East African Scholars Journal of Agriculture and Life Sciences
*Abbreviated Key Title: East African Scholars J Agri Life Sci*
ISSN 2617-4472 (Print) | ISSN 2617-7277 (Online) |
Published By East African Scholars Publisher, Kenya

OPEN ACCESS

Volume-2 | Issue-10 | Oct-2019 |

**Research Article**

# Effect of Anthropogenic Activities on Insect Pollinators Diversity and Abundances during Dry and Wet Seasons within Kakamega Forest, Kenya

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**Abstract:** Insect pollination provides service to sustain 80% flowering plants**.** Globally, it's observed that intensified anthropogenic activities causes decline in diversity and abundance of insect pollinators, since they alter plant community composition and structure. Several anthropogenic activities are on-going within Kenya Forest Service section of Kakamega Forest in Kenya. However, there is scarcity of information on their effects. The main objective of this study was to assess the effect of anthropogenic activities on insect pollinator diversity and abundance within Kakamega Forest during the dry and wet seasons. The research was conducted for 22 weeks; of 11 weeks in each season. A pre-survey was carried out to identify sites and anthropogenic activities. Systematic sampling was employed on five (5) sampling sites, comprising of protected forest site and four (4) forest sites under different anthropogenic activities. Sweep nets and binoculars were used to collect, count, identify and record pollinators. Flowers of visited plants were counted, identified and recorded. Statistical analysis was performed by PASW version 20.0 at $P \leq 0.05$. Kruskal Wallis test and Mann Whitney U test, Shannon index (H') were used to determine diversity. Orders Hymenoptera and Lepidoptera were most diverse. Families Apidae and Formicidae were the most diverse. *Apis mellifera* was the most abundant species. Dry season recorded higher diversity. The wet season recorded higher abundance. Protected forest was more diverse. Livestock grazing and deforestation significantly affected diversity and abundance of entomophilous plants, which proportionately affected diversity and abundance of insect pollinators**.**
**Keywords:** Abundance, Anthropogenic, Diversity, Forest, Insect pollinators, Seasons.

## INTRODUCTION

Pollinators are animals that mediate the exchange of pollen between flowers, facilitating fruit and seed production in roughly 88% of flowering plants globally (Ollerton *et al.*, 2011). However, members of the Class Insecta are uniquely specialized for pollen transport and account for the bulk of pollination services in both wild and cultivated plants (Willmer *et al.*, 2017). Animal pollination is an important input to the global food system, affecting 2/3 of crops worth billions of US dollars annually (Nicholson & Ricketts, 2019). There is mounting evidence of decline in insect pollination resulting from intensification of human activities (Riojas-López, 2019). In developing countries in the south of the Sahara, the human population has been growing very fast in the past few years, resulting in anthropogenic activities intensification to create space and resources to support such human populations (Riojas-López, 2019). There are very few studies that have been carried out to date to quantify the harm such human activities have caused to the biodiversity (Potts *et al.*, 2010).

In western Kenya, and especially at Kakamega forest, the decline may be aggravated due to intensified anthropogenic activities such as; livestock grazing, crop cultivation, charcoal burning among others (CEPF, 2003). Despite the ongoing concerns and controversy, there is little information on the response of insect pollinators to such changes in land-use (Brosi *et al.*, 2008) and a few studies in Kenya have been published on the farmlands adjacent to the Kakamega Forest (Gikungu *et al.*, 2011). The data of this study is important as it will provide an insight of the current diversity and the level each anthropogenic activity has affected biodiversity, and will help the management of

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Journal homepage:
http://www.easpublisher.com/easjals/

Article History
Received: 15.09.2019
Accepted: 26.09.2019
Published: 16.10.2019

the forest to develop strategies and strengthen regulations aimed at conserving insect pollinator biodiversity.

