JENRM, Vol. 2, No. 2, 44-50, 2015
Research Article

Impact of Eidolon helvum on roost trees on UENR campus

Danquah, E [1],Agyei-Ohemeng, J [2]

Abstract
Four sample plots, each of size 20m by 20m were systematically distributed in two strata (i.e. two plots in bat-occupied zone and the remaining two plots in bat-unoccupied zone, to serve as control units). Using six (20m × 20m) sample plots each, basal area, canopy, and heights of trees with DBH ≤ 1m were measured. Fourteen individual trees were recorded in the bat-unoccupied zone, resulting in only seven tree species. On the other hand, 16 tree species, corresponding to a total of 25 trees were recorded in the bat occupied zone. *Albizia zygia, Antiaris toxicaria, Azadiractha indicia, Holarrhena floribunda, Morinda lucinda, and Sterculia tragacantha* were common to both zones. The Shannon Wiener species diversity index was found to be higher (H1=1.92) in bat occupied zones and lower (H^1=1.45) in bat-unoccupied zone. Estimates of tree basal area and tree height were much higher in bat occupied zones compared to bat-unoccupied zones. (Mann-Whitney U test: $U = 573.0$, $p < 0.05$), tree basal area ($U = 674.0$, $p < 0.05$), tree height ($U = 632.0$, $p < 0.05$) and tree canopy cover ($U = 329.0$, $p < 0.05$). *Holarrhena floribunda* (0.34 m2/h) and *Ceiba pentandra* (0.22m2/ha) contributed the largest basal area (32.94% of the total basal area) whilst *Senna siamea* (0.01m2/ha) and *Tectona grandis* (0.01m^2/ha) yielded the smallest basal area (1.17%). In general, bats seem to greatly patronize areas with higher densities of tall trees than relatively open areas with shorter trees.

Keywords
Impact—Eidolon—helvum—roost—campus

[1]*emmanueldanquah@gmail.com*
[2]*james.agyei-ohemeng@uenr.edu.gh*

Contents

1. INTRODUCTION

Bats are known to cause a lot of damage to trees by eating their fruits [4], and by defoliating the trees onwhich they roost during the day [1]. A colony of fruit bats can cause a very destructive impact on their roost trees includingthe environment (Ritcher, 2004). The straw coloured fruit bat, Eidolon helvum (Kerr, 1792), is a typical example of afrugivorousbat of the Order Megachiroptera [9]. Eidolon helvum feeds entirely on flowering and fruiting trees [11]. Roosts sites are selected during the day among tall and large trees with scattered branches [3]. In Kasanka National Park, Zambia each year, the presence of E. helvum, have been known to increase roost tree mortality, lowering and opening of the forest canopy and a decrease in tree basal area (Swaine et al 2010).

Many research findings have quantified changes in species composition and other structural attributes for various parts of forests across the world due to bat roosting and other wildlife damage [8, 10, 6] . The straw coloured fruit bat, *E. helvum*, roosts all year round in the University of Energy and Natural Resources' Wildlife Sanctuary (Sanctuary) in Sunyani, and their behavior is likely to affect the phenology and morphology of the trees in the colony.

Studies elsewhere have shown that bats generally cause some structural changes among the trees they roost on. Some recorded observed changes include branch breaks; severe feeding on leaves that result in trees loosing foliage, suppressing flowering and fruiting, and debarking stems and in some instances an entire tree falling down when there is a high population of bats in the canopy [4, 1]. Trees can significantly influence the environment, even though very little research has been conducted to quantify their effects. Severe defoliation of trees by bats can affect tree growth, species composition and structure of the forest which may in turn affect their long term viability and role in forest dynamics [1].

Therefore, the study intends to:

1. Document any significant changes in tree diversity and some physical characteristics (i.e. basal area, height, canopy cover) of roost trees used by bats, *Eidolon helvum*, on the University of Energy and Natural Resources' Wildlife Sanctuary in Sunyani
2. Identify phenological and structural changes among trees due to the roosting behaviour of *E. helvum*.

