*Nigerian Journal of Entomology*
Published by the Entomological Society of Nigeria
www.esn.org.ng
ISSN: 0331-0094
Volume 33, 2017
DOI: 10.36108/NJE/7102/33(0111)

# Abundance and Diversity of Aerial Insects in the Jos Museum Zoological Garden, Plateau State, Nigeria

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Nig. J. Entomol. 33: 93 – 102 (2017)

**ABSTRACT:** The species composition and diversity of aerial insects inhabiting different ecosystems are not well known particularly in sub-Saharan Africa. Thus, a study on species diversity and abundance of aerial insects in the Jos Museum Zoological (JMZ) Garden, Plateau State, Nigeria was carried out between June and July, 2013. Aerial insects were collected from edge, mid and interior points of rocky outcrop and savannah woodland using a sweep net. Each transect point was 50 metres long, 20 sweeps were made in each transect point. Wilcoxon rank sum test was used to test for significant difference in the mean abundance of aerial insects between habitats. One-way ANOVA was used to test for significant difference in the mean abundance of aerial insects between points and insects' orders. The Shannon diversity index was used to compare species diversity in the two habitats. The Sorensen's similarity index was used to compare species compositional similarity or variation between habitats. A total of 103 individuals aerial insects distributed in 11 Orders, 36 Families, 35 genera and 27 species were collected. Fifty eight (58) insects representing 55.77% were collected from rocky outcrop while 45 insects representing 44.23% were collected from savanna woodland. The species diversity index did not vary significantly ($P<0.05$), but showed a complete dissimilarity in species composition in the two habitats. These findings clearly suggest that the JMZ Garden is rich in insect species of different orders and is a healthy ecosystem. It is, therefore, recommended that unsustainable anthropogenic activities such as refuse dumping, defeacating, logging and bush burning should be discouraged in the garden.

**Keywords:** Jos, Museum, Zoological Garden, aerial insects.

## INTRODUCTION

The Jos Museum was founded in December, 1955 and was approved in June 1960 when the Zoological Society of Nigeria was formed to manage it. Jos Museum is the second oldest museum in Nigeria, after the small museum at Esie, near Ilorin, which was opened in 1945. For many years Jos was the headquarters of the Federal Department of Antiquities until this was eventually transferred to Lagos. It is the second largest museum in the country offering a wide range of exhibits and facilities for visitors. It is also the principal research station for the Department. In line with the rainfall distribution, Plateau State falls largely within the northern guinea savannah zone which consists mainly of short trees, grasses and the Plateau type of mosaic vegetation. Fringing woodlands or gallery forests can be found along some river valleys. The unique physical features of Plateau State are its high relief, especially in the north, and its geological history. The high relief, or more

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appropriately. the Jos Plateau, provides a hydrological centre for many rivers in northern Nigeria and confers on the northern part of the state a cool climate suitable for livestock rearing and growing of exotic crops. The process of formation of its high relief makes Plateau State one of the mineral rich states in the country (Ajakpo and Okonkwo, 1984).

Aerial insects make more than half of the world's known animal species. The second largest and more diverse order is the Lepidoptera (Potts *et al.*, 2010). Aerial insects possess vital status in any ecosystem as they are involved in pollination, biological control, decomposition and herbivory. Aerial insects are also being used as biodiversity indicators for monitoring the changes in habitats as diversity is found to be declining with increasing disturbance (Hernandez, *et al.*, 2009). Aerial insects are the primary pollinators of much of the diversity of wild plants and crops, and are diverse group including moths, butterflies, bees, beetles and flies (Potts *et al.*, 2010). Kohler *et al.*, (2008) found that the distance to high quality resources and habitats affects the reproduction success of pollinators, and thus population abundance over time. This may threaten the persistence of both pollinators and plant species (Harris and Johnson, 2004).

Though the exact figure of species diversity of aerial insects is uncertain, estimates range from 1.4 to 1.8 million species. Most species likely remain undescribed for many years (Borror *et al.,* 1989). The four dominant orders of aerial insects in terms of numbers of described species, with an estimate of 600,000 - 795,000 species are Coleoptera, Diptera, Hymenoptera and Lepidoptera (Hernandez, *et al.*, 2009).

In view of the ecological importance of zoological gardens, the measurement of species diversity of insects has become critically important in understanding tropical communities and their conservation (Njila and Hadi, 2015). However, many populations of insect species have markedly declined over recent years, primarily as a result of anthropogenic activities and climate change (Aebischer, 1991) which may also take their toll on the JMZ Garden with time. Thus, this study was aimed at generating a species checklist of aerial insects as well as comparing their diversity and similarities in species composition between the edge, mid and interior transect points of rocky outcrop and savanna woodland of JMZ Garden.

