11 families and 5 orders were recorded collected using three different methods. The results show that sweep nets collected the highest number of insect pollinators (315) followed by pan traps (250) and lastly scan sampling (142), as shown in (Fig 5).

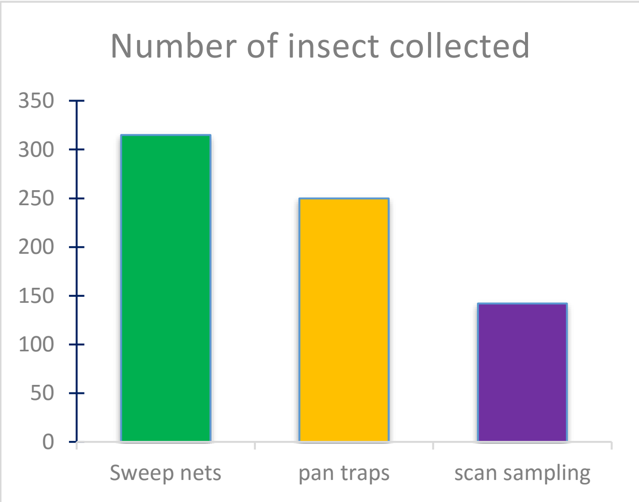

Fig 5. The number of insects collected by the three methods

From the three methods used to collect insect pollinators, the results show that sweep nets collected the highest number of insect pollinators (315) followed by pan traps (250) and lastly scan sampling (142), (Fig 5) below. This was so because sweep nets was used to collect insect pollinators around the forest kilns dominated with herbaceous vegetation which had a lot of flowers which attracted many insect pollinators hence making sweep netting to record highest number of insect pollinators, it was followed by pan traps because they were of different colours resembling different flowers therefore luring and capturing insect pollinators however the number was less than that of sweep netting because this pan traps were set at a distance of one meter above the ground so they were obstructed by the dense vegetation of the forest which hindered clear visibility to insect pollinators and scan sampling recorded the least number because of the dense vegetation which hindered clear scanning of the first moving insect pollinators and also the camera was not so clear at scanning

The largest number of insect pollinators were recorded from order Lepidoptera (415), followed with order Hymenoptera (211), then order Diptera (35) followed by order Hemiptera (28) and lastly Coleoptera had the least number recorded with a total of 17 insect pollinators. Among these orders, only two orders were analyzed two family level that is Lepidoptera and Hymenoptera, under Lepidoptera, the family Nyaphalidae showed the highest abundance 265(64%), followed by Pieridae 75(18%), Papilionidae 32(6%), Hesperidae 26(3%) with Rhiodinadae having the least number 5(1%). Under order Hymenoptera, family Apidae had the most abundant number 147(82%) followed by Vespidae 17(9%) Megachilidae 5(3%), Collectidae 4(2%) as in (Fig 9)