2. MATERIAL AND METHODS

2.1 Study Area

The University of Energy and Natural Resources covers an area of 120 acres (48.564ha) lies along the Sunyani Berekum highway. It shares a boundary with the Regional Administration and the closest community is Fiapre towards Berekum. It is directly opposite the Seventh Day Adventist Secondary School and Hospital. The campus is laid out with forest tree outgrowths, made up of indigenous tree species like *Ceiba pentandra, Triplochiton scleroxylon, and exotic plant species like Eucalyptus grandifolia, Tectona grandis and Senna siamea.* The Wildlife Sanctuary of the University of Energy and Natural Resources Campus; has coordinates of Latitudes 7^o $20^{'}$N and 7^o $05^{'}$N and Longitudes 2^o $30^{'}$W and 2^o $10^{'}$W (Figure 1) with a total area of 3.6ha and occupies 7.3% of the University Campus.

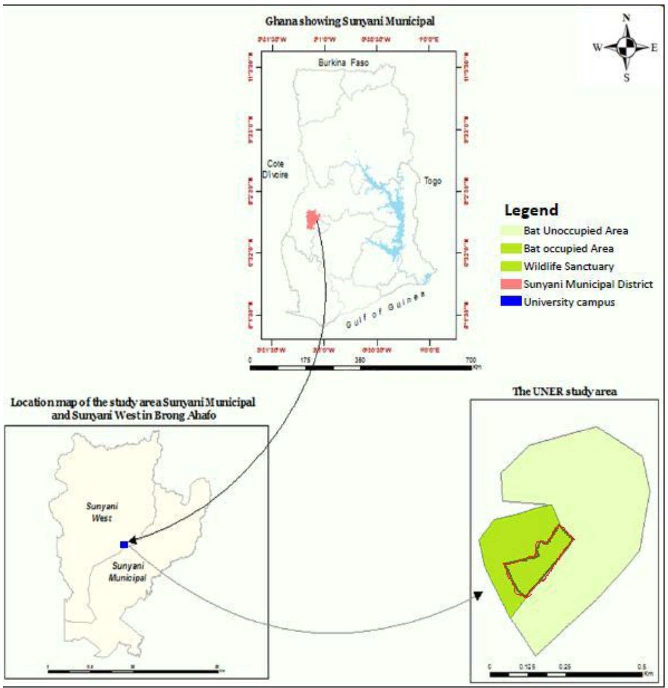

Figure 1. Map of Study Area

2.2 Location

The municipality has a total land area of 829.3 Square Kilometers (320.1square miles) (Figure 1). Sunyani also serves as the Regional Capital for Brong Ahafo. One third of the total land area is not inhabited or cultivated which provides arable lands for future investment. (RCC, 2014)

2.3 Biophysical Setting

The municipality falls within the wet Semi-Equatorial Climatic Zone of Ghana. The mean monthly temperatures vary between 23^oC and 33^oC with the lowest around August and the highest being observed around March and April. The relative humidity is high averaging between 75 and 80 percent during the rainy seasons and 70 and 80 percent during the dry seasons of the year which is ideal for luxurious vegetative growth (www.molgrd.org).

The average rainfall for Sunyani between 2000 and 2009 is 88.987cm. Sunyani experiences double maxima rainfall pattern. The main rainy season is between March and July with the minor between September and November. This offers two farming seasons in a year which supports higher agricultural production in the municipality. The dry season is between December and February. However, the rainfall pattern of the municipality is decreasing over the years as a result of deforestation and depletion of water bodies resulting from human activities [7].

The municipality is underlain by Precambrian Birimian formations which are believed to be rich in mineral deposits. Associated with the Birimian formations are extensive masses of granite. The Cape Coast Granite Complex is what pertains in the Municipality. The rich mineral deposits underlay in Precambrian Birimian and the Birimian presents a great potential for investment in mineral mining [12].

2.4 Experimental procedure

A reconnaissance exercise was conducted in the UENR in order to stratify the campus into bat-occupied and unoccupied zones (strata) based on the presence or absence of roost trees occupied by bats. The Wildlife Sanctuary represented the main bat roost site (bat-occupied zone) whilst the rest of the campus constituted the unoccupied zone. Four sample plots, each of size 20m by 20m were systematically distributed in the two strata (i.e. two plots in the bat-occupied zone (Wildlife Sanctuary) and the remaining two plots in the unoccupied zone (outside Wildlife Sanctuary) to serve as control units). Each plot was sub-divided into four belt transects (5m × 20m) for effective coverage of the plots.All trees (diameter at breast height (DBH)>10cm) in a plot were identified to the species level and counted.Some factors that describe the physical appearance of the trees (i.e. DBH, canopy cover, tree height, number of branches, bark condition) were also noted.