## METHODOLOGY

### Study Area

The study was conducted within the savanna woodland and rocky outcrop of the museum. It is located in the heart of Jos North, Plateau State, North-Central Nigeria and found on longitude 9°54' 51"North and latitude 8° 53' 9"East (Figure 1). Though situated in the tropical zone, its peculiar high altitude means that Jos has a near temperate climate with an average temperature of between 18°C and 22°C. Harmattan winds cause the coldest weather between December and February. The warmest temperatures usually occur in the dry season months of March and April. The mean annual rainfall varies from 131.75 cm (52 in) in the southern part to 146 cm (57 in) on the Plateau.

The highest rainfall is recorded during the months of July and August. The Jos Plateau is the source of many rivers in northern Nigeria including the Kaduna, Gongola, Hadejia and Yobe rivers (Ajakpo and Okonkwo, 1984).

The savanna woodland habitat comprises short trees, shrubs and grasses. It is also characterized by less dense canopy with scattered trees which mostly attract aerial insects. The rocky outcrop habitat comprises rocks and hills with short trees, shrubs and no tall trees due to the rocky nature of the habitats. There are *Ficus* plants which attract many insects like the Hymenoptera that feed on their fruits.

### Sampling period

Insects were collected during the mid-rainy season of 2016 (June-July). The insects were usually collected once weekly between the hours of 7am and 12 noon.

### Insect collection and preservation

The insect sweep-net of diameter 25cm and thickness of 2.7cm with net made up of muslin material fitted to a 32-inch long wooden handle