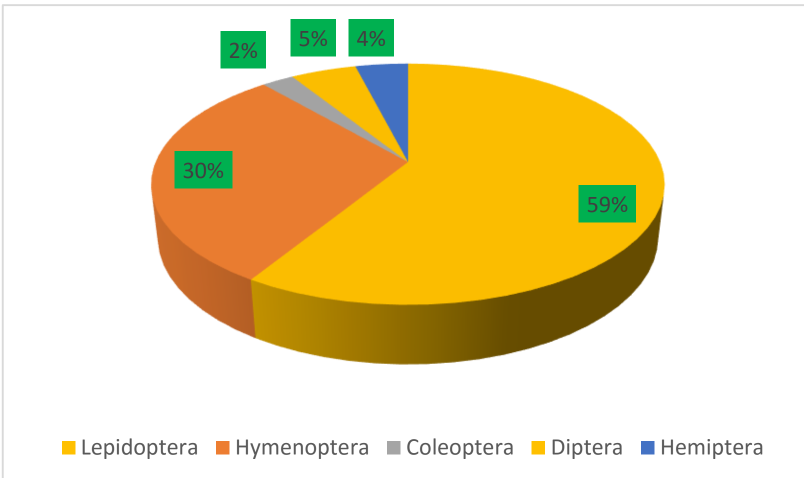

Fig 6. The orders of insect pollinators collected in the interior of the forest

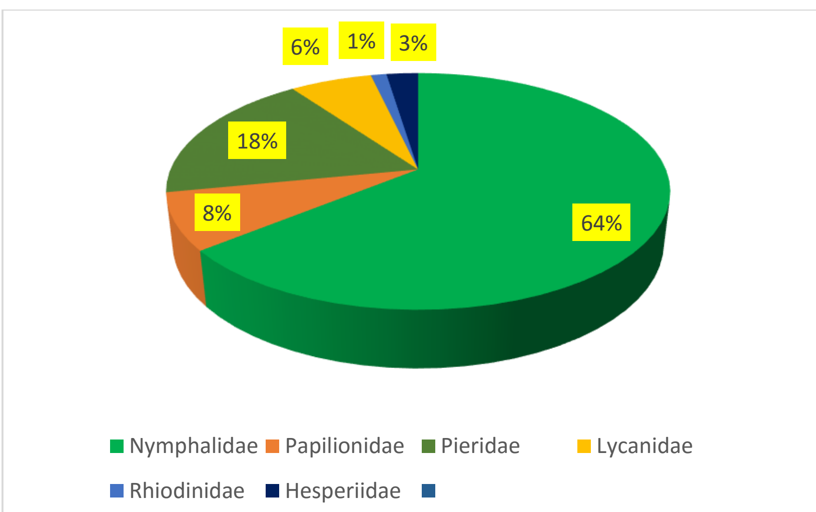

Fig 7. The families of order Lepidoptera collected in the forest interior

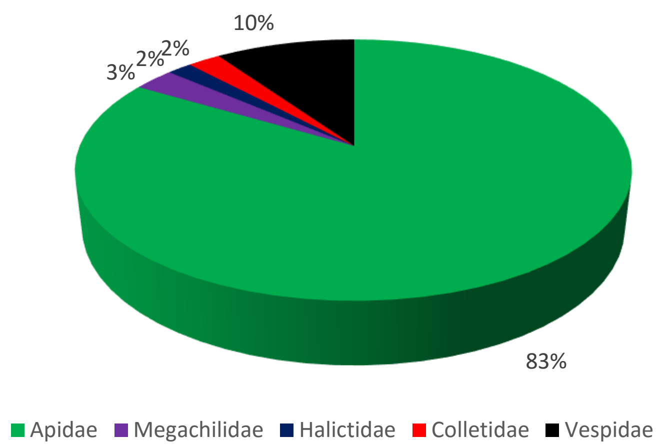

Fig 8. The families of order Hymenoptera collected in the forest interior

4.2 Relative abundance of insect pollinators

Nymphalidae had the highest relative abundance (44%) from order Lepidoptera followed by Apidae (25%) from order Hymenoptera and Pieridae (13%). Families like vespidae, lycanidae, Papilionidae and Hesperidae recorded relative abundance of 3%, 4%, 5% and 2% respectively. Families like Rhiodinidae, collectidae and Megachilidae recorded 1% (Fig 9).