The DBH measurements were used to calculate the basal area for plant species. Estimates Win800 Version 8.0.0 (Colewell, 2006) was used to determine indices oftree diversity in the defined zone types in the study area. Differences in tree diversity, basal area, height and canopy cover across the zone types were explored using the Mann-Whitney U nonparametric analyses tests. Tree height was measured using a Haga altimeter. Tree canopy was measured by taking two diameters at right angles to each other across the trees, one of which was the maximum diameter for the tree. The area of each treecanopy was calculated from the formula $A = {}^{D^2}\!/_4$ where D is the average crown diameter (Hall and Swaine, 1981). Four 20m line transects were laid randomly within each plot using a tape measure, and the presence or absence of canopy was recorded at one meter interval. Percentage cover was determined by the number of sampling points that had canopy presence divided by the number of sampling points per transect multiplied by hundred. All statistical analysis was conducted using InfoStats v 1.4. (Infostat, 2004).

3. RESULTS

Fourteen individual trees were recorded in plots placed in the zone not occupied by bats, resulting in only seven tree species. On the other hand, 16 tree species, corresponding to a total of 25 trees were recorded in the bat occupied zone. *Albizia zygia, Antiaris toxicaria, Azadiractha indicia, Holarrhena floribunda, Morinda lucinda, and Sterculia tragacantha* were common to both zones. The *Shannon Wiener* species diversity index was found to be higher ($H^1 = 1.92$) in bat occupied zones and lower ($H^1 = 1.45$) in zones without bats (Table 1).

Table 1. Number of trees and species diversity for bat occupied and unoccupied zones

	Zone Type	
Tree species	**Bat Occupied**	**Bat Unoccupied**
Albizia ferroginea	2	*
Albizia zygia	3	1
Alstonia boonei	2	*
Antiaris toxicaria	1	2
Azadiractha indica	1	1
Bombax buonopozense	1	*
Ceiba pentandra	1	*
Cordia senegalensis	1	*
Deloniix regia	2	*
Funtumia elastic	1	*
Holarrhena floribunda	2	1
Morinda lucidia	1	4
Newbouldia laevis	2	*
Pycnanthus angolensis	1	*
Senna siamea	*	4
Sterculia tragacantha	1	1
Tectona grandis	3	*
Total number of individuals	**25**	**14**
Total number of species	**16**	**7**
Tree density (per ha)	**62.5**	**17.5**
Species diversity index (H^1)	**1.92**	**1.45**

Comparative analysis of roost tree characteristics across the two categories of bat habitat in the Sanctuary, i.e. bat occupied and unoccupied zones showed significant differences in species composition (Mann-Whitney U test: U = 573.0, $p < 0.05$), tree basal area(U = 674.0, $p < 0.05$), tree height (U = 632.0, $p < 0.05$) and tree canopy cover (U = 329.0, $p < 0.05$). Estimates of tree basal area and tree height were much higher in bat occupied zones compared to unoccupied zones (Tables 2 and 3).

Table 2. Mean tree basal area estimates for bat occupied and unoccupied zones

	Basal Area (m^2/ha)	
Tree species	**Bat Occupied**	**Bat Unoccupied**
Albizia ferroginea	0.03	*
Albizia zygia	0.07	0.01
Alstonia boonei	0.02	*
Antiaris toxicaria	0.08	0.01
Azadiractha indica	0.04	0.02
Bombax buonopozense	0.13	*
Ceiba pentandra	0.22	*
Cordia senegalensis	0.02	*
Deloniix regia	0.12	*
Funtumia elastic	0.04	*
Holarrhena floribunda	0.34	0.2
Morinda lucidia	0.08	0.01
Newbouldia laevis	0.18	*
Pycnanthus angolensis	0.03	*
Senna siamea	*	0.01
Sterculia tragacantha	0.02	0.01
Tectona grandis	0.01	*
Total	**1.43**	**0.27**
Mean	**0.09**	**0.04**

In terms of individual contribution of tree species to the overall basal area of zones, *Holarrhena floribunda* ($0.34\ m^2/h$) and *Ceiba pentandra* ($0.22 m^2/ha$) contributed the largest basal area (32.94% of the total basal area) whilst Senna siamea ($0.01 m^2/ha$) and *Tectona grandis* ($0.01 m^2/ha$) yielded the smallest basal area (1.17

In general, bats seem to greatly patronize areas with higher densities of tall trees than relatively open areas with shorter trees. It is likely that bats' fruit-eating habits have led to a greater fruit dispersal ability which may explain the relatively higher flora diversity in bat occupied zones (Table 1).

