UDS International Journal of Development [UDSIJD]
Volume 6 No. 3, 2019
http://www.udsijd.org
ISSN: **2026-5336**

# EFFECT OF ANTHROPOGENIC DISTURBANCES ON INSECT DIVERSITY AND ABUNDANCE IN THE SINSABLEGBINI FOREST RESERVE, GHANA

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## Abstract
*This study was conducted to assess the effect of anthropogenic disturbances on insect diversity and abundance in the Sinsablegbini Forest Reserve. Insects were sampled in two types of disturbed habitats (encroached forest and burnt forest) in the reserve with the undisturbed forest as control. A one (1) hectare permanent sampling plot was demarcated in each habitat type for the collection of insects. Insects were sampled with pitfall traps, pan traps, sticky traps, sweep nets and handpicking for 12 sampling days across three months (February–April) of the dry season. 914 insects belonging to 10 insect orders and 40 families were identified in the reserve. Insect diversity was generally higher in the undisturbed forest than the disturbed area (burnt forest and encroached forest). Insect order distribution equally varied across the three habitats with the undisturbed forest recording ten orders (10) whilst the encroached forest and burnt forest recorded nine (9) and six (6) orders respectively. Anthropogenic disturbances also had a significant effect on insect abundance with the burnt forest recording a significantly low insect abundance as compared to the undisturbed forest (P > 0.05). The study showed that anthropogenic activities are having devastating effects on insect biodiversity in the Sinsablegbini Forest Reserve. A collaborative effort of both Forestry Services Division and fringe communities is recommended to curb these disturbances to help conserve biodiversity in the reserve.*

**Keywords***: **Diversity, Sinsablegbini Forest Reserve, Undisturbed, Encroached, Burnt***

## Introduction
The Sinsablegbini Forest Reserve is one of the few nature reserves in the Guinea Savanna zone of Ghana. The reserve was established in 1956 with the primary objectives of protecting the Moya River and its tributaries and to preserve a sample of the indigenous fauna and flora of the area (Husseini, Baatuuwie, & Issifu, 2015) The reserve contributes significantly to biodiversity as the only natural forest reserve in the Tamale Forest District providing habitat for diverse plants and animals endemic to the Guinea Savanna (Asase, Patrick & John, 2009). Despite its ecological significance, the reported anthropogenic disturbances such as indiscriminate bush burning, encroachment and illegal logging (Husseini et al., 2015) poses a threat to biodiversity in the reserve.
Human induced fires are known to be an ancient environmental disturbance in African savannas and have perhaps influenced the structure and function of the savanna landscape (Sheuyange, Oba & Weladji, 2005). Indiscriminate bushfire is an annual phenomenon in the Guinea savanna zone of Ghana with devastating effects on the fauna and flora of protected forests. Aside fires, extensive agriculture is known to be associated with biodiversity losses in Sub-Saharan Africa (Perrings & Halkos, 2015). Nonetheless, forest fringe communities are increasingly converting protected forests into cultivated lands in Ghana (Siaw, 1998). Additionally, fallow lands that served as alternative sources of timber and non-timber forest products are being converted to productive lands due to agricultural extensification (Tom-Dery, Sakyi, & Bayor, 2015). This phenomenon compels forest fringe communities to depend on forest resources of protected areas. (Hussein *et al*., 2015) reported that

fringe communities of the Sinsablegbini Forest Reserve largely depend on the reserve for fuelwood and other resource needs.

These disturbances fragment the natural forest habitat and reduce the area available for endemic plants and animals (Debinski & Holt, 2000). Moreover, anthropogenic disturbances result in qualitative changes in habitat to which tropical organisms might not be able to adapt (Hulme, 2006). A sustainable natural resources management would require a detailed understanding of the relationship between various disturbance regimes and their biodiversity outcomes on component species (Hulme, 2006). Nonetheless, studies in the Sinsablegbini Forest Reserve (Asase, Patrick, and John, 2009; Abdulai, 2012; Husseini et al., 2015) have focused more on floristic composition and management aspects with little information on fauna especially insects. This study was therefore conducted with the objectives of examining the effect of various anthropogenic disturbances on the diversity and abundance of insects in the Sinsablegbini Forest Reserve.

Although anthropogenic disturbances affect all life forms, (Zurlini, Petrosillo, Jones, Li, Riitters, Medagli, Marchiori, Zaccarelli, 2013) insects are the most sensitive to environmental stresses (Kremen, Colwell, Erwin, Murphy, Noss, & Sanjayan, 1993; Davis, Holloway, Huijbregts, Krikken, Kirk-Spriggs, and Sutton, 2001; Arun & Vijayan, 2004). In addition, insect biodiversity tends to provide clearer outcomes on ecological consequences of human-induced disturbances (Losey & Vaughan, 2006; Kyerematen, Owusu, Acquah-Lamptey, Anderson & Ntiamoa-Baidu, 2014). Moreover, ecological services provided by insects in nutrient recycling (Van Der Heijden, Bardgett, &Van Straalan 2008), decomposition (Losey & Vaughan, 2006), pollination (Klein, Vaissie`re, Cane, Steffan-Dewenter, & Cunningham, 2007; Ollerton, Winfree & Tarrant, 2011) and pest control (Clay, Lucas, Kaspari & Kay, 2013) form the basis of major biological interactions in forest ecosystems. Beneficial insects such as honeybees, wasps, butterflies, beetles and ants are essential to the sustainability of the entire forest ecosystem. For instance, without pollination, many interconnected species and processes functioning within an ecosystem would collapse (Klein, Vaissie`re, Cane, Steffan-Dewenter & Cunningham, 2007). Aside these ecological services, edible insects also contribute to food security. For instance, the caterpillar of *Cirina forda* is a food delicacy and a valuable Non-Timber Forest Product in northern Nigeria and many shea growing areas of Africa (Alamu, Amao, Nwokedi, Oke & Lawa, 2013).