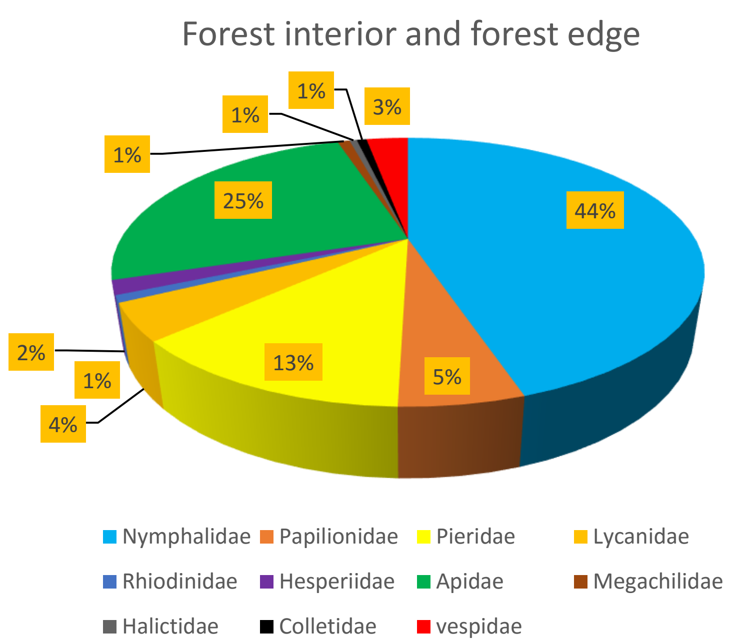

Fig 9. Relative abundance of families of order Lepidoptera and Hymenoptera in the forest interior

The family Nymphalidae recorded a high relative abundance of 256 members from the forest interior as compared to their counterpart from the forest edge which recorded 172 members, the family Apidae recorded 317 members from the forest edge as compared to 147 members recorded from the forest interior, the family Peridae also recorded the same relative abundance of 75 and 65 members from the forest interior and the edge respectively, Lycanidae recorded 26 from the interior and 21 from the edge, Papilionidae recorded 32 from the interior and 2 from the edge, Rhiodinadae recorded 5 from interior and 11 from the edge, Hesperiidae recorded 10 from the interior and 26 from the edge, Megachilidae recorded 5 from interior and 12 from the edge Halictidae recorded 30 from the interior and 30 from the edge and Vespidae recorded 17 from interior and 36 from the edge, Collectidae recorded 4 from the interior and 15 from the edge (Fig 10) below. This showed that Lepidoptera prefers a stable microhabitat provided by dense vegetation for example family like Nymphalidae was mostly dominant at sides of the forest dominated with shrubs while the family Lycanidae was abundant in areas of the forest with canopies this indicated specific microhabitats preference among these insect pollinators.

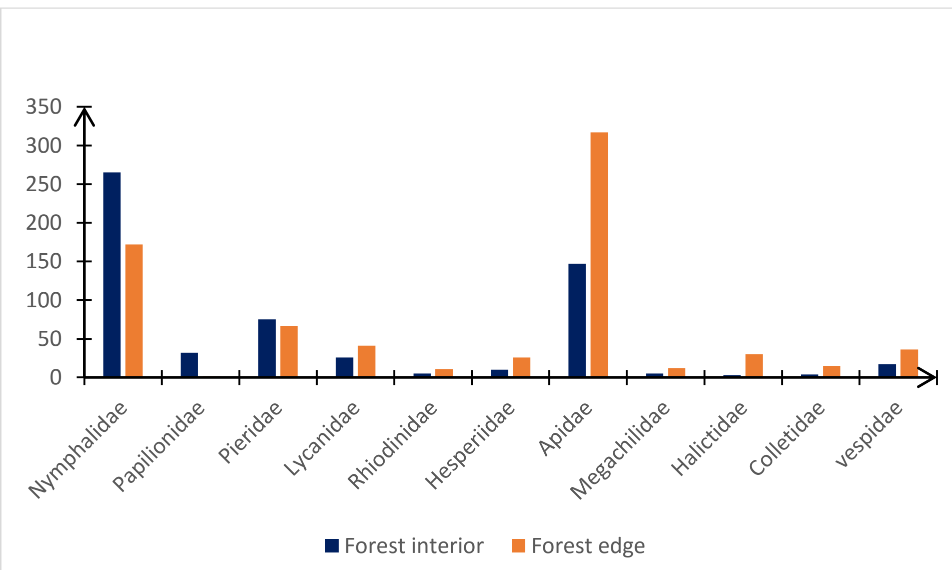

Fig 10. Relative abundance of insect pollinators at family level of orders Lepidoptera and Hymenoptera between forest edge and forest interior

4.3 Diversity indices of insect pollinators

Table 6.1. Results showing Shannon-Weiner and Simpson diversity indices.