Estimates of canopy cover were significantly lower in many bat-occupied trees (Table 3) in contrast to their relative larger basal areas and taller tree heights (Tables 2 and 3). It suggests that their association with colonies of bats might have resulted in higher rates of leaf defoliation, loss of branches and feeding on bark by bats.

Expected higher levels of sunlight penetration (as a result of estimated smaller tree canopy covers and perceived higher defoliation levels) in bat occupied zones may contribute further to the relatively higher flora diversity in bat occupied zones (Table 1)

Table 3. Mean tree height estimates for bat occupied and unoccupied zones

	Height(m)	
Tree species	**Bat Occupied**	**Bat Unoccupied**
Albizia ferroginea	19.4	*
Albizia zygia	12.2	2.6
Alstonia boonei	6.2	*
Antiaris toxicaria	14.2	13.5
Azadiractha indica	13.2	5.3
Bombax buonopozense	23.4	*
Ceiba pentandra	19.9	*
Cordia senegalensis	3.5	*
Deloniix regia	15.2	*
Funtumia elastic	5.7	*
Holarrhena floribunda	16.1	13.4
Morinda lucidia	10.2	3.2
Newbouldia laevis	15.8	*
Pycnanthus angolensis	31.2	*
Senna siamea	*	9.6
Sterculia tragacantha	13.6	5.7
Tectona grandis	4.4	*
Total	**224.2**	**53.3**
Mean	**14**	**7.6**

Table 4. Mean tree canopy cover estimates for bat occupied and unoccupied zones

	Canopy cover (m^2)	
Tree species	**Bat Occupied**	**Bat Unoccupied**
Albizia ferroginea	15.3	*
Albizia zygia	17.1	34.7
Alstonia boonei	4.1	*
Antiaris toxicaria	10.2	56.8
Azadiractha indica	3.8	65.7
Bombax buonopozense	18.8	*
Ceiba pentandra	8.6	*
Cordia senegalensis	5.6	*
Deloniix regia	10.8	*
Funtumia elastic	4.3	*
Holarrhena floribunda	24.6	54.8
Morinda lucidia	1.5	56.9
Newbouldia laevis	11.7	*
Pycnanthus angolensis	40.6	*
Senna siamea	*	24.9
Sterculia tragacantha	2.4	87.3
Tectona grandis	4.7	*
Total	**184.1**	**381.1**
Mean	**10.8**	**54.4**

4. DISCUSSION

E. helvum select and occupy tall trees with larger basal areas (Tables 2 and 3). *Albizia ferroginea, Bombax buonopozense, Ceiba pentandra and Pycnanthus angolensis* are all tall trees (19.4), (23.4), (19.9) and (31.2) meters and larger basal areas (0.03), (0.13), (0.22), (0.03) m2/ha respectively. These trees are absent in the unoccupied bat zone. The bats also select dense tree cover than open areas (Table 4). Despite the larger mean canopy cover of trees in the areas not occupied by bats, the bats prefer more open areas.

In Table 1, the diversity index (H^1) of trees in the occupied area was higher (1.92) than the unoccupied area (1.45). It was found out that the tree density in the occupied area was higher ($^{62.5trees}/_{ha}$) than the unoccupied area ($^{17.5trees}/_{ha}$). This an indication that bats prefer areas where the tree density is high than low density area.

The preference of high tree density areas in the study area correspond with the number of bats on trees. The weight of the bats and the fact that they gnaw the bark of the trees has destroyed most of the trees. Plates 1-6, indicate some of the impact that the bats have on trees they roost on. The *Tectona grandis* in the study area, plate 2 (a) and (b) have been left in 'pencil' like shapes. They do not flower during most time of the year when other similar trees are flowering and fruiting.

Some of the trees like *Deloniix regia* have had their branches broken at the top and debarked by the presence of the bats in the colony (Plate 3(a) and (b)). Whole tree fall is common during high population, when their weight on some of the trees cause the breaking of branches among some of the sanctuary trees (Plate 4).