## Materials and Methods

### *Study Area*

The study was conducted in the Sinsablegbini Forest Reserve, which has a land area of 72.62 $km^2$. The reserve is located about 20 km east of Tamale, the district capital of Northern region of Ghana and lies between latitude 09°24' N and longitude 00°38'W (figure 1). It is found in the Guinea Savanna zone of Ghana and therefore records a unimodal rainfall pattern with an annual average rainfall of 1,127 mm (SARI, 2016). The wet season occurs between May and October with peak rainfalls being recorded in the months of August and September whilst the dry season occurs between November and April. Maximum temperatures are experienced during the months of March and April, whilst the lowest temperatures are recorded in December when the north east-trade winds push the Inter Tropical Convergence Zone further south.

The vegetation is dominant grassland interspersed with woody perennials. Some of the most common woody species in the reserve include shea *(Vitellaria paradoxa)*, dawadawa *(Parkia biglobosa)*, baobab *(Adansonia digitata)*, neem *(Azadiracta indica),* African rosewood *(Pterocarpus erinaceus),* mahogany *(Khaya senegalenses)* and *Anogeissus leiocarpus* (Husseini *et al*., 2015). Herbaceous species indigenous to the savanna include *Tridax procumbens, Andropogon pseudapricus, Panicum maximu, Pennisetum purpureu* and *Boerhavi diffusa* (Ziblim, Abdul-Rasheed & Aikins, 2015).

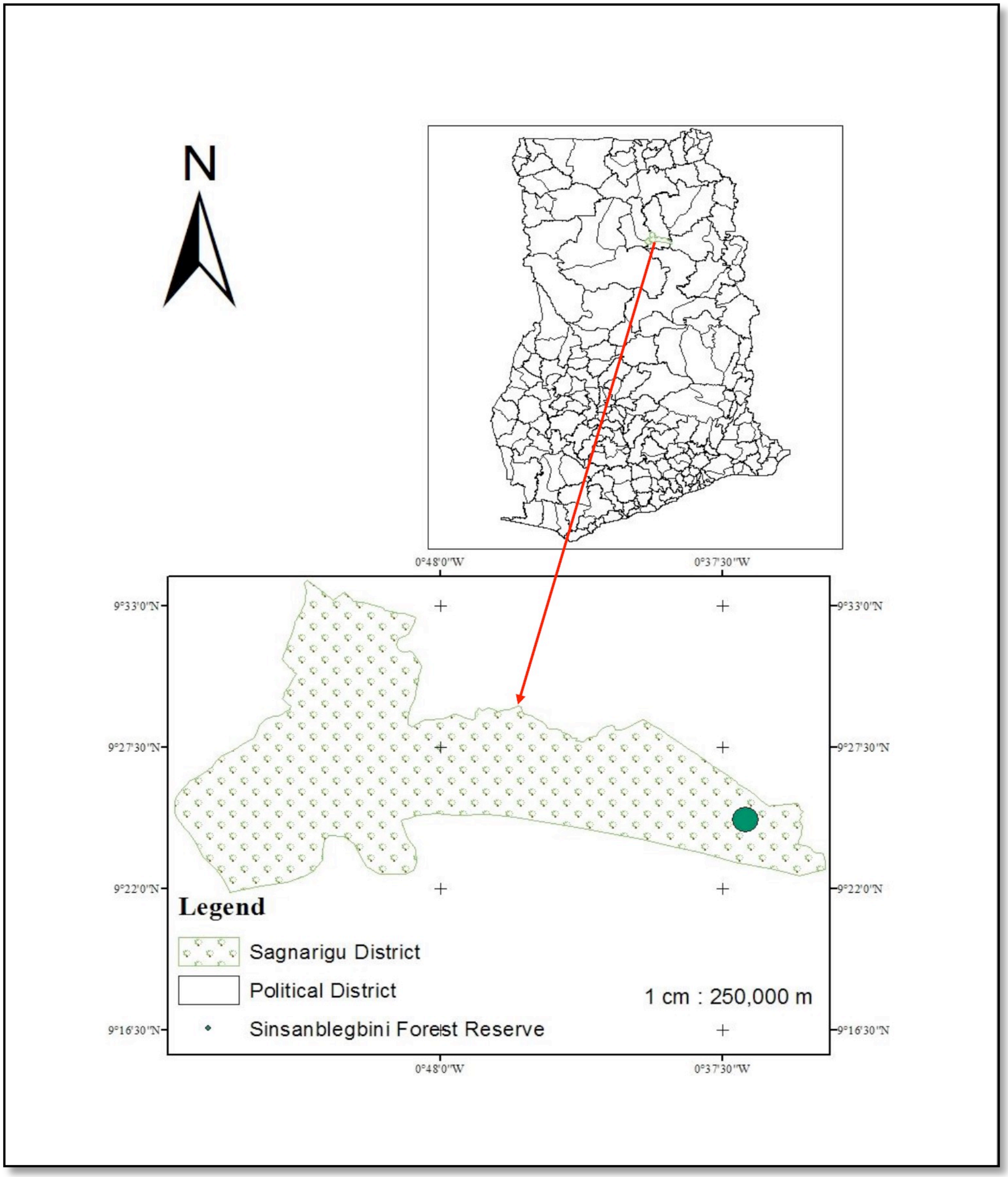


**Figure 1: Map of study Area**

***Site Selection***

A reconnaissance survey was conducted to identify the various types of anthropogenic activities in the reserve. Disturbed areas were stratified into Burnt Forest and Encroached forest. Insect sampling was done in these two strata and the undisturbed forest as a control.

