BUSITEMA UNIVERSITY
Pursuing Excellence

P.O. Box 236, Tororo, Uganda
Gen: +256 - 45 444 8838
Fax: +256 - 45 4436517
Email: info@adm.busitema.ac.ug
www.busitema.ac.ug

ASSESS INSECT POLLINATOR DIVERSITY AND RELATIVE ABUNDANCE IN WEST BUGWE CENTRAL FOREST RESERVE, BUSIA DISTRICT.

BY

KITAYI SOLOMON

BU/UP/2021/1619

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

SEPTEMBER, 2024

Abstract.

The pollination of plants by insects is one of the most important and essential ecosystem services in natural and agricultural landscapes. This is because they mediate the transfer of pollen from the anther to the stigma leading to fertilization. This study aims at determining insect pollinator diversity and abundance along forest edges of West Bugwe Central Forest Reserve. Three methods of insect collection were employed during the study period that is, sweep netting, pan-traps and scan sampling. A total of 808 insect pollinators were collected from the various sampling points that were identified using the Global Positioning System. Specimens collected were preserved in bottles containing 70% alcohol, identified using appropriate keys and later pinned in insect cages. The most abundant order was Hymenoptera (51%) followed by Lepidoptera (39%) and Diptera (1%) was the least abundant order. The most dominant families were Apidae (43%) and Nymphalidae (23%) while the least abundant families were Papilionidae (0.51%) and Stenotritidae (0.22%). The results showed that the forest edge habitat had a higher diversity and abundance of insect pollinators (H'=0.5624) and lower in the forest interior habitat. Therefore, it was concluded that different types of habitats affect the diversity and abundance of insect pollinators.

Keywords: Forest edge, diversity, abundance, insect, pollinator

Declaration

I KITAYI SOLOMON do declare that this research proposal on the ''Assessment of insect pollinator diversity and relative abundance in West Bugwe Central Forest Reserve, Busia district'' is entirely original, genuinely done by myself and it has never been presented at any university or academic institution for any award.

Signature..

Date.....19/09/2024.........

Approval

This research proposal has been submitted for examination with the approval of my supervisor, Madam Namusana Hellen.

Signed..............................

Date......19/09/2024......

Table of Contents

List of Figures.

List of Table

Dedication

I dedicate this dissertation to my mother Ms. Namono Rose, My sisters, Nelima Annet and Namikoye Harriet for their support throughout the course of my studies.

Acknowledgement.

First i want to thank God for his guidance and wisdom during compiling of my report. In a special way, I want to thank my supervisor, Madam Namusana Hellen for her constant guidance and support. I also want to appreciate my colleague, Mateya Costant for the teamwork, cooperation and encouragement during the study period and analysis of data. May God bless you.

CHAPTER 1.0: INTRODUCTION.

1.1 Background

Tropical forests are decreasing quite rapidly as a result of increased rates of deforestation for a number of reasons such as production of timber, construction and agriculture (Zhang et al., 2005). Globally, reports indicate that there is a great decline in the forest area due to encroachment by humans and other environmental disturbances. This has endangered the future of endemic plants species and animals inhabiting forest ecosystems as evidenced by reductions in species diversity (Corlett, 2016).

Insect pollinators mediate the exchange of pollen in flowering plants. Therefore, pollination is a fundamental ecological process that has influenced the diversity of many plant species throughout the evolutionary history (Barrett, 2010). These services sustain 80% of flowering plants because they significantly maintain biological relationships with other organisms as well as performing their role as pollinators (Kevan et al., 2011). Pollinators directly link the productivity of flora and fauna in almost all terrestrial ecosystems(Bailey et al., 2014)and these insect pollinators play a vital role in the pollination process of many flowering plants in both the natural and agricultural lands (Bentrup et al., 2019). Majority of flowering plants are pollinated by insects such as bees, butterflies, flies, beetles among others (Ollerton et al., 2011) with bees being the most effective pollinators of many plant species.

Worldwide, there are over 20,000 species of bees and they are the primary pollinators of the majority of flowering plants in almost all terrestrial ecosystems, followed by fly populations, estimating to about 120,000 species and other insect pollinators which include butterflies, wasps and beetles (IPBES, 2016).

Africa, has a relatively higher diversity and abundance of insect pollinators particularly in the sub Saharan Africa that sustains agriculture (Kumsa & Ballantyne, 2021) due to the unique mosaic pattern of favorable climatic conditions that encourage farming and general growth of flowering plants.

In Uganda, there is scanty information on insect pollinators in most natural reserve forests, yet the forests are being disturbed by human activi1ties. A lot of research has been done on insect diversity and abundance in most natural forests in Uganda. For instance research on the diversity and abundance of butterflies in and around Budongo Forest Reserve(Reserve et al., 2011) and in Mabira forest (Munyuli, 2012) indicates that there is a growing diversity and abundance of pollinators during blooming seasons.

West Bugwe Central Forest Reserve (WBCFR) is one of the biggest forest reserves in Uganda, providing a habitat to a variety of flora and fauna therefore conserving biodiversity. Several studies have been conducted to determine the diversity and abundance of insect pollinators in protected areas, agroforestry ecosystems and agricultural landscapes but there is inadequate research on insect pollinators at transition areas between forest edges and farmlands. For instance, influence of agroforestry practices on pollinators and pollination services (Alvarado et al, 2023), In addition, most research studies are concentrated around single pollinator groups such as the Hawkmoths (Johnson et al., 2017) and bees neglecting other insect pollinators. In WBCFR, research has been conducted on baboons, endemic species of butterflies and on tree species but no information on insect pollinators. Moreover, there is much evidence that pollinators are declining in most parts of the world (Kremen et al., 2007) due the anthropogenic activities such as forest encroachment, deforestation and changes in land use(Broadbent et al., 2012) along forest edges which has destroyed the habitat for insects because these activities destroy places for them to forage, nest, oviposit, and reproduce (Kevan, 1999). The use of agrochemicals on farmlands has also been a potential driver of pollinator decline (Steffan-Dewenter & Westphal, 2008). Thus, this research aims to assess the diversity and abundance of insect pollinators in West Bugwe Central Forest Reserve along forest edges bordering farmlands. The outcomes from this study will be of benefit to policy makers in enforcing well informed decisions about conserving the biodiversity.

1.2 Statement of the problem.

Insect pollinators play a crucial role in maintaining ecosystem functions and supporting agricultural productivity through their contribution to the pollination of flowering plants(Klein et al., 2007).

Forest edges being transitional zones between different habitats have high diversity and abundance of insect pollinators due to variations in microclimate and high floral resources(Laurance, 2004). This high diversity enhances the stability and resilience of ecosystems. However modern land use changes, habitat fragmentation and environmental degradation have led to declining populations of these vital organisms(Biesmeijer et al., 2006). According to Wagner et al., (2021), insect pollinators are declining drastically and this has been linked to changes in habitat structure and agricultural activities, yet the diversity and abundance of insect pollinators along these forest edges remains poorly understood. Understanding the patterns of insect pollinator diversity and abundance along forest edges could provide insights into habitat management and preservation of ecosystem services they provide. Therefore, the aim of this research study is to determine the diversity and abundance of various insect pollinators along forest edges of West Bugwe Central Forest Reserve bordered by agricultural land.