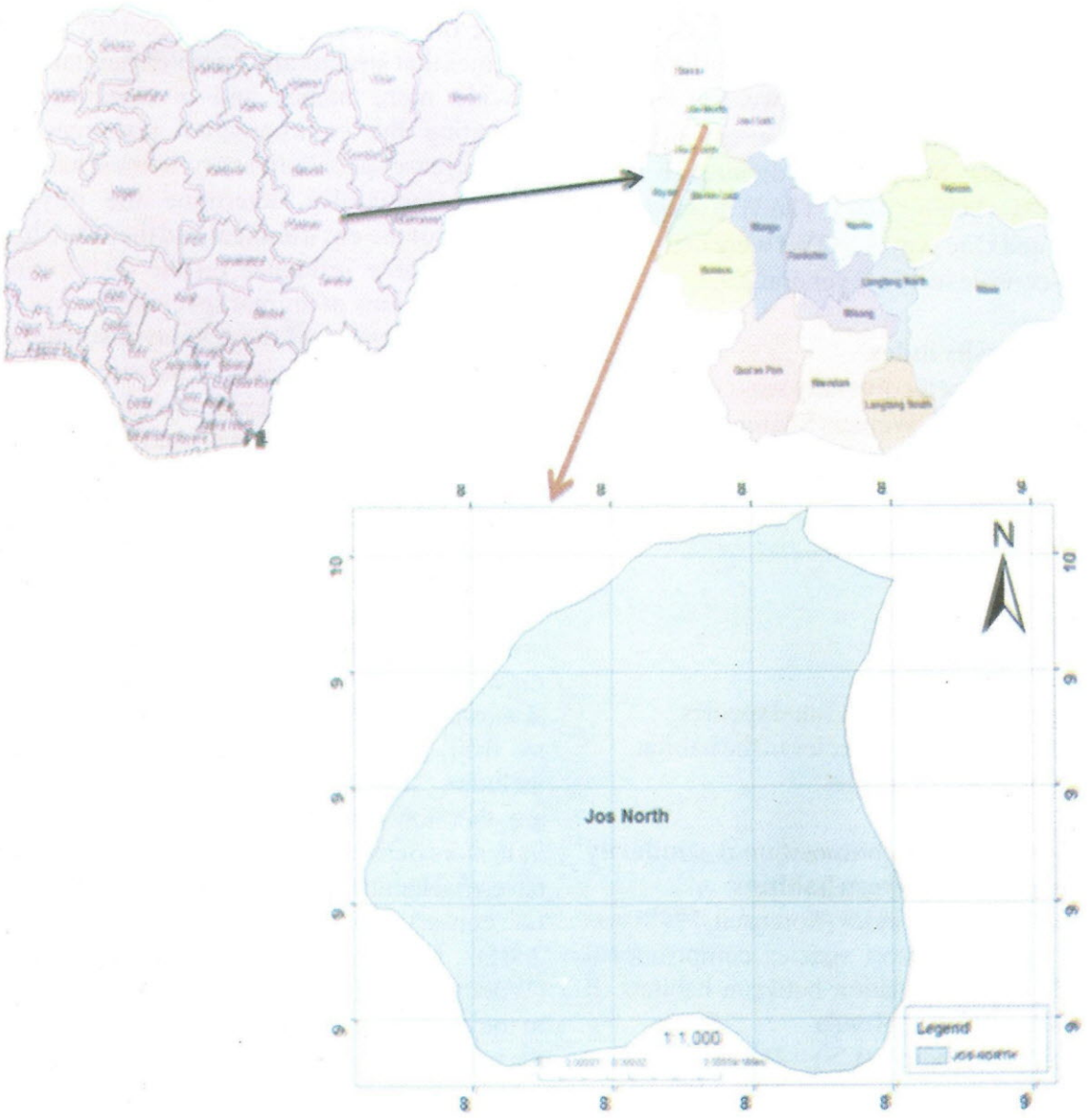


Figure 1: **Map of Plateau State, Nigeria showing location of the study area**

was used to trap aerial insects. In each sampling site, three belt transect points (edge, mid and interior) 50m apart were measured. The sweep-net was held at the wooden handle nearest to the ground and swung from side to side in full 180 degrees arc. A total of 20 sweeps were made at each transect point.

The insects trapped were transferred into a killing jar containing ethyl ethyl-acetate. Dead insects were then emptied into a sample bottle containing 70% ethanol and glycerol. All insects collected were taken to the laboratory for identification, counting and classification.

**Identification of insects**

The contents of each sample bottle were emptied into a Petri dish, sorted and identified using Photographic Atlas of Entomology and Guide to Insect Identification by Castner (2000). Most of the generic and specific identifications were made using the insects in the Systematic and Taxonomic Laboratory of the Department of Zoology, University of Jos, Nigeria.

**Data analyses**

Wilcoxon rank sum test was used to compare the means of aerial insects between rocky

outcrop and savanna woodland. One-way ANOVA was used to compare the mean abundance of aerial insects between points and the mean abundance of aerial insect orders in each habitat. Significant difference was determined when $p < 0.05$. The Wilcoxon rank sum test and One-way ANOVA were conducted using R-console software version 2.9.2.

**Species diversity index**

Aerial insect species diversity was computed using the Shannon-Weiner (Shannon and Weaver, 1949) Diversity index (H):

$$H = -\sum_{i=1}^{S} P_i \ln P_i$$

Where:
H is the diversity index
$P_i$ is the proportion of individual species
*S* is the total number of species in the habitat
i is the proportion of species.

**Aerial insect species compositional similarity and/or variation between habitats**

Sorensen's similarity index (Sorensen, 1948) was used to measure insect species compositional similarity and/or variation between habitats. It was measured by the formula
Sorenson's Coefficient **(CS) = 2c/a+b**

Where:
CS = coefficient of similarity
a = number of species present in both sites under consideration
b = number of species present in Site 1 but absent in Site 2
c = number of species present in Site 2 but absent in Site 1

## RESULTS AND DISCUSSION

**Species checklist of aerial insects**

The species checklist of aerial insects generated in this study is shown in Table 1. A total of 103 aerial insects which belong to 38 species representing 11 orders and 36 families were collected in JMZ Garden. These results support the idea that 'habitat heterogeneity hypothesis' is one of the cornerstones of ecology, which assumes that structurally complex habitats may provide more niches and diverse ways of exploiting the environmental resources and thus increase species diversity. In most habitats, plant communities determine the physical structure of the environment and therefore have a considerable influence on the distributions and interactions of animal species (Tews *et al.*, 2004). The results of these study also support the idea that landscape characteristics is important for species condition as well as for species richness since landscape heterogeneity is clearly an important factor for aerial insect's species diversity. Both large-scale and small-scale heterogeneity are important for the composition of species (Weibull *et al.*, 2000).