1) Burnt Forest refers to the area that was partially or completely burnt by bushfires primarily due to the activities of game hunters who deliberately burnt the vegetation for hunting expeditions. This area was characterized by scattered woody species with leaf canopy partially or

completely destroyed by fire and having limited or no grassland undergrowth.

2) Encroached forest; the area within the reserve that was illegally cleared and used for cultivation or the illegal cultivated area that has been abandoned. This area was characterized by few economic tree species such as shea (*Vitellaria paradoxa*), dawadawa (*Parkia biglobosa*), lannea (*Lannea acida*) Tamarind (*Tamarindus indica* and ebony (*Diospyros mespiliformis*) that were deliberately retained and managed by farmers. Although there was limited grass undergrowth in this area as well, it had thicker undergrowth than the burnt forest and the dominant grass was *Andropogon pseudapricus*.

3) Undisturbed forest; the area that had no major physical alteration to the native constituents of the vegetation. It had higher woody species density, denser canopy cover and grassland undergrowth than the other two habitats.

***Insect sampling***

A one (1) hectare land area was demarcated in each habitat type for sampling insects throughout the experiment. Insect sampling was done once weekly for a period of three months (February – April) with a total of twelve (12) sampling days per habitat type. Sampling methods employed were pitfall trapping, sweep netting, hand picking and sticky trapping.

Ten (10) pitfall traps spaced at 10 m apart were set along a 100 m transect in each habitat type for the collection of crawling and ground dwelling insects. Pitfalls were made of plastic cups of different colors (blue, yellow, white and pink) with open diameter of 7.5cm and a depth of 15 cm. The containers were buried with the opened end at the same level with the ground and half filled with saturated salt solution for drowning collected specimens. Salt solution is known to be effective in minimizing attractant bias (Kotze, Brandmayr, Casale, Dauffy-Richard, Dekoninck, Koivula, & Pizzolotto, 2011). Traps were set up for 24 hours before the removal of collected specimens.

Five sticky traps were hanged on trees in each habitat type for the collection of arboreal insects. Sticky traps were made of light-coated-glue cardboards, which were hanged (1.9 – 5 m above ground) on tree stems and branches (Covell, 2009) for the collection of flying and arboreal insects on trees. A sweep net was used to collect large free-flying insects and vegetation dwelling insects. Insects that were easy to reach were handpicked with forceps. Sweeping and handpicking were done in the morning and evening for thirty (30) minutes periods in each habitat type by moving along a 50 m transect.

All hard-bodied insects were preserved by pinning and storing in paper packets while soft-bodied insects were stored in 70% ethanol and transported to the Department of Forestry and Forest Resources Management (DFFRM) of the University for Development Studies (UDS) for sorting and identification. Identification was done with reference to picture guides and insect in collection at DFFRM (Insects that have been identified and stored in insect boxes in the department). Due to taxonomic difficulties, identification was limited to the family.

**Data Analysis**

Relative Frequency and Shannon diversity indices were used in determining community diversity. Relative Frequency (RF) refers to the number of individuals of a given species divided by the total number of individuals of all species found.

$$RF = \frac{ni}{N} \times 100$$

Where RF is relative frequency, ni is the number of individuals of species i, N is total number of individuals in the entire population.

Shannon-Wiener's (H′) diversity index was used in calculating insect diversity in various habitats following Steffan-Dewenter, Munzenberg, Burger, Thies & Tschorntke, (2002)

$$H' = \Sigma - (Pi * \ln Pi)$$

Where, H' is Shannon-Wiener's diversity index, Pi = fraction of the entire population made up of species (i), S = number of species encountered, Σ = sum from species 1 to species S.

Analysis of Variance was used to compare insect abundance between habitats after which Fisher's Least Significant Differences were used to separate means at 95% confidence level using SPSS Version 25.

## Results and Discussion

A total of 914 insects belonging to ten (10) orders and forty (40) families were recorded in the Sinsablegbini Forest Reserve during the survey. The order Diptera recorded the highest number of families (10) whilst Mantodea and Neoroptera recorded the least with one (1) family each (Table 1). Six (6) insect orders (Coleoptera, Hymenoptera, Lepidoptera, Diptera, Orthoptera and Odonata) were common to the three habitats but the orders Hemiptera, Mantodea, Neuroptera and Blattodea were recorded in the undisturbed and encroached forest but were not found in the burnt forest. Family distribution also differed across the three habitats with Diptera recording the highest number of families (10) in the undisturbed forest and the least (2) in the burnt forest. Similarly, Coleoptera recorded 6 families in the undisturbed forest and 4 families in the burnt forest as indicated in Table 1.