1.3 Justification

Pollinators play a critical role in the functioning of ecosystems by facilitating plant reproduction. Insect pollinators such as bees, butterflies, and beetles contribute significantly to the genetic diversity and stability of plant communities(Klein et al., 2007). Pollinators are essential for the provision of ecosystem services, particularly in agricultural systems where crop yields depend on insect pollination. Assessing the diversity and abundance of pollinators at forest edges can inform agricultural practices that support these services(Ghazoul, 2005). This is critical for understanding ecological interactions, informing conservation efforts and supporting sustainable agricultural practices. Therefore, this research will address the existing knowledge gap by providing quantitative information about the diversity and abundance of insect pollinators.

1.4.0 Objectives

1.4.1 General objective

To determine the diversity and abundance of insect pollinators in West Bugwe central forest reserve along forest edges bordered by farmlands.

1.4.2 Specific objectives.

1. To identify insect pollinators found along forest edges bordering agricultural land.
2. To compare diversity and abundance of insect pollinators along forest edges bordering agricultural land with Forest interior.

1.5.0 Hypothesis

1.5.1 Null hypothesis.

There is no significant difference between the diversity and abundance of insect pollinators along forest edges bordered by agricultural land and the forest interior.

1.5.2 Alternative hypothesis.

There is a significant difference between the diversity and abundance of insect pollinators along forest edges bordered by agricultural land and the forest interior.

1.6 Scope of study.

The study determined the diversity and abundance of insect pollinators in West Bugwe Central Forest Reserve located in three sub-counties; Bulumbi, Buyanga and Busitema, Tororo district. The research study was aimed at identifying and comparing insect pollinators along forest edges with the forest interior. Sampling techniques used to collect data on insect pollinators were sweep nets, colored pan traps and scan sampling only (Berglund & Milberg, 2019). Other methods of insect collection were not used due to limitation of time. Additionally, the GPS positioning of the sampling area was considered to identify the different sampling points.

CHAPTER 2.0: LITERATURE REVIEW.

2.1 Introduction

Insect pollinators comprise of a diverse array of species such as bees, butterflies, beetles, flies, wasps and moths which play a crucial role as pollinating agents of flowering plants. This review seeks to provide a comprehensive overview of the role of pollinators, current trends and status of pollinators, drivers of changes in the diversity and abundance of pollinators, land use changes and the overall composition of pollinators along forest edges.

2.2 Role of insect pollinators

Insect pollinators transfer pollen from the male reproductive organ of one flower to the female reproductive organ of another flower, enhancing plant reproduction(Dar et al., 2017). Therefore pollinators are the work horses of modern farms(Guo et al., 2017) which rely on the insects to pollinate crops and 70% of the world's crops depend on animal pollinators(Klein et al., 2007). Insects have diverse and numerous benefits to humans in a number of ways, such as higher food yields and the production of honey as well as being important pollinators. Pollinating insects play an important role in maintaining biodiversity and the operation of ecosystems such as agro settings(Winfree& Kremen, 2009). Insect pollinators provide essential ecosystem services beyond agriculture beyond agriculture by maintaining the reproductive health of non-crop plants which supports wildlife habitats and human well-being(Gallai & Salles, 2013).

2.3 Status and trends of insect pollinators

Numerous studies have indicated a decline in insect pollinator populations globally mainly due to habitat loss and improper use of pesticides(Vanbergen et al., 2013). Pesticide use reduces pollinator populations significantly as it affects their foraging behavior and reproductive success(Goulson et al., 2015).

The loss of pollinators is a serious worry since they offer an essential ecosystem service(Kevan & Viana, 2003). 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). However, insect pollinators such as butterflies and bees, are highly prevalent along the edges and decreases with increasing distance into farmlands(Nicholls & Altieri, 2013)as agricultural land use practices can lead to increased floral diversity at forest edges resulting in richer pollinator communities due to edge effect.. 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.

2.4 Drivers of changes in the diversity and abundance 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(Kevan et al., 2011). The loss of natural like forests habitats due to anthropogenic activities has significant negative effect on pollinator communities. The anthropogenic activities within natural forests may also play a role in insect pollinator population dynamics (Barrett, 2010). According to Wagner et al., 2021, it is 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.

2.5 Land use changes along forest edges.

Land use changes along forest edges are influenced by various ecological, economic and social factors. Although conservation strategies have been adopted(NEMA.Pdf, n.d.). There are many illegal activities that are being carried out along forest edges. Such activities include charcoal burning, firewood collection, grazing and pesticide use that influence the abundance and diversity of pollinators. Habitat fragmentation is also a serious threat to insect pollinator groups because it reduces the availability of suitable environments for insect pollinators as well as disrupting pollinator population(Ricketts et al., 2008). In contrast, agro ecological practices that integrate flowering plants and minimize pesticide use have been shown to enhance pollinator abundance along forest edges(Lowe et al., 2021).

2.6 Diversity of insect pollinator.

Insect pollinators, particularly bees, butterflies and other arthropods play a vital role in the maintenance of biodiversity and agricultural productivity. Forest edges create microhabitats that influence the diversity of insect pollinators (Didham et al, 1998). The transition between forest and agricultural land supports a variety of pollinator species owing to different floral resources. (Goulson et al, 2008). These floral resources attract and support a unique assemblage of insect pollinators that venture from the forest and therefore insect pollinators are often more along these transitional areas.

2.7 Abundance of insect pollinators.

Research shows that forest edges serve as transitional zones that offer various resources for pollinators, such as diverse floral resources, nesting sites and reduced exposure to pesticides found in agricultural land. Additionally, the abundance of insect pollinators along forest edges can vary seasonally, with peaks often occurring during specific flowering periods (Klein, A. M, et al, 2007). Studies indicate that these areas between forest and farmlands support and sustain a high abundance of insect pollinators compared to forest interiors and homogenous agricultural landscapes (Ricketts, T. H, 2004). This is because of the increased floral diversity that supports a variety of insect pollinators.

CHAPTER 3.0: MATERIALS AND METHODS

3.1 Study area

The study was conducted at West Bugwe Central Forest Reserve, a tropical forest with medium altitude, moist and semi deciduous forest(Group, 2006). The forest is located in Busia district in South Eastern Uganda lying 003'-0033'N and 3056'-4305'E. It covers an area of $31km^2$| with an altitudinal range of 1102-1136mS(Howard et al., 2000).

The forest is divided into three blocks that is, Sidimbire central block with 3054ha (79%), Sitambogo block with 650ha (17%) and Amonikakenyi block with 163ha (4%). However, the research will be conducted at the natural forest block (Sidimbire) since it is the block with the natural vegetation. The reserve also covers three sub-counties namely, Bulumbi, Buyanga and Busitema. The area receives an annual rainfall of about 1180mm with a double maxima and minima temperature of 28.7ºC and 16.2ºC respectively(Howard et al., 2000). The study area was established along the forest edges, extending about 50m into the agricultural land.