The presence of *Bittacus* species, *Cicada orni*, *Harmonia axyridis*, *Leptocorisa acuta*, *Lucilia sericata*, *Megaselia halterata*, *Musca domestica* and *Paratettrix albolimatus* is linked to their high demands for habitat quality including vegetation structure and types. They are, therefore, generally considered to be useful indicators of habitat quality changes in particular terrestrial habitats and are possibly the best group for conservation planning (Maes and Dyck, 2001). There was no significant difference (Wilcoxon rank sum test: W = 1175, P = 0.06163) in the mean abundance of aerial insects between the rocky outcrop and savannah woodland of the

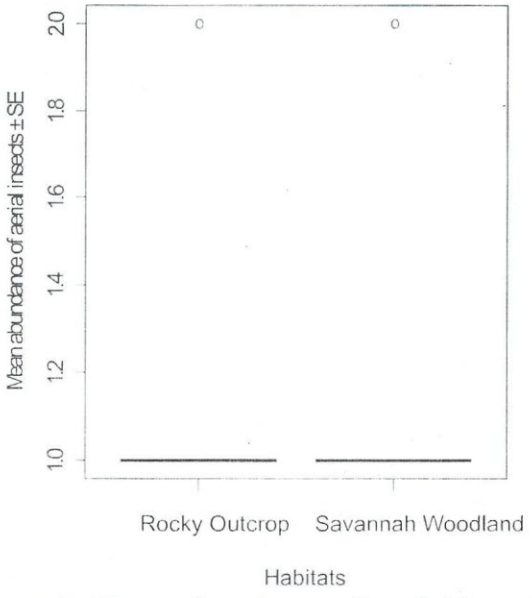


Figure 2: **Mean abundance of aerial insects between the habitats in the Jos Museum Zoological Garden**

Table 1: **Checklist of aerial insects from two habitats in the Jos Museum Zoological Garden**

| Common name | Species | Rocky outcrop | Savannah woodland | Total (%) |
|---|---|---|---|---|
| Damsel fly | *Agrion maculatum* | 1 | 2 | 3 (2.91) |
| Stink bug | *Alcaeorrhychus grandis* | 1 | 2 | 3 (2.91) |
| Darner dragonfly | *Anax junius* | - | 1 | 1 (0.97) |
| Weed aphid | *Aphis nerii* | 2 | - | 2 (1.94) |
| Hanging scorpion fly | *Bittacus* species | 1 | 6 | 7 (6.80) |
| Bee fly | *Bombylius major* | 1 | - | 1 (0.97) |
| Bumble bee | *Bumbus* species | 2 | 2 | 4 (3.88) |
| Owl moth | *Caligo species* | 1 | - | 1 (0.97) |
| Midge | *Chironomus species* | 4 | - | 4 (3.88) |
| Cicadas | *Cicada orni* | 3 | 3 | 6 (5.83) |
| Vinegar fly | *Drosophila melanogaster* | 2 | - | 2 (1.94) |
| Lady bug | *Harmonia axyridis* | 2 | 3 | 5 (4.85) |
| Spider wasp | *Hemipepsis australasiae* | 3 | - | 3 (2.91) |
| Broad- headed bug | *Leptocorisa acuta* | 2 | 4 | 6 (5.83) |
| Drangon fly | *Libellula saturate* | 1 | - | 1 (0.97) |
| Green bottlefly | *Lucilia sericata* | 3 | 2 | 5 (4.85) |
| Tarnished plant bug | *Lygus lineolaris* | 1 | - | 1 (0.97) |
| Scuttle fly | *Megaselia halterata* | 5 | 1 | 6 (5.83) |
| Short-horned grasshopper | *Melanophis keeleri* | - | 2 | 2 (1.94) |
| Wasp-mimicking mydas fly | *Musca clavata* | 3 | - | 3 (2.91) |
| House fly | *Musca domestica* | 4 | 1 | 5 (4.85) |
| Satyrs butterfly | *Neonympha mitchellii* | - | 2 | 2 (1.94) |
| Stonefly | *Neoperla spio* | - | 2 | 2 (1.94) |
| Milkweed bug | *Oncopeltus fasciatus* | 2 | 1 | 3 (2.91) |
| Pygmy grasshopper | *Paratettrix albolimatus* | 5 | | 5 (4.85) |
| June beetle | *Phyllophaga* | 1 | - | 1 (0.97) |
| Wasp-like thick headed fly | *Physoconopsis species* | 2 | 1 | 3 (2.91) |
| Cone head Katydid | *Pterophylla camellifornia* | 1 | - | 1 (0.97) |
| Plant hopper | *Rhynchomitra lingual* | - | 1 | 1 (0.97) |
| Mantid | *Stagomatis Carolina* | 1 | - | 1 (0.97) |
| Shield-backed bug | *Tectocokis diophthalmus* | - | 1 | 1 (0.97) |
| Lantana lace bug | *Teleonemia scrupulosa* | 2 | 2 | 4 (3.88) |
| Crane fly | *Tipula paludosa* | - | 2 | 2 (1.94) |
| Assassin bug | *Triatoma* species | 2 | 1 | 3 (2.91) |
| Unidentified | - | - | 1 | 1 (0.97) |
| Yellow jacket wasp | *Vespula* species | 3 | 1 | 2 (1.94) |
| **Total** | | **58** | **45** | **103 (100)** |

JMZ Garden (Figure 2).