## MATERIALS AND METHODS

### Description of Study Area

The study was carried out at Kakamega Forest (KF). Kakamega Forest is located about 10 km east of Kakamega Town. The Forest lies between latitudes 00°08'N and 00°22'N and longitudes 34°46'E and 34°57'E, and at an altitude of about 1500 to 1700m (KIFCON, 1994). Kakamega Forest receives mean of 2000 mm of rains a year (UNESCO, 2010). The temperatures are fairly constant throughout the year, with mean daily minimums of 11 C° (52 F) and maximums of 26 C° (79 F) (Onyango *et al.*, 2004). The reasons for conducting this study within KF, were; KF is placed under two sections, the Northern part of the forest is under Kenya Wildlife Service (KWS forest section) and completely protected from human activities, while the Southern part is under Kenya Forest Service (KFS) forest section, and has allowed the neighbouring community to use the forest (KFEMP, 2012). The ongoing anthropogenic activities, namely livestock grazing, crop cultivation, deforestation and exotic tree placements were visible and distinct within specific sites at KFS managed forest section and would make it easier to study and conclude if anthropogenic activities have had any effects on insect pollinator biodiversity.

### Study Design

A preliminary study to identify the anthropogenic activities and the sites was done. This was a horizontal study, done for 6 months in two seasons of dry and wet of 11 weeks each.

### Sampling Technique

Sampling was carried out between 0900hours and 1700 hours. The number of insect pollinator samples collected at all sub-plots of a site were computed and their means calculated for the site for that week.

Systematic sampling was selected. Flying insects observed visiting flowers were swept twice using a sweep net, and or counted using a hand-held binoculars for those visiting flowers of tall trees. Collected samples were identified, recorded and released. Camel brush and pair of forceps were used to collect crawling flower visitors in flowers with longer funnels. Visited plants were counted, identified and recorded. Un-identified insect samples were preserved in 70% ethanol and chloroform and then mounted in insect boxes using entomological pins for further identification using morphological features. Insects and plants were identified at higher taxonomic levels using identification keys according to Borror *et al.*, (1989). All collected insect samples were then sorted out to separate pollinators from non-pollinator species.

## RESULTS

### Comparison of insect pollinator diversity and abundance between protected and un-protected forest

In the protected forest, a total 3,972 insect pollinators belonging to 9 families and 21 species were collected during the dry season, while 3,879 insect pollinators in 12 families and 23 species were collected during the wet season. Diversity was higher during the dry season (H'=1.6) compared to the wet season (H'=0.7). In the un-protected forest, a total 7,128 insect pollinators belonging to 10 families and 23 Species were recorded during the dry season, while 6,620 insect pollinators in 15 families and 24 species were recorded during the wet season. Diversity was higher during the dry season (H'=1.5) compared to the wet season (H'=1.2).

Order Hymenoptera was the most diverse in both forest portions during the dry season, while Order Lepidoptera was the most diverse in both forest during the wet season (Table 1). Order Hymenoptera was the most abundant in all the forest sections in all the seasons (Table 1).

**Table 1: A Comparison of diversity and abundance of insect pollinators between protected and un-protected forest sections in the dry and wet seasons**

| | Protected Forest | | | | Un-protected Forest | | | |
|---|---|---|---|---|---|---|---|---|
| | Dry Season | | Wet Season | | Dry Season | | Wet Season | |
| Order | Abundance | H' | Abundance | H' | Abundance | H' | Abundance | H' |
| Coleoptera | 5 | 0.67 | 12 | 0 | 2 | 0 | 0 | - |
| Diptera | 23 | 0 | 120 | 0.10 | 162 | 0.20 | 322 | 0.51 |
| Hymenoptera | 3851 | 1.45 | 3660 | 0.50 | 6816 | 1.33 | 6036 | 0.82 |
| Lepidoptera | 93 | 0.14 | 87 | 1.40 | 116 | 0 | 247 | 1.48 |
| Hemiptera | 0 | - | 0 | - | 32 | 0 | 5 | 0 |

In both the protected forest and un-protected forest sections, Family Formicidae was the most diverse during the dry season, while Family Apidae during the wet season. However, species *A. mellifera* was the most abundant in the two seasons. Un-protected forest recorded the highest abundance of *A. mellifera* (Table 2).