**Table 1: Insect orders and families enumerated in the three habitats of the Forest Reserve**

| 11 | | Undisturbed Forest | | Encroached forest | | Burnt Forest | |
|---|---|---|---|---|---|---|---|
| **Order** | **Family** | **No. of Individuals** | **Rel. Freq.** | **No. of Individuals** | **Rel. Freq.** | **No. of Individuals** | **Rel. Freq.** |
| Coleoptera | Carabidae | 36 | 0.08 | 28 | 0.09 | 23 | 0.1 |
| | Chrysomelidae | 16 | 0.04 | 12 | 0.04 | 0 | 0.0 |
| | Coccinellidae | 7 | 0.02 | 9 | 0.03 | 0 | 0.0 |
| | Tenebrionidae | 16 | 0.04 | 19 | 0.06 | 12 | 0.1 |
| | Staphylinidae | 7 | 0.02 | 8 | 0.02 | 2 | 0.0 |
| | Scarabaeidae | 18 | 0.04 | 25 | 0.08 | 12 | 0.1 |
| Orthoptera | Acrididae | 29 | 0.07 | 18 | 0.06 | 25 | 0.2 |
| | Pyrgomorphidae | 15 | 0.03 | 15 | 0.05 | 7 | 0.0 |
| | Tettigoniidae | 9 | 0.02 | 8 | 0.02 | 11 | 0.1 |
| | Tridactylidae | 4 | 0.01 | 7 | 0.02 | 3 | 0.0 |
| Hymenoptera | Apidae | 7 | 0.02 | 4 | 0.01 | 0 | 0.0 |
| | Formicidae | 18 | 0.04 | 21 | 0.07 | 18 | 0.1 |
| | Braconidae | 7 | 0.02 | 3 | 0.01 | 3 | 0.0 |
| | Chrysididae | 4 | 0.01 | 0 | 0.00 | 0 | 0.0 |
| | Eulophidae | 7 | 0.02 | 4 | 0.01 | 6 | 0.0 |
| | Halictidae | 15 | 0.03 | 8 | 0.02 | 2 | 0.0 |
| Odonata | Coenagrionidae | 14 | 0.03 | 14 | 0.04 | 6 | 0.0 |
| | Libellulidae | 6 | 0.01 | 5 | 0.02 | 3 | 0.0 |
| Lepidoptera | Arctiidae | 6 | 0.01 | 7 | 0.02 | 0 | 0.0 |
| | Noctuidae | 11 | 0.03 | 2 | 0.01 | 8 | 0.1 |
| | Nymphalidae | 5 | 0.01 | 1 | 0.00 | 0 | 0.0 |
| | Pieridae | 13 | 0.03 | 14 | 0.04 | 3 | 0.0 |
| | Sphingidae | 8 | 0.02 | 6 | 0.02 | 0 | 0.0 |
| Diptera | Asilidae | 2 | 0.00 | 0 | 0.00 | 0 | 0.0 |
| | Bombyliidae | 11 | 0.03 | 4 | 0.01 | 0 | 0.0 |
| | Calliphoridae | 4 | 0.01 | 0 | 0.00 | 0 | 0.0 |
| | Chloropidae | 15 | 0.03 | 17 | 0.05 | 0 | 0.0 |
| | Culicidae | 10 | 0.02 | 3 | 0.01 | 0 | 0.0 |
| | Tipulidae | 16 | 0.04 | 11 | 0.03 | 0 | 0.0 |
| | Sarcophagidae | 17 | 0.04 | 10 | 0.03 | 3 | 0.0 |
| | Muscidae | 12 | 0.03 | 9 | 0.03 | 0 | 0.0 |
| | Phoridae | 7 | 0.02 | 0 | 0.00 | 0 | 0.0 |
| | Glossinidae | 2 | 0.00 | 6 | 0.02 | 0 | 0.0 |
| Hemiptera | Psyllidae | 2 | 0.00 | 0 | 0.00 | 0 | 0.0 |
| | Pyrrhocoridae | 11 | 0.03 | 5 | 0.02 | 0 | 0.0 |
| | Aleyrodidae | 3 | 0.01 | 1 | 0.00 | 0 | 0.0 |
| Mantodea | Mantidae | 17 | 0.04 | 8 | 0.02 | 0 | 0.0 |
| Neoroptera | Acalaphidae | 2 | 0.00 | 0 | 0.00 | 0 | 0.0 |
| Blattodea | Blattidae | 7 | 0.02 | 2 | 0.01 | 0 | 0.0 |
| | Termitidae | 18 | 0.04 | 9 | 0.03 | 10 | 0.1 |
| **Total** | | **434** | **1** | **323** | **1** | **157** | **1** |

Source: Field data (2017)

Insect diversity also varied across the three habitats with the undisturbed forest recording the highest Shannon diversity index (H'= 0.36) whilst the burnt forest recorded the least (H' = 0.31) as shown in Table 2.

**Table 2: Shannon Diversity index for three habitat types in the Sinsablegbini Forest Reserve**

| Habitat type | Shannon Diversity index (H') |
|---|---|
| Burnt Forest | 0.31 |
| Encroached forest | 0.35 |
| Undisturbed Forest | 0.36 |

Insect abundance as well varied significantly between the undisturbed and burnt forest ($P < 0.05$) (Table 3) with the undisturbed forest recording 48% whilst the burnt forest recorded 17% (Figure 2).