The rocky outcrop had 58 (55.77%) insects representing 10 orders which spread across 29 families with 30 species, while 45 (44.23%) recorded insects in the savannah woodland representing 10 orders spread across 23 families with 24 species. High abundance of aerial insects in the rocky outcrop compared to savannah woodland is due to habitat quality including microclimate, vegetation structure, co-occurrence of vegetation types at a local scale and less habitat deterioration. This is in agreement with Stork *et al.*, (2003) work on butterfly diversity and silvicultural practice in lowland rainforests of Cameroon. They revealed that insects and plants are at risk of becoming extinct because of pollution, habitat quality, vegetation structure, overpopulation and global climatic changes. Similarly, high abundance in the rocky outcrop could be as a

result of higher diversity of plant species and restriction of human induced activities. Food and Agricultural Organization (FAO) (2001) affirmed that insect species in protected habitats are found abundant because of their protection from human induced activities. Because of the diverse nature of plant species in protected habitats, insects are more attracted to plant species for foraging purpose which could result in richness and abundance (FAO, 2001).

One major problem observed in the savannah woodland of the Jos Museum Zoological Garden is anthropogenic activities such as refuse dumping, defecating, logging and bush burning. These activities greatly influence the abundance and diversity of insect species.

**Abundance of aerial insects between transect points**

The mean abundance of aerial insects in relation to transect points in the rocky outcrop showed no significant difference ($F_{45} = 2.058$, Adjusted R-squared = 0.04309, P = 0.1395) as showed in Figure 3. The breakdown of the result revealed that the edge point of the rocky outcrop had the highest abundance of aerial insects. Figure 3 shows that interior and mid-point had the least number of insects in the Rocky Outcrop habitat. Similarly, the mean abundance of aerial insects in relation to transect points in the savannah woodland showed no significant difference ($F_{40} = 0.4966$, Adjusted R-squared = -0.02456, P = 0.6123, Figure 4). Figure 4 shows the same level of insects in all the transect points of the savannah woodland. The observed non-significant difference in the abundance of aerial insects in relation to transect points in the two habitats studied may be due to even distribution of vegetation and food resources. This is consistent with the findings of Barbosa *et al.*, (2005) who worked on the distribution pattern of herbivorous insects in a remnant of Brazilian Atlantic forest. They obtained non-significant difference in the abundance of herbivorous insects in the forest edge and interior section respectively. The highest abundance of aerial insects encountered in the edge transect point could be attributed to the fact that there are more desirable trees, plants and exposure to sunlight that could attract aerial insects and

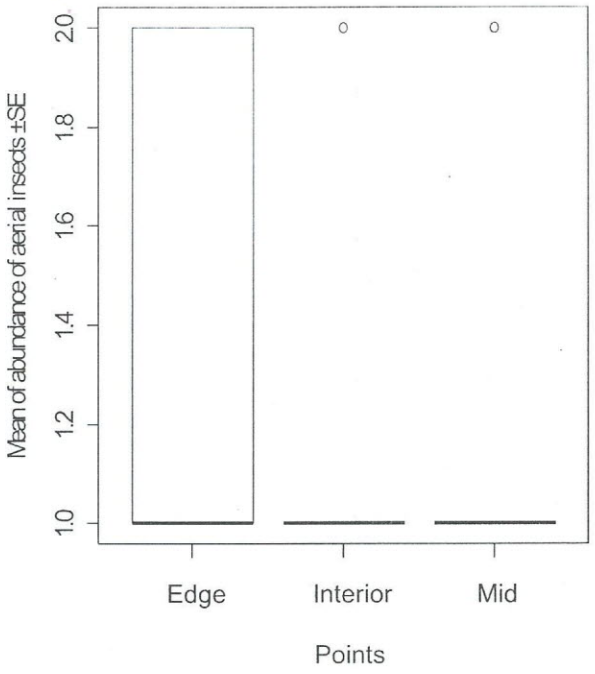


Figure 3: **Mean abundance of aerial insects between the points in rocky outcrop in the Jos Museum Zoological Garden**