**Table 2: A Comparison of most diverse insect pollinator Family and most abundant pollinator species between protected and un-protected forest sections in the dry and wet seasons**

| | Protected Forest | | | | Un-protected Forest | | | |
|---|---|---|---|---|---|---|---|---|
| **Season** | **Most diverse Family** | **H' value** | **Most abundant species** | **Abundance** | **Most diverse Family** | **H' value** | **Most abundant species** | **Abundance** |
| Dry | Formicidae | 0.7 | *A. mellifera* | 2027 | Formicidae | 0.8 | *A. mellifera* | 4320 |
| Wet | Apidae | 0.5 | *A. mellifera* | 3344 | Apidae | 0.6 | *A. mellifera* | 4956 |

**Comparison of insect pollinator diversity between sites under different anthropogenic activities**

Insect pollinators were more diverse in deforestation site in both seasons compared to the rest of the sites, while, insect pollinators were more abundant in the exotic tree placements site in both seasons. However, the abundance dropped from the dry to wet season (Table 3).

**Table 3: A Comparison of abundance and diversity of insect pollinators under different anthropogenic activities for the dry and wet seasons**

| Season | Site | Abundance | H' Index |
|---|---|---|---|
| Dry | Livestock Grazing | 546 | 1.50 |
| | Crop Cultivation | 2824 | 1.20 |
| | Deforestation | 1751 | 1.80 |
| | Exotic Tree placements | 3960 | 0.60 |
| Wet | Livestock Grazing | 1045 | 1.10 |
| | Crop Cultivation | 1238 | 1.60 |
| | Deforestation | 811 | 2.00 |
| | Exotic Tree placements | 3529 | 0.40 |
| | | | |

A Kruskal-Wallis H test showed that there was a statistically significant difference in insect pollinator abundance between protected forest and sites of the un-protected forest during the dry season, while there was no significant difference in abundance between sites of un-protected forest. However, during the wet season, protected forest, exotic tree placement and crop cultivation were significantly different from livestock grazing and deforestation (Table 4).

**Table 4: A comparison on insect pollinator abundance between anthropogenic activities in un-protected section with the protected section using Kruskal-Wallis test for dry and wet seasons**

| Dry Season | | | Wet Season | | |
|---|---|---|---|---|---|
| **Site** | **Site value** | **site rank** | **Site** | **Site value** | **site rank** |
| Protected Forest (KWS) | 41.36 a | 1 | Protected Forest (KWS) | 44.95 a | 1 |
| Crop Cultivation (KFS) | 32.18 b | 2 | Exotic tree placements (KFS) | 33.32 a | 2 |
| Exotic tree placements (KFS) | 31.91 b | 3 | Crop Cultivation (KFS) | 29.86 a | 3 |
| Deforestation (KFS) | 21.00 b | 4 | Livestock grazing (KFS) | 18.68 ab | 4 |
| Livestock grazing (KFS) | 13.55 bc | 5 | Deforestation (KFS) | 13.18 bc | 5 |
| Test Values P≤ | 0.001 | | Test Values P≤ | 0.001 | |
| df | 4 | | Df | 4 | |
| Test statistics | 20.145 | | Test statistics | 26.836 | |
| N | 55 | | N | 55 | |

A spearman's rank-order correlation was performed to determine the relationship between insect pollinator abundance and anthropogenic activities. The results revealed that the relationships were not significant in both seasons. However, there was a significant relationship with entomophilous plants abundance in both seasons - dry ($r_s$ = 0.41, P=0.002) and wet ($r_s$ = 0.28, P=0.04) (Table 5).

**Table 5: Results of Spearman's rank-order correlation of insect pollinator abundance with anthropogenic activities and entomophilous plants for dry and wet seasons**

| | | Dry Season | | Wet Season | |
|---|---|---|---|---|---|
| **Variable** | **N** | $r_s$ | **P** | $r_s$ | **P** |
| Crop Cultivation | 11 | 0.48 | 0.133 | 0.19 | 0.57 |
| Livestock grazing | 11 | -0.11 | 0.758 | -0.03 | 0.93 |
| Exotic tree placements | 11 | 0.30 | 0.365 | -0.02 | 0.96 |
| Charcoal burning | 11 | 0.30 | 0.378 | - | - |
| Entomophilous plants | 55 | 0.41 | 0.002 | 0.28 | 0.04 |
| Dead wood collection | 11 | 0.26 | 0.437 | 0.07 | 0.83 |
| | | | | | |