**Table 3: LSD comparisons of insect abundance in three different habitats**

| (I) Type of habitat | (J) Type of habitat | Mean Difference (I-J) | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| Undisturbed forest | Encroached forest | 11.1 | 0.396 | -15.32 | 37.52 |
| | Burnt Forest | 27.700* | 0.041 | 1.28 | 54.12 |
| Encroached forest | Undisturbed forest | -11.1 | 0.396 | -37.52 | 15.32 |
| | Burnt Forest | 16.6 | 0.208 | -9.82 | 43.02 |
| Burnt Forest | Undisturbed forest | -27.700* | 0.041 | -54.12 | -1.28 |
| | Encroached forest | -16.6 | 0.208 | -43.02 | 9.82 |

***.** *The mean difference is significant at the 0.05 level.*

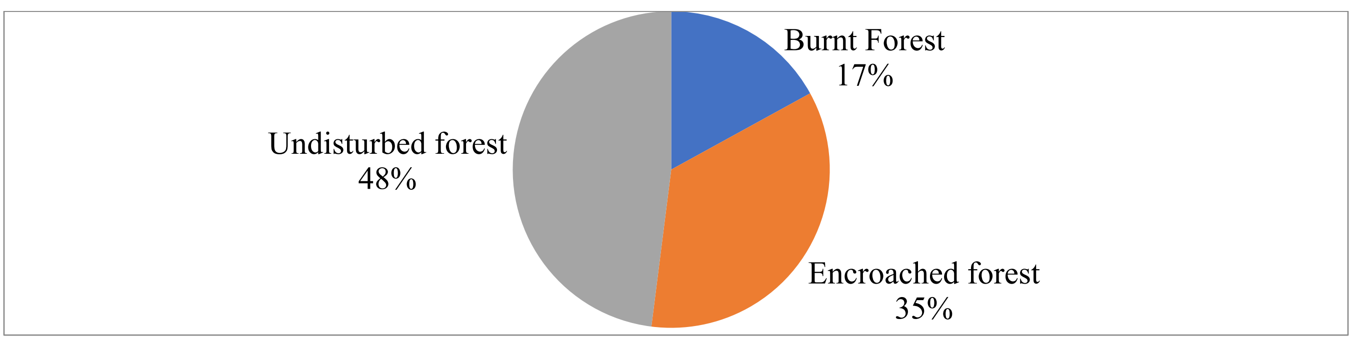


**Figure 2: Insect distribution in the three habitats of the Sinsablegbini Forest Reserve (N= 916)**

The occurrence of higher insect diversity in the undisturbed forest (Figure 2) confirms Adebuntan (2009) who reported higher insect species diversity in an unlogged forest than a disturbed forest in Nigeria. Similarly, Addo-Fordjour, Osei, and Kpontsu (2015) recorded higher butterfly richness, abundance and evenness in an undisturbed forest than a heavily disturbed and moderately disturbed portions of the Atewa Range Forest Reserve in Ghana. The disparity in insect diversity and abundance across the three habitats could be attributed to the variation in the intensity of anthropogenic disturbances in these habitats. Human disturbance is known to be an important factor that affects insect diversity in a forest ecosystem (Sutrisno, 2010; Rajagopal, Sekar, Manimozhi, Baskar & Archunana, 2011). Logging was reported as a common anthropogenic disturbance in the Sinsablegbini forest reserve especially in encroached areas that had significant portions of the vegetation cleared for farming (Hussein et al., 2015). This could have deprived insects of woody species that provided shelter and food resources. This observation is also in consonance with Jaganmohan, Vailshery and Nagendra (2013) who reported positive correlations between tree species diversity and insect diversity in India. The result also affirms Rajagopal, Sekar, Manimozhi, Baskar, and Archunana, (2011) who stressed the role of vegetation in structuring insect species diversity and abundance in forest ecosystems.

The physical complexity and microclimate of habitats are also known to be determinants of insect diversity and abundance (Novotny, Drozd, Miller, Kulfan, Janda, Basset, & Weiblen, 2006). The undisturbed forest had a denser tree canopy cover as compared to the disturbed habitats (burnt forest and encroached forest). This canopy cover might have provided a more conducive microclimate that supported insect activity especially ground dwelling insects. This is supported by Adjaloo, Oduro and Mochiah (2012) who reported higher insect diversity in heavily shaded cocoa farms than cocoa farms that were widely spaced with little canopy cover. The burnt forest for instance had its grassland undergrowth and tree canopy burnt and this exposed ground dwelling insects to the harsh climate of the savanna. Shading is also known to enhance the regeneration of wildings and poles, which increase food resource availability for insects (Adebuntan, 2009). The trend of insect diversity and abundance in the three habitats could therefore be attributed to response to the microclimate of the habitats.

Aside shading effect, food resource availability is known to be a determinant of insect distribution and abundance (Appiah, Afreh-Nuamah & Obeng, 2009; Kyerematen, Owusu, Acquah-Lamptey, Anderson, & Ntiamoa-Baidu, 2014). Crane and Baker (2011) revealed that, organic matter and woody debris serve as shelter and food for insects. Anthropogenic activities such as burning destroy plant and animal remains as well as woody debris, which would have supported scavengers and predatory insects. This could have contributed to the significantly low insect abundance recorded in the burnt forest as compared to the undisturbed forest. Ranio and Niemela (2003) stressed that dynamics of insect species abundance is often due to environmental disturbances.