	Forest edge	Forest interior
Taxa_S	5	5
Individuals	808	706
Dominance_D	0.4176	0.4395
Simpson_1-D	0.5824	0.5605
Shannon_H	1.03	1.04
Evenness_e^H/S	0.5602	0.5658

The diversity indices showed that the forest edge has more abundant insect pollinators (808) as compared to the forest interior (706), whoever, the forest interior has more diversity of insect pollinators (H' = 1.04) and evenness (0.5658) as compared to the forest edge's diversity (H =1.03) and evenness (0.5602) but the number of orders recorded were the same (5)

Table 6.2. Relative abundance of insect pollinators in different habitats

Habitat	number of species	Evenness	Relative abundance
Forest edge	808	0.5602	53.37
Forest interior	706	0.5658	46.63

From table 6.2, results showed that the forest interior had more species evenness (0.5602) as compared to the forest edge

Table 6.3. The two-way ANOVA showing results for significance difference between forest edges and Forest interior at 5% confidence interval.

Tests for equal means					
Forest interior	Forest edge				
N:	5	N:	5		
Mean:	141.2	Mean:	161.6		
95% conf.:	(-73.289)	95% conf.:	(-72.656)		
Variance:	29839	Variance:	35515		
Difference between means:	20.4				
95% conf. interval (parametric):	(-243.2404)				
95% conf. interval (bootstrap):	(-177.838)				
t :	0.17843	p (same mean):	0.86282	Critical t value (p=0.05):	2.306
Uneq. var. t :	0.17843	p (same mean):	0.86285		
Monte Carlo permutation:	p (same mean):	0.8747			
Exact permutation:	p (same mean):	0.87302			

From the above table 6.3, the Two-Way ANOVA statistical analysis at 5% showed no significant difference in species diversity and abundance of insect pollinators between the forest interior and forest edge since the calculated t-value (0.17843) was less than the critical t-value (2.306), and the p-value was greater than the significant level (0.05), this fails to reject the null hypothesis (HO).

4.4 Limitations of the study

1. Some parts of the forest had thick an impenetrable vegetation cover which hindered me from accessing them. The thick vegetation also made use of sampling methods like sweep netting almost impossible.

2. Sampling in dense forest was labour intensive and time consuming then I used scanning

3. There was some degree of bias due to fear of dangerous wild animals like snakes found inside the forest. I used some routes already established in the forest.

4. The research was quite expensive in terms of buying equipment's for use like pan traps, insect cage, permission from National Forest Authority and transport fee which slowed the process of executing it

5. It took time to get clearance from the National Forest Authority and yet there was a signed MoU with Busitema University to use the forest for study purposes.

CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1. Discussion

A total of 706 insect pollinators were collected during the survey period in West Bugwe Central Forest Reserve and my results revealed a total 5 orders (Fig 5), 11 families (Fig 6) and (Fig 7) of insect pollinator species which were collected in the forest interior of West Bugwe Central Forest Reserve. A total of 564 individual insect pollinators were collected using pan traps and sweep nets while 142 individual insect pollinators were scan sampled. Different methods were used to collect these insect pollinators. My findings agrees with the report of Gill & O'neal, (2015) who showed that using a combination of methods gives better species richness data.

The insect pollinators in the interior of the forest were distributed according to the different vegetation covers which constitutes the forest and also in accordance to the anthropogenic activities occurring within the forest. The highly abundant and diverse order was Lepidoptera (butterflies and moths) which recorded six families (Nymphalidae, Pieridae, Papilionidae Lycanidae, Rhiodinadae and Hesperidae) followed by order Hymenoptera (which includes bees wasps and aunts) which recorded five families (Apidae, Megachillidae, Collectidae, Halictidae and vespidae). This showed that Lepidoptera prefers a stable microhabitat provided by dense vegetation for example family like Nymphalidae was mostly dominant at sides of the forest dominated with shrubs while the family Lycanidae was abundant in areas of the forest with canopies this indicated specific microhabitats preference among these insect pollinators. The distribution patterns among these Lepidoptera in accordance to vegetation cover emphasise the importance of habitat structure. This study is in agreement with the report (Carneiro, Mielke, Casagrande, & Fiedler, 2014) which shows that species richness is often linked to habitat complexity; therefore areas with varied vegetation types can support a greater diversity of Lepidoptera as insect pollinators