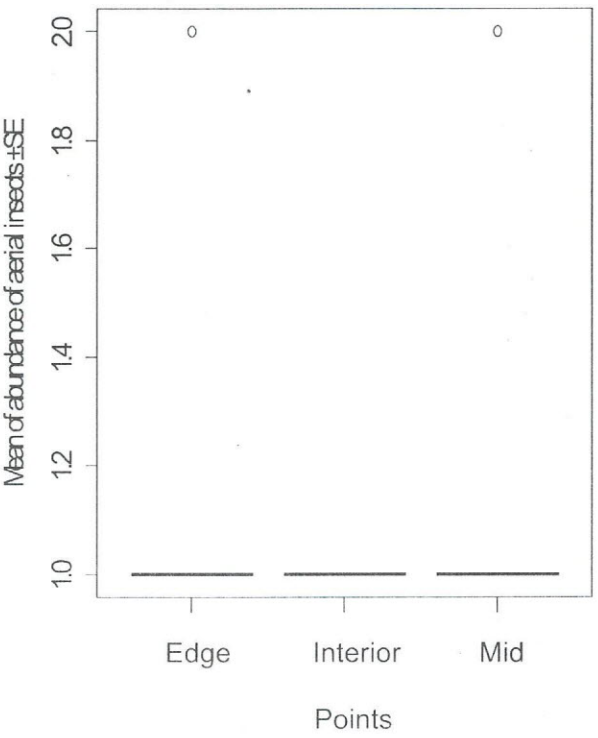


Figure 4: **Mean abundance of aerial insects between the points in savannah woodland of Jos Museum Zoological Garden**

create a conducive environment and moderated microclimates for aerial insects habitats. Adebuntan (2007) reported that high diversity of insects taxa are generally found

where light penetrate and are partly covered by plants. However, the low abundance of aerial insects in the mid and interior points of rocky outcrop and savannah woodland suggest that eutrophication and anthropogenic stressors such as pollution and solid wastes may be influencing the insect communities along these transect points thus resulting in relatively poor foraging conditions for the aerial insects. King and Brazner (1999) working on Coastal wetland insect communities in Wisconsin, United States, along a trophic gradient reported that distinct regional differences exist between lower, middle and upper bay of insect assemblage among wetland and beach habitats in Green bay.

**Abundance of aerial insects between orders**

The mean abundance of aerial insects in relation to orders showed no significant difference ($F_{38}$ = 1.118, Adjusted R-squared = 0.02217, P = 0.3739) in the rocky outcrop (Figure 5).The abundance depicted this trend: Homoptera > Coleoptera > Hymenoptera > Diptera > Orthoptera > Lepidoptera = Mantodea = Mecoptera = Odonata = Hemiptera. Similarly, the mean abundance of aerial insects in relation to orders in savannah woodland showed no significant difference ($F_{33}$ = 1.693, Adjusted R-squared = 0.1293, P = 0.1303) (Figure 6). The abundance of aerial insects followed this trend: Mecoptera > Hemiptera > Coleoptera = Diptera = Homoptera = Hymenoptera = Lepidoptera = Odonata = Orthoptera = Plecoptera. The non-significant difference in the abundance of aerial insects in the two habitat types is attributed to the presence of *Ficus* plants in both habitats which attract insects that feed on its fruits. Basset *et al.* (1997) also reported the importance of *Ficus* plants as an important component of tropical floras as well as one of keystone resources for herbivorous arthropods in the forests. However, in a study of the distribution of insects by aerial currents carried out by Freeman (1995), it was revealed that there was a significant difference in aerial insect's abundance in relation to orders at various heights above ground level. But on the average the abundance of Homoptera was the highest in rocky outcrop while the Mecoptera had the highest in savannah woodland. The orders of Homoptera, Mecoptera, Coleoptera, Hemiptera and Hymenoptera dominate other insect orders because of their large adaptation to critical and extreme conditions (Mesa *et al.*, 2013) while Diptera, Orthoptera, Lepidoptera and Plecoptera are fewer in number with similar densities in the two habitats due to their low dispersal abilities. Cobos (1987) reported that Coleoptera and Hymenoptera are dominant insect orders, while Dermaptera, Heteroptera, Homoptera and Diptera are the

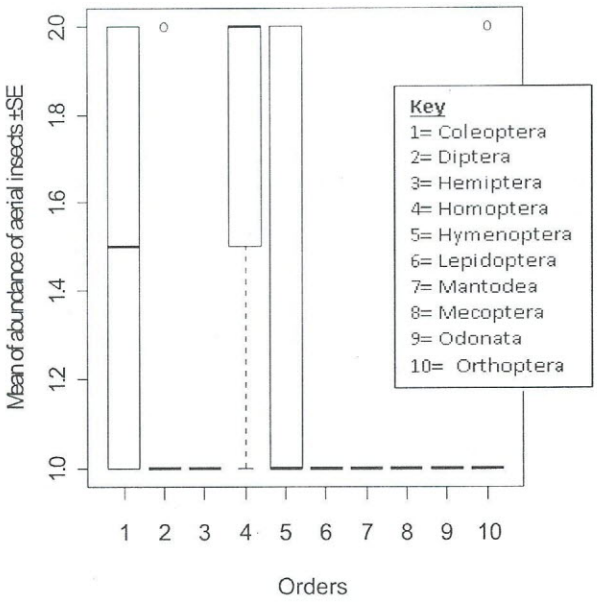


Figure 5: **Mean abundance of aerial insects in relation to orders in rocky outcrop**