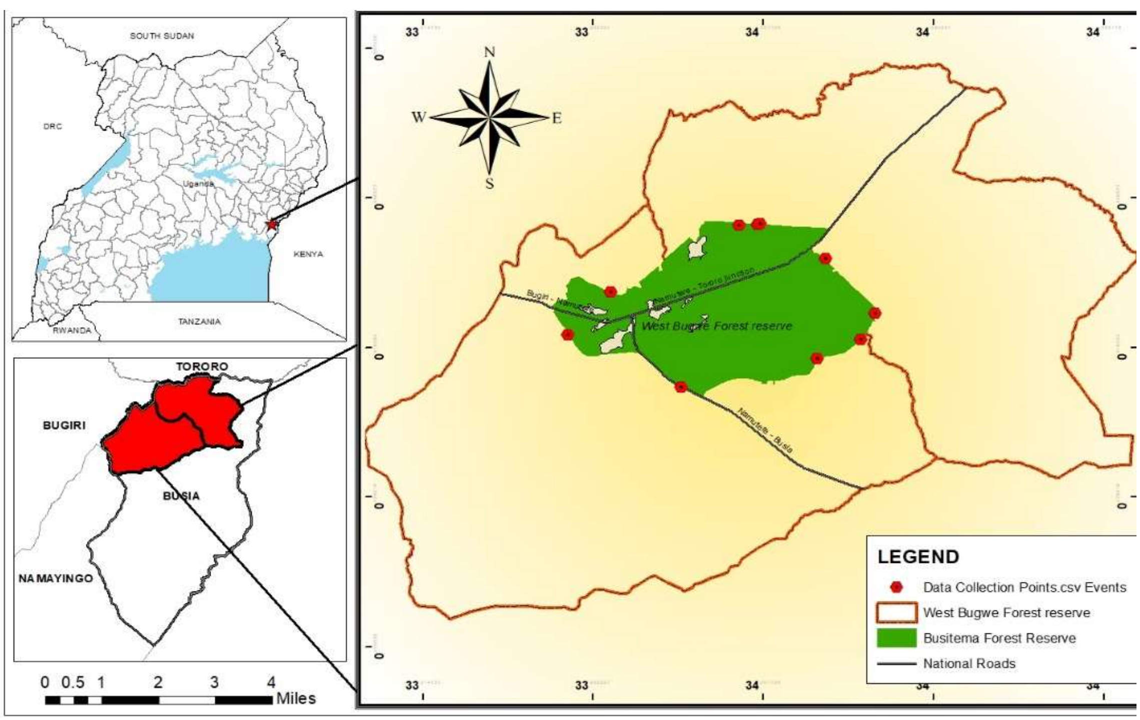


Fig.1: Map of West Bugwe Central Forest Reserve showing sampling points along forest edges.

3.2 Sampling method

Sampling was carried out from 8:00am to 5:00pm on clear sunny days for one month. The sampling site was established between the forest edges and the agricultural land. Sweep nets were used to collect insect pollinators visiting flowers at the understory canopy and around herb layers. Colored pan traps were also used to capture a variety of insect pollinators(Campbell & Hanula, 2007)and for those foraging at higher levels of tall plants, they were observed and counted by scan sampling(Rubiana et al., 2015). Insect specimens collected were kept in bottles containing 70% ethyl alcohol for temporary preservation after which they will be pinned in insect cages for identification using appropriate identification keys such for bees and (Liseki & Vane-Wright, 2018) and (The Bees (Apocrita: Hymenoptera), 2019) for butterflies.

3.2.1 Sweep Net.

Sweep nets were used to collect insect pollinators in open places and around herb layers. Sweep netting is an effective method for capturing a variety of mobile insect pollinators (Thomson et al, 2015). Sweeping was done along a line transect so as to avoid bias. This collected the highest number of insect pollinators particularly butterflies and bees. However, it is Labour intensive and highly determined by the energy input during the periods of sampling. Insect pollinators collected were preserved in insect bottles containing 70% alcohol, identified and pinned in insect cages and taken in the Biology Laboratory at the Faculty of science education.

Fig 2: Collection of insect pollinators using a sweep net.

Fig 2a

Fig 2b

3.2.2 Pan-traps.

Colored pan traps were used to collect insect pollinators due to their efficacy in attracting a wide range of species. Pan traps of different colors such as Yellow, Green, Red, White and Blue were used during the collection process to mimic natural flowers and therefore attract different taxa of insects based on their visual responses (Saunders & Luck, 2013). It was observed that Yellow pan traps were the most effective and attracted the highest number of insect pollinators whereas red ones attracted the least number of insect pollinators. This is because insects have an innate preference for yellow flowers over red flowers coupled with high amounts of nectar and pollen production (Heuschen et al., 2005) The pan traps were set along a line transect with a distance of 10m between them at each sampling point.

Fig 3: Insect pollinator collection using pan traps.

Fig 3a

Fig 3b

3.2.3 Scan sampling.

This method was used to observe and count insect pollinators foraging at higher levels of tall plants where sweep nets cannot be used. Insects visiting flowers were observed using a camera to observe their activities for a certain time interval for example every 10 seconds (Lehner, 1992). However, the timing of the scan can significantly influence the results obtained because insects might exhibit different activity patterns at different times of the day.

Fig 4: Scan samples of insect pollinators

Fig 4a

Fig 4b

3.3 Data Analysis.

In this study, data was analyzed using Shannon-Weiner index to determine the diversity of insect pollinators. Assessment of diversity was calculated by species richness, evenness and dominance. The formula below was used to determine Shannon index (H'); ($H' = - \Sigma\, pi \ln pi$) where **p** is the proportion n/N of individuals of one particular species (**n**) and **N** is the total number of species. The abundance of insect pollinators will be 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 along forest edges with the forest interior at various sampling points.

4.0 CHAPTER FOUR: RESULTS.

4.1 Diversity of insects.

A total of 808 insects belonging to 5 orders (Hemiptera, Lepidoptera, Diptera, Hymenoptera and Coleoptera) were recorded. The largest insect order was Hymenoptera (51%) followed by Lepidoptera (39%) while the remaining insect orders had very few individuals. These two orders comprised several families, for example order Hymenoptera had 8 families including; Apidae, Megachilidae, Vespidae, Halictidae, Andrenidae, Melicttidae, Stenotritidae and Collectidae. Apidae had the highest abundance (76%) and Diptera had the least abundance (1%).

Lepidoptera consisted of 6 families, for example Hesperidae, Papilionidae, Pieridae, Nymphalidae, Lycaenidae and Riodinidae. Nymphalidae was the most abundant family (54%) whereas Papilionidae was the least abundant (1%).

Insect pollinators were distributed differently basing on the availability of resources. Bees were more abundant in agricultural compared to other species. The diversity of different pollinator communities was evaluated using different diversity indices. The Shannon-Weiner index (H) and the Simpson index (1-D) were employed to determine the diversity and relative abundance of insect pollinators.

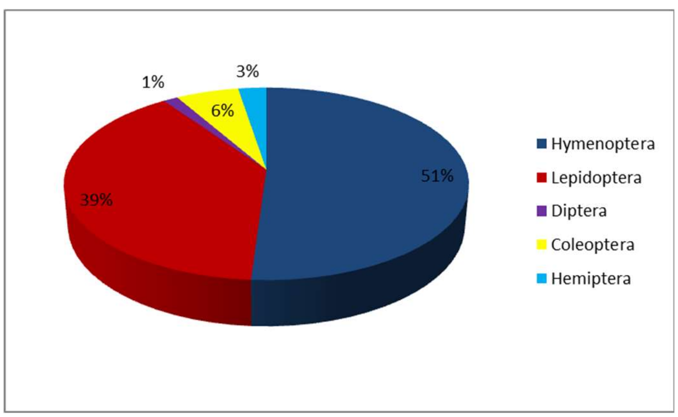


Fig 4.1.1: The orders of insects collected along forest edges.