Although the undisturbed forest recorded the highest insect diversity and abundance, various insect orders responded differently to anthropogenic disturbances. The two most abundant insect orders in the undisturbed forest were Coleoptera (23%) and Diptera (22.1%) with Neoroptera being the least abundant (0.5 %). Similarly, Coleoptera (31.3%) and Diptera (18.6 %) dominated in the encroached forest with Hemiptera as the least abundant order (1.9%). However, contrary to the occurrence of Diptera as the second most abundant order in the undisturbed forest and encroached forest, Orthoptera occurred as the second most abundant (29.3%) insect order in the Burnt Forest (Figure 3).

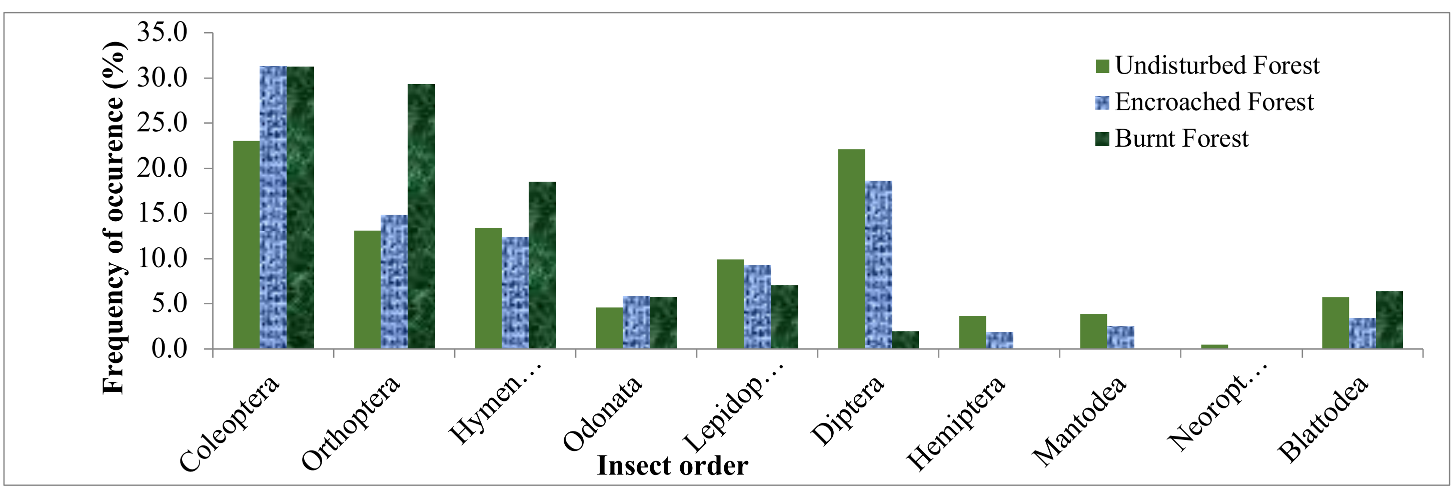


**Figure 3: Insect order abundance in three different habitats**

This trend of Coleopteran dominance in all the three habitats confirm Ojija, Sapeck and Mnyalape (2016) who recorded Coleoptera as the most abundant insect order in two distinct habitats (grassland and woodland) in Tanzania. This could be attributed to the ability of Coleoptera to colonize and inhabit different habitats (Nyundo & Yarro, 2007). Many other studies in different parts of the world have equally recorded high coleopteran richness (Belamkar & Jadesh 2014; Khadijah, Azidah & Meor**,** 2013; Balakrishnan et al. 2014). Coleopterans commonly referred to as beetles are generally herbivores, scavengers and predators, which are extensively involved in the breakdown of organic materials (Lee, Kwon, Lee, & Sung, 2012). These provide them with a wide variety of food which enhances their ability to adapt to vegetation complexity of diverse habitats (Lassau, Hochuli & Cassis, 2005).

That notwithstanding, the occurrence of Diptera as the second most abundant insect order in the undisturbed forest and encroached forest contradicts the findings of Ojija, Sapeck and Mnyalape**,** (2016) who recorded Diptera among the five least dominant insect orders in grassland and woodland community of Tanzania. Orthoptera being the second most dominant insect order in the burnt forest (figure 3) is in consonance with earlier authors (Rahman 2001; Sultana, Wagan & Wagan, 2013) who revealed that insects such as grasshoppers, locusts and crickets are well adapted to the grasslands of open savannas. The recordings of Mantodea, Blattodea, Hemiptera and Odonata (figure 3) as the least abundant insect orders in all the three habitats confirm Ojija et al. (2016) who recorded these among the least dominant orders in Tanzania.
In terms of insect family distribution, Carabidae and Acrididae were the most abundant families in all the three habitats (Table 1). The families Carabidae and Formicidae were found to be most abundant in the encroached forest whilst Carabidae and Acrididae were the most abundant in the burnt forest. The occurrence of Carabidae as the most abundant family among the 40 insect families recorded in the reserve could be attributed to its opportunistic feeding habit. The Carabidae family commonly known as ground beetles is reported to feed on wide variety of foods including carrion and plant materials (Lovei & Sunderland, 1996). The relatively high dominance of the family Acrididae confirms the finding of Ojija et al. (2016) who reported it as the second most abundant insect family in Tanzania.