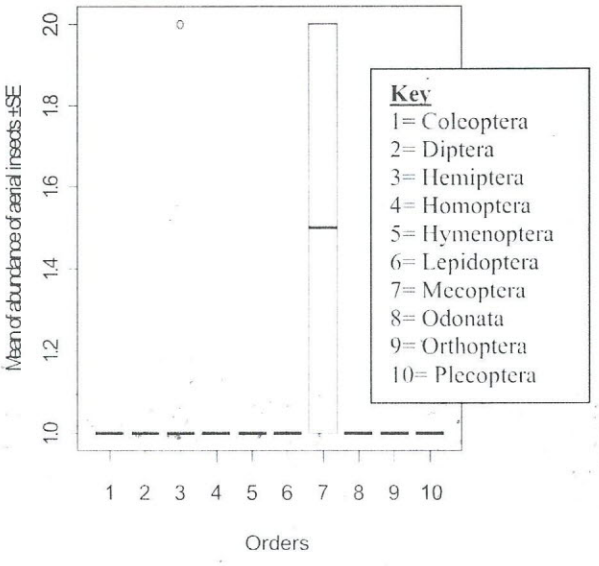


Figure 6: **Mean abundance of aerial insects in relation to orders in savannah woodland**

Table 2: **Shannon-Weiner diversity indices for aerial insect species collected from rocky outcrop**

| Species | No. | (Pi)*ln(Pi) |
|---|---|---|
| *Aphis nerii* | 2 | -0.11611 |
| *Bombylius major* | 1 | -0.07001 |
| *Cicada orni* | 1 | -0.07001 |
| *Megaselia halterata* | 5 | -0.21129 |
| *Libellula saturate* | 1 | -0.07001 |
| *Cicada orni* | 2 | -0.11611 |
| *Pterophylla camellifornia* | 1 | -0.07001 |
| *Phyllophaga* species | 1 | -0.07001 |
| *Alcaeorrhychus grandis* | 1 | -0.07001 |
| *Lygus lineolaris* | 1 | -0.07001 |
| *Vespula* species | 2 | -0.11611 |
| *Chironomus* species | 3 | -0.15319 |
| *Drosophila melanogaster* | 2 | -0.11611 |
| *Bittacus* species | 1 | -0.07001 |
| *Triatoma* species | 2 | -0.11611 |
| *Stagomatis Carolina* | 1 | -0.07001 |
| *Romalea guttata* | 1 | -0.07001 |
| *Caligo* species | 1 | -0.07001 |
| *Musca domestica* | 2 | -0.11611 |
| *Paratettrix albolimatus* | 5 | -0.21129 |
| *Oncopeltus fasciatus* | 2 | -0.11611 |
| *Bumbus* species | 2 | -0.11611 |
| *Agrion maculatum* | 1 | -0.07001 |
| *Lucilia sericata* | 3 | -0.15319 |
| *Teleonemia scrupulosa* | 2 | -0.11611 |
| *Leptocorisa acuta* | 2 | -0.11611 |
| *Hemipepsis australasiae* | 2 | -0.11611 |
| *Musca clavata* | 3 | -0.15319 |
| *Physoconopsis* species | 2 | -0.11611 |
| *Harmonia axyridis* | 2 | -0.11611 |
| **Total** | **58** | **-3.58276** |

**Shannon-Weiner index (H′) = -Σ (Pi) In (Pi) = 3.58**

least present in different study stations in the mountainous regions of the Alps and Pyrenees in Spain. He attributed this sparse distribution to low dispersal ability.