Hymenopterans had the highest abundance along forest edges because they exhibit a wide range of lifestyles and adaptations. This versatility allows them to exploit different food sources and habitats, increasing their abundance. The edge environment allows for easier movement and foraging; therefore, they can easily access flower resources without having to navigate longer distances. Other insect orders for example Lepidoptera require special environmental conditions like high humidity and cool temperatures.

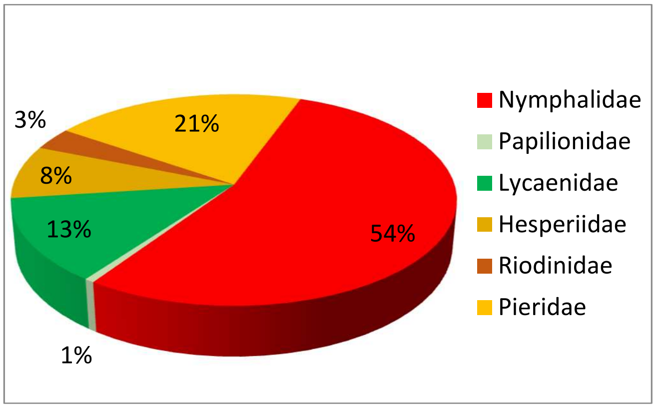


Fig 4.1.1: Families of order Lepidoptera

This study revealed that Nymphalidae had more species than any other butterfly family. Nymphalidae are found in a variety of habitats including rainforests, temperate forests and grasslands allowing them to adapt to different environmental conditions. This family of butterflies has a higher rate of reproduction and their larvae are known to feed on a broad range of host plants, increasing their dietary preferences (Carol. L Boggs, 1986). On the other hand, Riodinidae had the lowest abundance because individuals of this family have specialized habitat requirements such as habitats that are protected from sun light and are more susceptible to parasites (Vu et al, 2015)

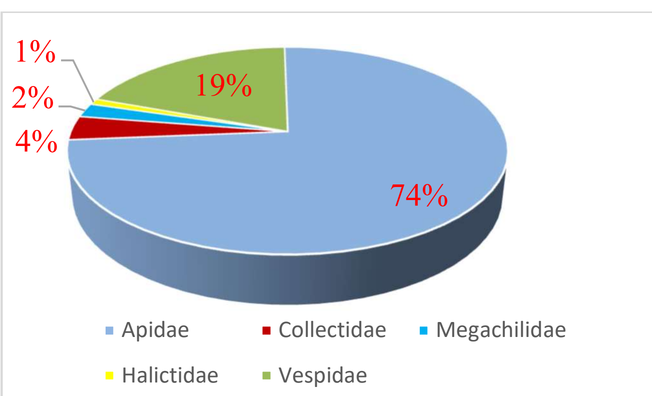


Fig 4.1.3 Families of order Hymenoptera.

Members of family Apidae exhibit complex social behaviors and cooperative living which enhance their survival and productivity, with division of labour in colonies which allows them to exploit resources efficiently and defend against predators (Winston, M. L, 1987). Their ability to exploit a wide range of floral resources with ability to forage on varied plants including wildflowers and cultivated crops allows them to thrive in diverse habitats (Danforth et al, 2006). This gives them a competitive advantage over other hymenopteran families.

4.2 Relative abundance of insect pollinators.

Apidae had the highest relative abundance (43%) followed by Nymphalidae (23%) and Pieridae (9%). Families such as Collectidae, Stenotritidae and papilionidae had the least number of species along the forest edges. Forest edges had a higher diversity and abundance pollinators (53.37%) than the forest interior (46.6%). Hymenopterans were more abundant and diverse at the forest edges than the forest interior, but Lepidopterans and Dipterans were more abundant inside the forest than along forest edges. Generally, forest edges had low Species evenness (0.56) compared with the forest interior (0.57). (figure 4.2)

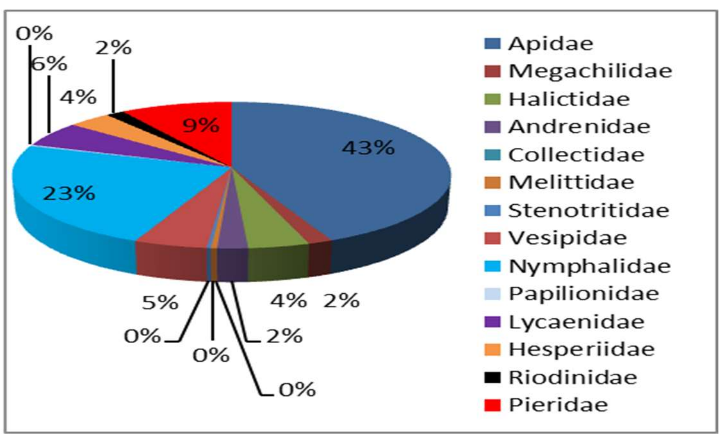


Figure 4.2.1: Abundance of insect pollinator families.

Apidae was the most abundant family (43%) because this family exhibit complex social structures (colonies) that allow them to efficiently gather food resources, build nests and protect their young. This social behavior makes them more resilient to environmental changes. Nymphalidae was the second most abundant because members of this family of butterflies have a higher rate of reproduction and their larvae are known to feed on a broad range of host plants, increasing their dietary preferences (Carol. L Boggs, 1986). Other families had the lowest abundance because most individuals of these families have specialized habitat requirements such as habitats that are protected from sun light.

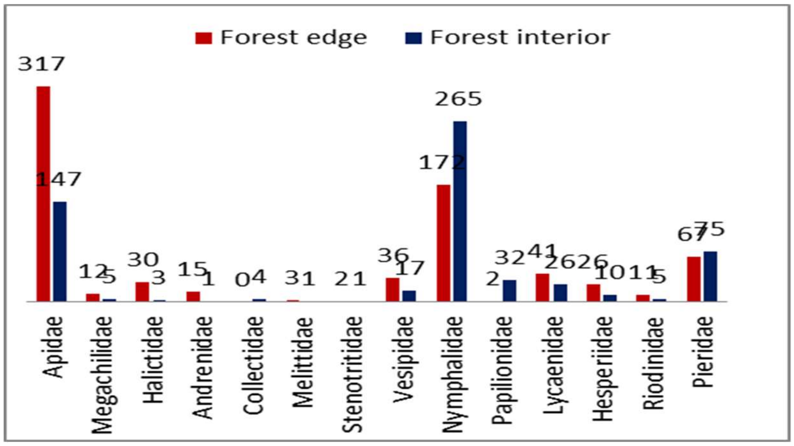
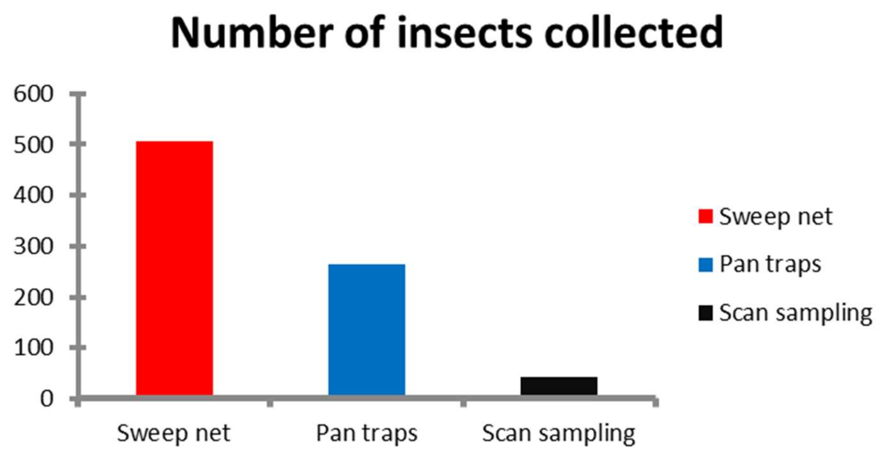