**Conclusion**

Anthropogenic disturbances (Encroachment and indiscriminate bush burning) have negative effects on the diversity and abundance of insects in the Sinsablegbini Forest Reserve. Insect species diversity could therefore decrease further if these disturbances alter the floristic composition of the reserve. Although both disturbance regimes had negative effects on the environment, indiscriminate bush burning resulted in a more devastating effect on insects than encroachment. In order to promote insect biodiversity in the reserve, the Forestry Services Division should intensify forest monitoring to curb these anthropogenic disturbances in the Sinsablegbini Forest Reserve. Subsequent studies should also assess insect diversity in both seasons since seasonality could have equally influenced the outcome of the present study.

**References**


Abdulai, Y. (2012). Woody species composition of the Sinsablegbine Forest Reserve. Bachelor of Science dissertation submitted to university for Development Studies.

Addo-Fordjour, P., Osei, B.A. & Kpontsu, E.A. (2015). Butterfly community assemblages in relation to human disturbance in a tropical upland forest in Ghana, and implications for conservation. ***Journal of Insect Biodiversity*** 3(6): 1-18.

Adebuntan, S. A. (2009). Influence of human activities on diversity and abundance of insects in Akure Forest Reserve, Ondo State, Nigeria. ***International Journal of Biological and Chemical Sciences,*** 3(6): 1320 - 1335.

Adjaloo, M. K., Oduro, W. & Mochiah, M. B. (2012). Spatial distribution of insect assemblage in cocoa farms in relation to natural forest. ***Journal of Applied Biosciences***, 54: 3870 – 3879.

Alamu, O. T., Amao, A. O., Nwokedi, C. I., Oke, O. A. and Lawa, I. O. (2013). Diversity and nutritional status of edible insects in Nigeria: A review. *International Journal of Biodiversity and Conservation,* 5(4): 215-222.

Appiah, E. F, Afreh-Nuamah, K. & Obeng O. D. (2009). Abundance and Distribution of Mediterranean Fruit Fly, *Ceratitis capitata* (Diptera: Tephritidae) in Late Valencia Orchards in Ghana. ***International Journal of Tropical Insect Science***, 29 (1): 11 - 16.

Arun, P. R. & Vijayan, V. S. (2004). Patterns in abundance and seasonality of insects in the Siruvani Forest of Western Ghats, Nilgiri

Biosphere Reserve, Southern India. ***The Scientific World Journal***, 4: 381 – 392.

Asase A, Patrick K.E., John, Y.A. (2009). Floristic composition, abundance and distribution pattern of woody plants in a tropical savanna in Northern Ghana. ***Journal of the Botanical Research Institute of Texas*** 3: 309-316.

Balakrishnan, S., Srinivasan, M. & Mohanra, J. (2014). Diversity of some insect fauna in different coastal habitats of Tamil Nadu, southeast coast of India. ***Journal of Asia-Pacific Biodiversity***, 7: 408 - 414.

Belamkar, N.V., & Jadesh, M. (2014). A Preliminary study on abundance and diversity of insect fauna in Gulbarga District, Karnataka, India. ***International Journal of Science and Research***, 3(12): 1670- 1675

Clay, N.A., Lucas, J., Kaspari, M., & Kay, A.D. (2013). Manna from heaven: refuse from an arboreal ant links above ground and below ground processes in a lowland tropical forest. ***Ecosphere*** 4 (11):1-15.

Covell, C. V., Jr. (2009). *Collection and preservation. In:* ***Encyclopedia of Insects***, 2nd ed. San Diego, CA: Elsevier.

Crane, S. & Baker, C (2011). Ants and moths: Analysis of biodiversity and abundance in revegetated pastoral land. ***Natural Sciences***, 10: 1-21.

Davis, A. J., Holloway, J. D., Huijbregts, H., Krikken, J., Kirk-Spriggs, A. H. & Sutton, S. L. (2001). Dung beetles as indicators of change in the forests of northern Borneo. ***Journal of Applied Ecology***, 38: 593 – 616

Debinski, D. M. & Holt, R. D. (2000). A survey and overview of habitat fragmentation experiments. ***Conservation Biology***, 14: 342-355.

Hulme, P. E. (2006). Beyond control: wider implications for the management of biological invasions. ***Journal of Applied Ecology***, 43: 835-847.

Husseini, R., Baatuuwie, B. & Issifu, H. (2015). Natural forest reserves in the northern region of Ghana: Description and management status. ***Journal of Forestry***, *2* (6): 1 - 15.

Jaganmohan, M., Vailshery, L. S. & Nagendra, H. (2013). Patterns of insect abundance and distribution in urban domestic gardens in Bangalore, India. ***Diversity***, 5: 767 – 778.

Khadijah A. R., Azidah A. A. & Meor S. R (2013). Diversity and abundance of insect species at Kota Damansara Community Forest Reserve, Selangor. ***Scientific Research and Essays***, 8 (9): 359-374.

Klein, A. M., Vaissie`re, B. E., Cane, J. H., Steffan-Dewenter, I. & Cunningham, S. A. (2007). Importance of pollinators in changing landscapes for world crops. ***Proceedings of the Royal Society of London B: Biological Sciences*** 274: 303–313.

Kotze, D. J., Brandmayr, P., Casale, A., Dauffy-Richard, E., Dekoninck, W., Koivula, M. J., & Pizzolotto, R. (2011). Forty years of carabid beetle research in Europe–from taxonomy, biology, ecology and population studies to bioindication, habitat assessment and conservation. ***Zoo Keys***, 100: 55-148.