## DISCUSSION

The results obtained indicate that diversity of pollinators was higher in protected forest than in the un-protected forest. The high diversity could be due to fact that the protected forest exhibited different kinds of flowers of varying phenologies which attracted different or diverse insect pollinator visitors. Furthermore it is suggested that co-evolutionary processes that enhanced flower diversity in response to pollinator requirements might have been interrupted by the anthropogenic activities which were intensified in the unprotected forest portion. Further the areas with intensified anthropogenic activities such as crop cultivation might have been dominated by uniformity of flowers with similar sizes, shapes, and colors (Kevan, 1999) occurring at the same time during the seasons could only attract similar insect pollinators requiring similar flowers of the same shape and colour type. Besides, in disturbed areas, flowers tend to bloom massively in synchronous periods and only last shortly that they require peak numbers of pollinators according to Kremen *et al*., (2002).

The study found that insect pollinator diversity was high in the forest during the dry season than the wet season. This could have been due to the fact that adjacent farmlands had less flower resources available for the insect pollinators such as bees and butterflies; and therefore, the protected evergreen tropical Kakamega forest was the only site with abundant resources of flowers attracting large diversity insect pollinators. However, during the wet season, the adjacent farmlands and open deforested areas might have had more resources for insect pollinators, thus, attracting some specific species of insect pollinators. This could have therefore, led to a decline in the diversity at the protected forest.

The Order Hymenoptera was the most diverse and abundant group during the dry season in both seasons. This could be due to the fact that the group comprises species that are mainly generalists (Gikungu, 2006). Family Formicidae and Apidae were the most diverse since most species in these groups are generalists according to Gikungu (2006). The two families might have been attracted by the diversity species of flowers of weeds in the open portions of the forest and in the presence of plant Families such as Asteraceae, Acanthaceae, Dracaenaceae and Solanaceae which flowered at that time. Gikungu *et al.,* (2011) observed similar findings when researching on ants as pollinators in the Kakamega forest.

In comparing areas with anthropogenic activities it was found that deforested sites recorded highest diversity of insect pollinators compared to other sites that experienced other anthropogenic activities. 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. Exotic tree placement sites recorded the high abundance of insect pollinators during the wet season due to abundance of flowering weeds belonging to families Asteraceae, Acanthaceae, and Solanaceae, Myrsinaceae that had grown and flowered in between the exotic trees.

In areas with anthropogenic activities, Table 4 indicated that there is significantly higher pollinators' abundance compared with areas with anthropogenic activities namely, crop cultivation, deforestation and exotic tree plantation thus highlighting the fact that these activities had reduced the insect pollinators' populations simply by not having sufficient numbers shapes or colours of flowers that could attract the insect pollinators (Brosi *et al.*, 2008; Riojas-López, 2019).

High abundance witnessed during the wet season was most likely influenced by the high reproductive capacity and short developmental periods of most members of the Order Hymenoptera where bees and ants belong. Besides the butterflies swarmed during this period in order to feed, mate and reproduce.

## CONCLUSION

The results revealed that protected forest had the most diverse insect pollinators compared to un-protected forest sites since there were interferences such as tree cutting and charcoal burning while the protected forest had given the insect pollinators longer time and as evidenced during both seasons, due to its maturity and evergreen mixed flowering plants which drew in the insect pollinators. Families Apidae and Formicidae were the most dominant with the highest diversity, while *A. mellifera* the most abundant pollinator species in both forest sections during both seasons.

Livestock grazing and deforestation exhibited significant effects on the abundance and diversity of entomophilous plants more than the other anthropogenic activities. This resulted in proportional effect on the insect pollinators' diversity and abundance. Thus, the study revealed that deforestation and livestock grazing exerts devastating effects on insect pollinators in the Kakamega forest than other anthropogenic activities.

## RECOMMENADTIONS

This study recommends that patches of natural habitats be protected for the purposes of insect pollinator biodiversity conservation. Strategies be developed and regulations followed to help minimize deforestation and livestock grazing in forests.

## ACKNOWLEDGEMENT

Acknowledgement goes to National Research Fund (Kenya) for funding this research, Kenya Wildlife Service (KWS) for supporting this research by providing research assistants and some research materials and allowing this research to be conducted in Kakamega Forest.

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