Figure 4.2.2: Comparison of abundance of insect pollinators along forest edges with forest interior.

Generally forest edges have a higher diversity and abundance of insect pollinators because forest edges have a complex mix of floral resources from both wild flowers and cultivated crops and weeds. Also forest edges experience different microclimatic conditions than the interior due to increased sunlight, temperature fluctuations and wind exposure. These conditions create a more favorable environment for certain pollinator species that thrive in the open. For instance, edges may have warmer temperature and more stable humidity levels that are conducive for pollinator activity. Edges also provide suitable nesting sites that are more favorable for certain insect groups compared to shaded forest interior.



In this study, three methods were employed during insect collection. The results reveal that sweep netting collected the highest number of insect pollinators (504) followed by Pan traps (262) and scan sampling yielded the least number of pollinators (42). Much as sweep nets collected the highest number of insect pollinators, it is labor intensive and highly influenced by the energy input during the periods of sampling. Different colors of pan traps were chosen because they are widely used to represent a range of wavelengths found in the visual spectrum, and are similar to flower colors (Curtis, 1983).

4.3 Diversity indices of insect pollinators along forest edges.

Forest edge had a higher relative abundance of insect pollinators (53.37%) compared to forest interior that had a lower relative abundance (46.63%). Also species diversity and richness was higher at the forest edges bordering agricultural land than the interior of the forest except species evenness which was higher inside the forest. The high diversity and richness of insect pollinators along the edges of the forest can be attributed to the high floral resources and a complex mixture of habitats that provide both nesting and foraging sites.

Table 4.1: Simpson diversity index

Insect pollinator	Number of species (**n**)	**n-1**	**n(n-1)**		
Hymenoptera	412	411	169332		
Diptera	9	8	72		
Coleoptera	48	47	2256		
Hemiptera	24	23	552		
Lepidoptera	315	314	98910		
N	808		271122		
N-1	807			**D**	**0.5842**
N(N-1)	652056				

Table 4.2: Showing Shannon-Weiner index.

Insect pollinator	Number of species (**n**)	pi	lnpi	pi*lnpi
Hymenoptera	412	0.3099	-0.6735	-0.2434
Diptera	9	0.01114	-3.4973	-0.0501
Coleoptera	48	0.05941	-1.8234	-0.1677
Hemiptera	24	0.0297	-2.5165	-0.1045
Lepidoptera	315	0.18985	-0.942	-0.0672
N	808		**H'=**	**0.5624**

Table 4.3.1: Relative abundance of insect pollinators in different habitats.

Habitat	Number of species	Evenness	Relative abundance	Simpson diversity
Forest edge	808	0.5602	53.37	0.5824
Forest interior	706	0.5658	46.63	0.5605

It was observed that the diversity of insect pollinators was higher at the forest edges than forest interior because forest edges experience different microclimatic conditions than the interior due to increased sunlight, temperature fluctuations and wind exposure. These conditions create a more favorable environment for certain pollinator species that thrive in the open. For instance, edges may have warmer temperature and more stable humidity levels that are conducive for pollinator activity(Wallace & Clarkson, 2019). There is also high floral resources from both forest and agricultural land allowing insect pollinators to access a greater variety of food sources (Ries et al., 2004). Edges also provide suitable nesting sites that are more favorable for certain insect groups compared to shaded forest interior (Haines et al, 2015).

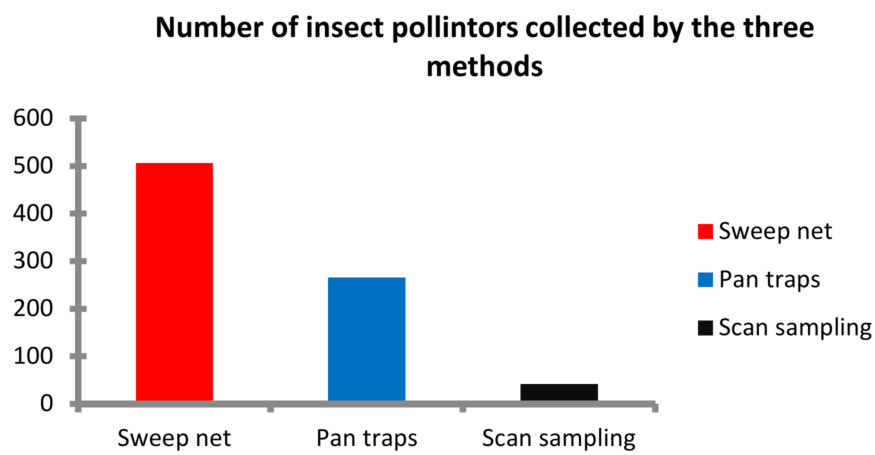
Hymenopterans exhibit a wide range of lifestyles and adaptations. This versatility allows them to exploit different food sources and habitats, increasing their abundance. The edge environment allows for easier movement and foraging; therefore, the can easily access flower resources without having to navigate longer distances. Other insect orders for example Lepidoptera require special environmental conditions like high humidity.

Table 4.3.2: 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			

The two-way ANOVA statistical analysis at 5% interval showed that there was no significant difference in species diversity and abundance between forest edges and forest interior. This is clearly shown since the calculated t-value (0.17843) is less than the critical t-value (2.306) and thus the null hypothesis was not rejected. This is because the the difference in the diversity and abundance of insect pollinators along forest edges and forest interior was negligible.

In this study, three methods were employed during insect collection. The results reveal that sweep netting collected the highest number of insect pollinators (504) followed by Pan traps (262) and scan sampling yielded the least number of pollinators (42). Much as sweep nets collected the highest number of insect pollinators, it is labor intensive and highly influenced by the energy input during the periods of sampling. Different colors of pan traps were chosen because they are widely used to represent a range of wavelengths found in the visual spectrum, and are similar to flower colors (Curtis, 1983).