**Species Diversity Index**

The conservation of natural habitat is very essential for the existence of many species of aerial insects (Mathew and Rahmatullah, 1993). The Shannon-Weiner species diversity index in rocky outcrop revealed that *Megaselia halterata* and *Paratettrix albolimatus* recorded the highest diversity index of-0.21 (Table 2). *Bittacus* species had the highest species diversity index of -0.27 in the savannah woodland (Table 3).This possibly suggests that the rocky outcrop and savannah woodland of the garden provide natural environment that supports their existence and survival. It is therefore important that frequent monitoring of ecological processes beside adoption of appropriate conservation strategy to safeguard their rich genetic diversity be encouraged. The overall diversity index of the two habitat types studied did not vary significantly (P>0.05). The rocky outcrop had 3.58 and savannah woodland 3.19.This clearly suggests that the JMZ Garden is a healthy ecosystem since species diversity value H for biological communities is not below 2.5 and does not exceed 5.0. Metcalfe-Smith (1996) also observed a higher value of Shannon-Weiner diversity index supposedly as a result of greater diversity it has in healthier environments.

**Evaluation of aerial insect species compositional similarity/variation between habitats**

There are 103 species in both habitats; 15 species present in rocky outcrop but absent in savannah woodland and 8 species present in savannah woodland but absent in rocky outcrop. Thus, Sorenson's Coefficient (CS) = CS=2 x 8/103+15=0.14.

From the calculated Sorenson's coefficient value, the two habitat types studied do not have much overlap, therefore, it showed a complete dissimilarity in species composition of aerial insects. This is probably due to their floristic composition and structure. The constituent species of assemblage in the rocky outcrop are generalists, adapting to most environmental

conditions that stimulate their development and dispersal. This was also reported by Montagna *et al.*, (2012) study on insect community structure and insect biodiversity conservation in an Alpine wetland subjected to an intermediate diversified management regime. They revealed that insect diversification is well marked in different stations due to changes in the weather parameters, floral dissimilarity in species composition. The study recommended that for the protection of insect habitats, the flora of Jos Museum Zoological Garden should be protected. One major problem observed in the Jos Museum Zoological Garden is anthropogenic activities such as refuse dump, defecating, logging and bush burning. It is therefore important that adequate measures be mounted to curb these anthropogenic activities. Further studies should also be carried out on the impact of anthropogenic activities on insect's distribution and abundance.

Table 3: **Shannon-Weiner diversity index of aerial insect species collected from savannah woodland**

| Species | No. | (Pi)*ln(Pi) |
|---|---|---|
| *Lucilia sericata* | 2 | -0.13838 |
| *Teleonemia scrupulosa* | 2 | -0.13838 |
| *Cicada orni* | 3 | -0.18054 |
| *Megaselia halterata* | 1 | -0.08459 |
| *Melanophis keeleri* | 2 | -0.13838 |
| *Agrion maculatum* | 2 | -0.13838 |
| *Rhynchomitra lingual* | 1 | -0.08459 |
| *Neoperla spio* | 2 | -0.13838 |
| *Oncopeltus fasciatus* | 1 | -0.08459 |
| *Tipula paludosa* | 2 | -0.13838 |
| *Nabis rugosus* | 1 | -0.08459 |
| *Tecto cokis diophthalmus* | 1 | -0.08459 |
| *Harmonia axyridis* | 3 | -0.18054 |
| *Bittacus* species | 6 | -0.26865 |
| *Alcaeorrhychus grandis* | 2 | -0.13838 |
| *Triatoma* species | 1 | -0.08459 |
| *Vespula* species | 2 | -0.13838 |
| *Leptocorisa acuta* | 4 | -0.21514 |
| *Neonympha mitchellii* | 2 | -0.13838 |
| *Anax junius* | 1 | -0.08459 |
| *Physoconopsis* species | 1 | -0.08459 |
| *Bumbus* species | 2 | -0.13838 |
| unidentified | 1 | -0.08459 |
| **Total** | **45** | **-3.18641** |

**Shannon-Weiner index (H′) = -Σ (Pi) In (Pi) = 3.19**

## CONCLUSION AND RECOMMENDATIONS

The abundance of aerial insect species had no significant difference between habitats, transect points and insects orders. The two habitats had high diversity index, but showed complete dissimilarity in species composition. The study recommended that for the protection of insect habitats, the flora of Jos Museum Zoological Garden should be protected. One major problem observed in the Jos Museum Zoological Garden is anthropogenic activities such as refuse dump, defecating, logging and bush burning. It is therefore important that adequate measures be mounted to curb these anthropogenic activities. Further studies should also be carried out on the impact of anthropogenic activities on insect's distribution and abundance.

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***Njila, H. L., Mwansat, G. S., Barnabas, F., Ombugadu, A., Pukuma, S. M., Dibal, M.** and **Mafuyai, M. J.**
*Nigerian Journal of Entomology*
Published by the Entomological Society of Nigeria
www.esn.org.ng
ISSN: 0331-0094
Volume 33, 2017
pp. 93-102
DOI:10.36108/NJE/7102/33(0111)