While looking at areas with anthropogenic activities it was found that deforested sites where charcoal burning had taken place, recorded highest diversity of insect pollinators more especially from the order Hymenoptera compared to other sites that experienced other anthropogenic activities like lumbering. This could be due to presence of abundant dicotyledonous weeds that were growing especially from sites of previous charcoal mounds where the soils had extra nutrients and minerals from the burned trees. The hymenoptera with in the forest were abundant and diverse where charcoal burning had taken place as compared to Lepidoptera and other orders of insect pollinators and this agrees with (Wafubwa & Ndong'a Millicent, 2019),which showed that charcoal burning can alter local biodiversity dynamics. Charcoal burning can to changes in vegetation structure and composition, which potentially favor certain pollinator species as compared to others.

Finding from my study also found out that insect pollinators found inside the forest interior is not different from that found at the edge of the forest as equal number orders of insect pollinators were recorded from both sites this indicated that the ecological habitat in the forest interior and the forest edge in terms of insect pollinator preference is less or more similar, however at the forest edges, the order hymenoptera was more abundance and diverse compared to other orders like Lepidoptera this is in agreement with (González, Salvo, & Valladares, 2017) which shows that forest edges often provide a different microclimate compared to the interior of the forest including increased sunlight, which enhance floral resources available for these insect pollinators. The disturbance from human activities often leads to an increase in herbaceous plants that attract these insect pollinators (Totland, Nielsen, Bjerknes, & Ohlson, 2006).

The Two-Way ANOVA statistical analysis at 5% (Table 6.3) showed no significant difference in species diversity and abundance of insect pollinators between the forest interior and forest edge since the calculated t-value (0.17843) was less than the critical t-value (2.306), and the p-value was greater than the significant level (0.05), this fails to reject the null hypothesis (HO), this is in agreement with (Proesmans, Bonte, Smagghe, Meeus, & Verheyen, 2019) who got similar findings. This indicates that the forest edge and interior have similar habitat characteristics, leading to similar pollinator communities (Andrieu et al., 2018), also this could be attributed to the fact that the forest edge and interior are ecologically connected, allowing pollinators to move freely and maintain similar populations (Gutiérrez-Chacón, Dormann, & Klein, 2018).

5.2. Conclusion

The ultimate aim of this study was to determine the abundance and diversity of insect pollinators found in West Bugwe Central Forest Reserve and compare it with that found at the forest edges.

The study found out that there is no significant difference in the abudance and diversity of insect pollinators found between the forest edge and the forest interior

Observations made in the field during this study showed that anthropogenic activities like charcoal burning affect negatively some of insect pollinators for example Lepidoptera pollinator species were less diverse and abundant in area where charcoal burning had taken place. The study also observed that the forest edges and forest interior ecological habitats are connected as they share the almost similar abundance and diversity of insect pollinators however species evenness and diversity increases as you advance into the interior of the forest ecosystem. This study has revealed that there are a diverse groups of insect pollinators. Others being more abundant at the forest edges and recovering kilns of the forest for instance. More of the insect pollinators were observe in undisturbed areas of the forest.

5.3. Recommendation

- West Bugwe Central Forest Reserve harbors a diversity of insect pollinators. Communities near the reserve be sensitized and participate in insect biodiversity conservation.
- Strategies be developed and regulations by the Government and National Forest Authority to minimize deforestation and charcoal burning as it reduces the diversity and abundance of insect pollinators.
- Furfure studies to be carried out to determine the differences in pollinator communities since this was just a baseline study
- More studies on pollinator diversity should be carried out in the other parts of the forest reserve for a longer period of time

Appendix

Appendix 1. Insect pollinators of Orders Hemiptera, Coleoptera, Diptera and Hymenoptera collected from West Bugwe Central Forest Reserve preserved in a cage

Appendix 2. The Lepidopteran families preserved in the cage after collections from West Bugwe Central Forest Reserve

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