5.0 CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATION.

5.1 Discussion.

A total of 808 insect pollinators were collected along forest edges and these belonged to 5 orders and several families (Fig 4.1.1). It was observed that the diversity of insect pollinators was higher at the forest edges than forest interior because forest edges experience different microclimatic conditions than the interior due to increased sunlight, temperature fluctuations and wind exposure. These conditions create a more favorable environment for certain pollinator species that thrive in the open. For instance, edges may have warmer temperature and more stable humidity levels that are conducive for pollinator activity (Wallace & Clarkson, 2019). There is also high floral resources from both forest and agricultural land allowing insect pollinators to access a greater variety of food sources (Ries et al., 2004). Edges also provide suitable nesting sites that are more favorable for certain insect groups compared to shaded forest interior (Haines et al, 2015).

According to Blitzer et al., (2012), forest edge environment allow for reduction in competition among pollinator species that thrive in open habitats. Results of this study are in agreement with the work done by (Andrieu et al., 2018)**.** However, Hymenoptera is the order that registered the highest number of individual species. This could be as a result of high color recognition capabilities and may have an innate preference for color. This is still in agreement with similar work done by (Briscoe & Chittka, 2001). Apidae (74%) and Vespidae (19%) are families of Hymenoptera which had the highest abundance in the agricultural land since crops are specifically planted to produce flowers, which serve as food sources for these insects and agriculture fields also have more homogenous plant structures that reduces competition for food and nesting sites. Similarly, Saeed et al. (2012) reported the profiles of pollinator communities where the study concluded that Apidae was the most dominant family.

Lepidoptera was the second largest order of insect pollinators and it had the highest abundance along forest edges but lowest abundance in agricultural field. This is because forests provide a more diverse habitat with a variety of plants and flowers that serve as food sources for butterflies in different life stages. Studies conducted by (Hussain & Batool, 2016) suggest that Lepidoptera species are more prevalent along forest edges to minimize flight costs due their relatively larger body sizes. This does not agree with my findings since Lepidopteran species were more abundant inside the forest than forest edges (Table 4.3.1). Also studies by Kremen et al. (2007) suggest that there is a high diversity and abundance of insect pollinators along forest edges bordered by agricultural land than forest interiors due to additional resources such as flowering crops and weeds that enhance food availability for pollinators. This is in agreement with my findings because it was discovered that forest edges have higher species diversity and abundance compared to forest interior.

5.2 Conclusion.

Results from this study indicate that forest edges had higher diversity and abundance of insect pollinators than the forest interior. Forest edges are transitional zones between two interacting ecosystems and are important for biodiversity conservation. The most abundant orders were Hymenoptera followed by Lepidoptera while the least abundant orders were Diptera and Hemiptera. Insights gained from studying these interactions can inform sustainable agricultural practices, such as creation of buffer zones that support insect pollinator populations to enhance crop yields. Therefore, attention should not only be given to these two types of habitats (Forest edge and Forest interior) but also to the farmlands and other habitat types to boost the diversity of various insect pollinators.

5.3 Recommendation

This is so far the first research to be conducted on insect pollinators along forest edges of West Bugwe Central Forest Reserve and therefore, these research findings are preliminary and require further verification. I therefore recommend more research be conducted in other blocks of West Bugwe Central Forest for an extended period of time and communities around the forest should be sensitized about the importance of insect pollinators and the need to conserve them.

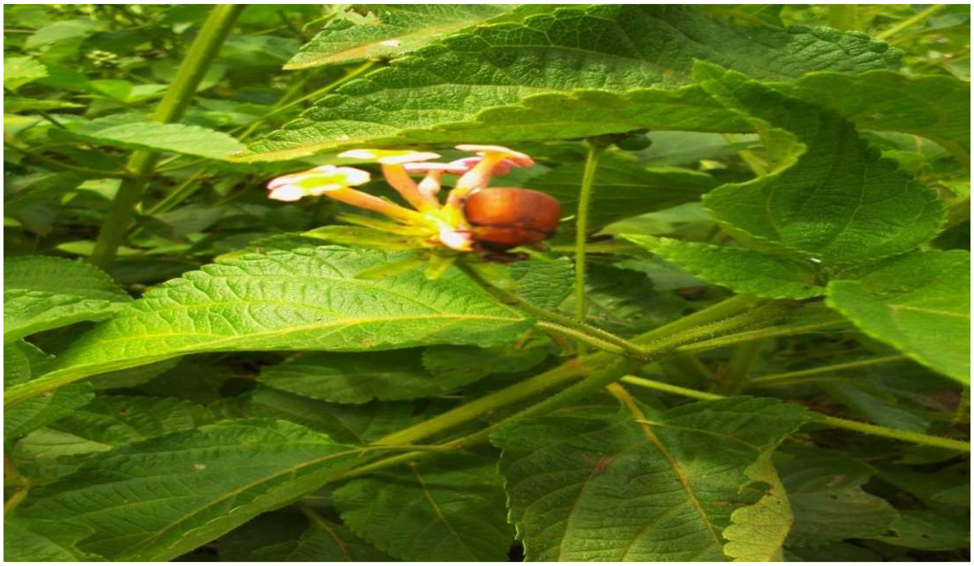
APPENDIX

Appendix 1: Figures showing sweep netting.

1a

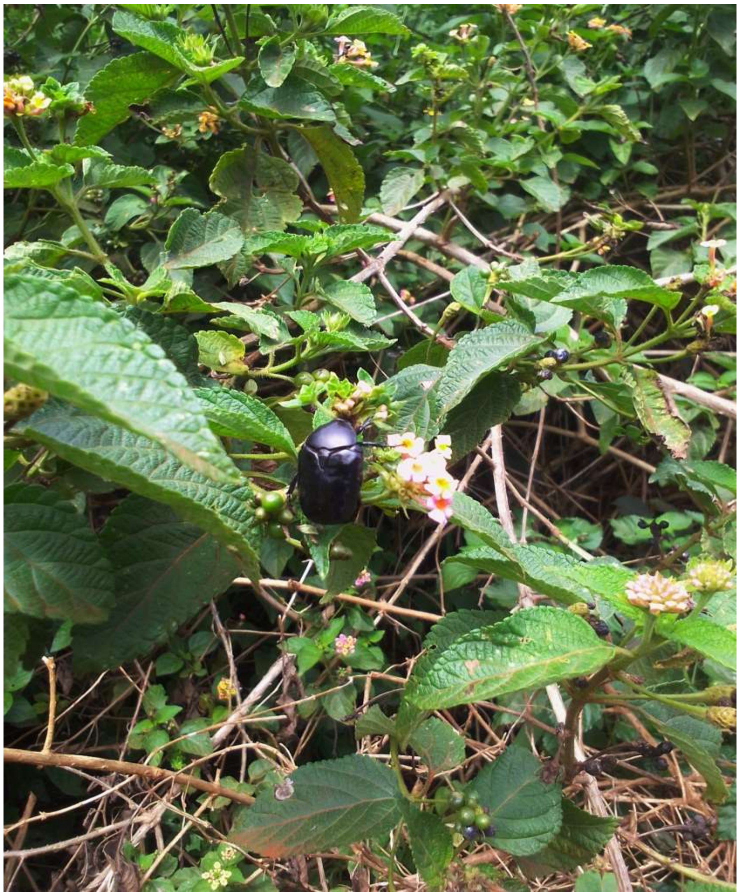
1b

Appendix 2: Figures showing scan sampling.



2a

2b



2c

Appendix 3: Figures showing pan traps.

3a

3b

3c


3d

Appendix4. Orders of different insect pollinators pinned in the cage.