Damage to trees seemed to result mainly from the weight of bats hanging from the trees. It was apparent that trees below 10m tall were undamaged, the reason being that the bats were found not roost below this height. The damages were progressive, as some of the trees are destroyed and became unsuitable for roosting they move to adjacent trees that will provide good roost sites. Once *E. helvum* become attached to a particular tree they occupy it even though other trees become unoccupied. This leaves some of the trees dead but standing, *Newbouldia laevis, and Tectona grandis*, leaving a 'pencil' like nature in the roost (Plate 6).

The impact of the bats on trees will require that some of the dead trees could be felled and replaced so that in the long term trees would be available for the bats to roost. Failure to manage the trees can cause the movement of the bats to look for other suitable sites due to the absence of trees for roosting in UENR in some time to come.

During the study period, it was not possible to establish what features attract bats to the roosting trees; however, height could be predicted to be the most attractive feature during the period. Some permanent damages to trees were also recorded during the period of study (Table 5).

5. CONCLUSION AND RECOMMENDATION

This study has revealed that the roosting behaviour of E. helvum on the UENR campus has brought about some structural changes among the trees they roost on. Observed changes which include branch breaks; defoliation, suppression of flowering and fruiting, as well as debarking of stems due to gnawing of bark of trees and in some instances an entire tree fall due to high population of bats in the canopy were recorded. This study has therefore provided us with a clear understanding of the extent the resident *E. helvum* has on the trees on the UENR campus, as well as the effect it can have on the environment.

This can lead to suggest better management of the bats and trees, leading to a more pleasant and healthy environment.

6. ACKNOWLEDGEMENT

We would like to acknowledge the unflinching support of Dominic Appiah and Shadrack Sraku, National Service personnel attached to the Department of Ecotourism who assisted in collecting the population data and Mr. Shroeda, the Technician in the School of Natural Resources who assisted in the tree identification. Our sincere gratitude also goes to all staff of the University of Energy and Natural Resources who assisted us through words of encouragement to undertake this project.

Table 5. Descriptive observations of some trees damaged and type of damage in the Sanctuary

No	Tree Species Sampled	Total Number of Trees in the Study Area	No. of trees occupied by E. helvum in the Sanctuary	No of Damaged trees	Type of Damaged observed
1	*Ceiba pentandra*	3	3	3	Suppression of flowering,fruiting and defoliation
2	*Newbouldia laevis*		150	82	Defoliation, debarking
3	*Tectona grandis*	119	108	96	Suppression of flowering, fruiting and defoliation
4	*Holarrhena floribunda*	150	85	59	Defoliation, branch breaking
5	*Senna siamea*	76	40	36	Defoliation, suppression of flowering
6	*Albizia zygia*	18	5	9	Defoliation and debarking
7	*Blighia sapida*	14	10	5	Defoliation and suppression of flowering
8	*Alstonia boonei*	12	9	2	Defoliation, branch breaking
10	*Bombax buonopozense*	2	2	2	Defoliation and suppression of flowering
11	*Delonix regia*	2	3	2	Defoliation, suppression of flowering, branch breaks, debarking
12	*Albizia ferroginea*	6	2	3	Defoliation, branch breaks
13	*Triplochiton scleroxylon*	3	3	3	Suppression of flowering,fruiting and defoliation

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7. APPENDIX

(a) Plate1: *E. helvum* $1-10$ or more clusters on tree branches in the Sanctuary

(b) Plate2: Cluster sizes of bats on the same tree on different months during the study period

(c) Plate3: E. helvum suppressing leafing, flowering on a Newbouldia laevis in the colony

(d) Plate4: Tree fall, debarking, suppression of leaf formation and flowering on Tectona grandis at the roosting site

(e) Plate5: Ceiba pentandra at different stages of bat occupation during the study period

(f) Plate6: Defoliated Ceiba pentandra in a. December and b. February respectively

(g) Plate7: Tectona grandis in the roosting site

(h) Plate8: Deloniix regia branches breaking in the roosting site

(i) Plate9: Branch breaking of Deloniix regia in the roosting site

(j) Plate10: Debarked stem of Deloniix regia with bats in the roosting site

Figure 2. Lab Analysis of *E. helvum*