Kremen, C., Colwell, R.K., Erwin, T.L., Murphy, D.D., Noss, R.F. & Sanjayan, M.A. (1993). Terrestrial arthropod assemblages: Their use in conservation planning. ***Conservation Biology***, 7: 796-808.

Kyerematen, R., Owusu, E. H., Acquah-Lamptey, D., Anderson, R. S. & Ntiamoa-Baidu, Y. (2014). Species composition and diversity of insects of the Kogyae Strict Nature Reserve in Ghana. ***Journal of Ecology***, 4: 1061 – 1079.

Lassau, S.A., Hochuli, D.F., Gerasimos & Reid (2005). Effects of habitat complexity on forest beetle diversity: do functional groups respond consistently? ***Diversity and Distribution***, 11:73-82.

Lee, C.M., Kwon, T.S., Lee, B.W., & Sung, J.H (2012). Beetles (Coleoptera) inhabiting deadwoods of *Quercus serrate* and *Carpinus laxiflora* in forest of Gwangneung. ***Research note*** 448. Korea Forest Research Institute.

Losey, J. E. and Vaughan, M. (2006). The Economic value of ecological services provided by insects. ***BioScience***, 56 (4): 311 – 323.

Lovei, G. & Sunderland, K. D. (1996). Ecology and behavior of ground beetles (Coleoptera: Carabidae). ***Annual review of entomology***. 41(1):23-56

Novotny, V., Drozd, P., Miller, S. E., Kulfan, M., Janda, M., Basset, Y., & Weiblen, G. D. (2006). Why are there so many species of herbivorous insects in tropical rainforests? ***Science***, *313*(5790): 1115-1118.

Nyundo, B.A., and Yarro, J. G. (2007). An assessment of methods for sampling Carabid beetles

(Coleoptera: Carabidae) in a montane rain forest. ***Tanzania Journal of Science**,* 33: 41-49.

Ojija, F., Sapeck, E., Mnyalape, T. (2016). Diversity analysis of insect fauna in grassland and goodland community at Mbeya University of Science and Technology, Tanzania. ***Journal of Scientific and Engineering Research*,** 3 (4): 187 – 197.

Ollerton, J., Winfree, R. & Tarrant, S. (2011). How many flowering plants are pollinated by animals? ***Oikos,*** 120: 321 - 326.

Perrings, C. & Halkos, G. (2015). Agriculture and the threat to biodiversity in sub-saharan Africa. ***Environmental Research Letters,*** 10(9) {095015}.

Rahman, K. M. A. (2001). Food consumption and utilisation of the grasshopper Chrotogonuslugubris Blanchard (orthoptera, acridoidea, pyrgomorphidae) and its effect on the egg deposition. ***Journal of Central European Agriculture***, 2: 263 - 270.

Rainio, J., & Niemela, J. (2003). Ground beetles (Coleoptera: Carabidae) as bioindicators. ***Biodiversity and Conservation***, 12: 487–506.

Rajagopal T., Sekar, M., Manimozhi, A., Baskar, N. & Archunana, G. (2011). Diversity and community structure of butterfly of Arignar Anna Zoological Park, Chennai, Tamil Nadu. ***Journal of Environmental Biology*** 32 (2): 201–207.

Savannah Agricultural Research Institute (2016). Meteorological Weather Report. Nyankpala station

Sheuyange, A., Oba, G. & Weladji, R. B. (2005). Effect of anthropogenic fire history on savanna vegetation in northeastern Namibia. ***Journal of Environmental Management***, 75:189-198.

Siaw, D. E. K. A. (1998). State of forest genetic resources in Ghana. Forest Genetic Resources Working Papers.

Steffan-Dewenter, I., Munzenberg, U., Burger, C., Thies, C., Tschorntke, T. (2002). Swcale dependent effects of landscape context on three pollinator guilds. ***Ecology**,* 83: 1421-1432.

Sultana, R., Wagan, Y. S. & Wagan, M. S. (2013). Orthopteran biodiversity of Thar desert, Sindh, Pakistan. ***Pakistan Journal of Zoology**,* 45: 299 - 304.

Sutrisno, H. (2010). The impact of human activities to dynamic of insect communities: a case study in Gunung Salak, West Java. ***HAYATI Journal of Biosciences,*** 17(4):161-166.

Tom-Dery, D., Sakyi, D. & Bayor, H. (2015). Assessment of *Vitellaria paradoxa* population under different land use types in Northern Ghana. ***Environment and Forestry -Elixir International Journal***, 78: 30088 – 30096.

Van Der Heijden, M. G. A., Bardgett, M. D., & Van Straalan N. M. (2008). The unseen majority: soil microbes as drivers of plant diversity and productivity in terrestrial ecosystems: ***Ecological Letters**,* 11: 296 -310.

Ziblim, A. I., Abdul-Rasheed, S. and Aikins, T. K. (2015). Forage species used by livestock in the Kumbungu district of the northern region, Ghana. ***UDS International Journal of Development,*** 1 (1): 18 - 29.

Zurlini, G., Petrosillo, I., Jones, K. B., Li, B. L., Riitters, K. H., Medagli, P., Marchiori, S. & Zaccarelli, N. (2013). Towards the planning and design of disturbance patterns across scales to counter biological invasions**. *Journal of Environmental Management***, 128: 192-203