Appendix 5: Budget

S/N	**Activity**	**Amount**
1.	Transport	200,000
2.	Materials	100,000
3.	Facilitation	250,000
4.	Printing	50,000
TOTAL		600,000

Appendix 6: Insect collection using pan-traps.

Color of pan-trap	**Number of insects captured**							**TOTAL**
Yellow	23	17	24	16	11	15	16	**122**
Blue	2	6	3	1	3	5	4	**24**
Red	3	0	4	3	1	4	1	**16**
Green	11	8	9	5	12	6	12	**63**
White	6	5	10	5	4	1	6	**37**

Appendix 7: Different insect orders collected.

DAYs	Hymenoptera	Diptera	Coleoptera	Hemiptera	Lepidoptera
Day1	59	2	4	6	47
Day2	41	1	3	3	23
Day3	34	0	3	1	36
Day4	46	1	6	2	39
Day5	29	0	5	2	19
Day6	50	0	8	1	22
Day7	36	1	4	3	40
Day8	43	2	3	3	27
Day9	37	0	7	1	32
Day10	41	2	5	2	34

TOTAL	**412**	**9**	**48**	**24**	**315**

REFERENCES

Andrieu, E., Cabanettes, A., Alignier, A., Van Halder, I., Alard, D., Archaux, F., Barbaro, L., Bouget, C., Bailey, S., Corcket, E., Deconchat, M., Vigan, M., Villemey, A., & Ouin, A. (2018). Edge contrast does not modulate edge effect on plants and pollinators. *Basic and Applied Ecology*, *27*(November), 83–95. https://doi.org/10.1016/j.baae.2017.11.003

Bailey, S., Requier, F., Roberts, S. P. M., Potts, S. G., & Bouget, C. (2014). *Distance from forest edge affects bee pollinators in oilseed rape fields*. https://doi.org/10.1002/ece3.924

Barrett, S. C. H. (2010). Understanding plant reproductive diversity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1537), 99–109. https://doi.org/10.1098/rstb.2009.0199

Bentrup, G., Hopwood, J., Adamson, N. L., & Vaughan, M. (2019). Temperate agroforestry systems and insect pollinators: A review. *Forests*, *10*(11), 14–16. https://doi.org/10.3390/f10110981

Berglund, H. L., & Milberg, P. (2019). Sampling of flower-visiting insects: Poor correspondence between the catches of colour pan-trap and sweep netting. *European Journal of Entomology*, *116*, 425–431. https://doi.org/10.14411/EJE.2019.043

Biesmeijer, J. C., Roberts, S. P. M., Reemer, M., Ohlemüller, R., Edwards, M., Peeters, T., Schaffers, A. P., Potts, S. G., Kleukers, R., Thomas, C. D., Settele, J., & Kunin, W. E. (2006). Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science*, *313*(5785), 351–354. https://doi.org/10.1126/science.1127863

Blitzer, E. J., Dormann, C. F., Holzschuh, A., Klein, A. M., Rand, T. A., & Tscharntke, T. (2012). Spillover of functionally important organisms between managed and natural habitats. *Agriculture, Ecosystems and Environment*, *146*(1), 34–43. https://doi.org/10.1016/j.agee.2011.09.005

Briscoe, A. D., & Chittka, L. (2001). T <scp>HE</scp> E <scp>VOLUTION OF</scp> C <scp>OLOR</scp> V <scp>ISION IN</scp> I <scp>NSECTS</scp>. *Annual Review of Entomology*, *46*(1), 471–510. https://www.annualreviews.org/doi/10.1146/annurev.ento.46.1.471

Broadbent, E. N., Zambrano, A. M. A., Dirzo, R., Durham, W. H., Driscoll, L., Gallagher, P., Salters, R., Schultz, J., Colmenares, A., & Randolph, S. G. (2012). The effect of land use change and ecotourism on biodiversity: a case study of Manuel Antonio, Costa Rica, from 1985 to 2008. *Landscape Ecology*, *27*(5), 731–744. https://doi.org/10.1007/s10980-012-9722-7

Campbell, J. W., & Hanula, J. L. (2007). Efficiency of Malaise traps and colored pan traps for collecting flower visiting insects from three forested ecosystems. *Journal of Insect Conservation*, *11*(4), 399–408. https://doi.org/10.1007/s10841-006-9055-4

Corlett, R. T. (2016). Plant diversity in a changing world: Status, trends, and conservation needs. *Plant Diversity*, *38*(1), 10–16. https://doi.org/10.1016/j.pld.2016.01.001

Dar, S. A., Hassan, G. I., Padder, B. A., Wani, A. R., & Sajad, H. (2017). Pollination and evolution of plant and insect interaction. *Journal of Pharmacognosy and Phytochemistry*, *6*(3), 304–311.

Gallai, B. N., & Salles, J. (2013). Adaptation of society confronted with a pollinator decline: A local market analysis. *Colloque SFER, Angers*, 1–17.

Ghazoul, J. (2005). Buzziness as usual? Questioning the global pollination crisis. *Trends in Ecology and Evolution*, *20*(7), 367–373. https://doi.org/10.1016/j.tree.2005.04.026

Goulson, D., Nicholls, E., Botías, C., & Rotheray, E. L. (2015). Bee declines driven by combined Stress from parasites, pesticides, and lack of flowers. *Science*, *347*(6229).

https://doi.org/10.1126/science.1255957

Group, I. R. (2006). *UGANDA BIODIVERSITY AND TROPICAL FOREST ASSESSMENT*. *July*.

Guo, Y., Zhang, X., Shao, Y., & Li, J. (2017). Evaluation of diversity and abundance of pollinating insects on oilseed rape in major planting area of China. *International Journal of Agricultural Policy and Research*, *5*(6), 117–124.

Heuschen, B., Gumbert, A., & Lunau, K. (2005). A generalised mimicry system involving angiosperm flower colour, pollen and bumblebees' innate colour preferences. *Plant Systematics and Evolution*, *252*(3–4), 121–137. https://doi.org/10.1007/s00606-004-0249-5

Howard, P. C., Davenport, T. R. B., Kigenyi, F. W., Viskanic, P., Baltzer, M. C., Dickinson, C. J., Lwanga, J., Matthews, R. A., & Mupada, E. (2000). Protected area planning in the tropics: Uganda's national system of forest nature reserves. *Conservation Biology*, *14*(3), 858–875. https://doi.org/10.1046/j.1523-1739.2000.99180.x

Hussain, M., & Batool, S. (2016). Diversity and distribution of butterflies in Pakistan: A review. *Journal of Entomology and Zoology Studies*, *4*(October), 579–585.

IPBES. (2016). Pollination and. In *Science* (Vol. 325, Issue 5940).

Johnson, S. D., Moré, M., Amorim, F. W., Haber, W. A., Frankie, G. W., Stanley, D. A., Cocucci, A. A., & Raguso, R. A. (2017). The long and the short of it: a global analysis of hawkmoth pollination niches and interaction networks. *Functional Ecology*, *31*(1), 101–115. https://doi.org/10.1111/1365-2435.12753

Kevan, P. G. (1999). Pollinators as bioindicators of the state of the environment: Species, activity and diversity. *Agriculture, Ecosystems and Environment*, *74*(1–3), 373–393. https://doi.org/10.1016/S0167-8809(99)00044-4

Kevan, P. G., & Viana, B. F. (2003). The global decline of pollination services. *Biodiversity*, *4*(4), 3–8. https://doi.org/10.1080/14888386.2003.9712703

Kevan, P. G., Viana, B. F., & Kevan, P. G. (2011). *The global decline of pollination services The global decline of pollination services*. *8386*(2003). https://doi.org/10.1080/14888386.2003.9712703

Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1608), 303–313. https://doi.org/10.1098/rspb.2006.3721

Kohler, F., Verhulst, J., Van Klink, R., & Kleijn, D. (2008). At what spatial scale do high-quality habitats enhance the diversity of forbs and pollinators in intensively farmed landscapes? *Journal of Applied Ecology*, *45*(3), 753–762. https://doi.org/10.1111/j.1365-2664.2007.01394.x

Kremen, C., Williams, N. M., Aizen, M. A., Gemmill-Herren, B., LeBuhn, G., Minckley, R., Packer, L., Potts, S. G., Roulston, T., Steffan-Dewenter, I., Vázquez, D. P., Winfree, R., Adams, L., Crone, E. E., Greenleaf, S. S., Keitt, T. H., Klein, A. M., Regetz, J., & Ricketts, T. H. (2007). Pollination and other ecosystem services produced by mobile organisms: A conceptual framework for the effects of land-use change. *Ecology Letters*, *10*(4), 299–314. https://doi.org/10.1111/j.1461-0248.2007.01018.x

Kumsa, T., & Ballantyne, G. (2021). Insect pollination and sustainable agriculture in Sub-Saharan Africa. *Journal of Pollination Ecology*, *27*(December 2020), 36–46. https://doi.org/10.26786/1920-7603(2021)615

Laurance, W. F. (2004). Forest-climate interactions in fragmented tropical landscapes. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *359*(1443), 345–352. https://doi.org/10.1098/rstb.2003.1430

Lehner, P. N. (1992). Sampling methods in behavior research. *Poultry Science*, *71*(4), 643–649. https://doi.org/10.3382/ps.0710643

Liseki, S. D., & Vane-Wright, R. I. (2018). Butterflies (Lepidoptera: Papilionoidea) of mount kilimanjaro: Nymphalidae subfamily helconiinae. *Journal of Natural History*, *52*(39–40), 39–40. https://doi.org/10.1080/00222933.2018.1539780

Lowe, E. B., Groves, R., & Gratton, C. (2021). Impacts of field-edge flower plantings on pollinator conservation and ecosystem service delivery – A meta-analysis. *Agriculture, Ecosystems and Environment*, *310*. https://doi.org/10.1016/j.agee.2020.107290

Munyuli, M. B. T. (2012). Butterfly diversity from farmlands of central Uganda. *Psyche (London)*, *2012*. https://doi.org/10.1155/2012/481509

NEMA.pdf. (n.d.).

Nicholls, C. I., & Altieri, M. A. (2013). Plant biodiversity enhances bees and other insect pollinators in agroecosystems. A review. *Agronomy for Sustainable Development*, *33*(2), 257–274. https://doi.org/10.1007/s13593-012-0092-y

Ollerton, J., Winfree, R., & Tarrant, S. (2011). How many flowering plants are pollinated by animals? *Oikos*, *120*(3), 321–326. https://doi.org/10.1111/j.1600-0706.2010.18644.x

Requier, F., Pérez-Méndez, N., Andersson, G. K. S., Blareau, E., Merle, I., & Garibaldi, L. A. (2023). Bee and non-bee pollinator importance for local food security. *Trends in Ecology and Evolution*, *38*(2), 196–205. https://doi.org/10.1016/j.tree.2022.10.006

Reserve, F., Gard, T., & Forestry, B. S. (2011). *Butterfly Abundance and Diversity in and Around Budongo By a Research Dissertation Submitted To the School of Forestry Environmental and Geographical Sciences in Partial Fulfillment of the Degree of Bachelor of Science in Forestry of Makerere University*. *May*.

Ricketts, T. H., Regetz, J., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., Bogdanski, A., Gemmill-Herren, B., Greenleaf, S. S., Klein, A. M., Mayfield, M. M., Morandin, L. A., Ochieng', A., & Viana, B. F. (2008). Landscape effects on crop pollination services: Are there general patterns? *Ecology Letters*, *11*(5), 499–515. https://doi.org/10.1111/j.1461-0248.2008.01157.x

Ries, L., Fletcher, R. J., Battin, J., & Sisk, T. D. (2004). Ecological responses to habitat edges: Mechanisms, models, and variability explained. *Annual Review of Ecology, Evolution, and Systematics*, *35*, 491–522. https://doi.org/10.1146/annurev.ecolsys.35.112202.130148

Rubiana, R., Rizali, A., Denmead, L. H., Alamsari, W., Hidayat, P., Pudjianto, Hindayana, D., Clough, Y., Tscharntke, T., & Buchori, D. (2015). Agricultural land use alters species composition but not species richness of ant communities. *Asian Myrmecology*, *7*(1), 73–85.

Steffan-Dewenter, I., & Westphal, C. (2008). The interplay of pollinator diversity, pollination services and landscape change. *Journal of Applied Ecology*, *45*(3), 737–741. https://doi.org/10.1111/j.1365-2664.2008.01483.x

THE BEES (APOCRITA: HYMENOPTERA) OF DHAKA CITY, BANGLADESH Akter, T., S. Akther, S. Sultana, J. A. Jhorna and S. Begum Entomology Laboratory, Department of Zoology, University of Dhaka, Dhaka-1000, Bangladesh. (2019). *5*(1), 113–120.

Vanbergen, A. J., Garratt, M. P., Vanbergen, A. J., Baude, M., Biesmeijer, J. C., Britton, N. F., Brown, M. J. F., Brown, M., Bryden, J., Budge, G. E., Bull, J. C., Carvell, C., Challinor, A. J., Connolly, C. N., Evans, D. J., Feil, E. J., Garratt, M. P., Greco, M. K., Heard, M. S., … Wright, G. A. (2013). Threats to an ecosystem service: Pressures on pollinators. *Frontiers in Ecology and the Environment*, *11*(5), 251–259. https://doi.org/10.1890/120126

Wagner, D. L., Grames, E. M., Forister, M. L., Berenbaum, M. R., & Stopak, D. (2021). Insect decline in the Anthropocene: Death by a thousand cuts. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(2), 1–10. https://doi.org/10.1073/PNAS.2023989118

Wallace, K. J., & Clarkson, B. D. (2019). Urban forest restoration ecology: a review from Hamilton, New Zealand. *Journal of the Royal Society of New Zealand*, *49*(3), 347–369. https://doi.org/10.1080/03036758.2019.1637352

Winfree, R., & Kremen, C. (2009). Are ecosystem services stabilized by differences among species? A test using crop pollination. *Proceedings of the Royal Society B: Biological Sciences*, *276*(1655), 229–237. https://doi.org/10.1098/rspb.2008.0709

Zhang, Q., Devers, D., Desch, A., Justice, C. O., & Townshend, J. (2005). Mapping tropical deforestation in Central Africa. *Environmental Monitoring and Assessment*, *101*(1–3), 69–83.