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DEPARTMENT OFWILDLIFE AND RANGE MANAGEMENT

ASPECTS OF THE ECOLOGY OF FRUIT BAT (*Eidolon helvum*) IN THE UNIVERSITY OF ENERGY AND NATURAL RESOURCES, SUNYANI

By

James Agyei-Ohemeng

Post Graduate Diploma

March, 2015

ASPECTS OF THE ECOLOGY OF FRUIT BAT (*Eidolon helvum*) IN THE UNIVERSITY OF ENERGY AND NATURAL RESOURCES, SUNYANI

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DEGREE OF MASTER OF PHILOSOPHY

IN

WILDLIFE AND RANGE MANAGEMENT

By

James Agyei-Ohemeng

Post Graduate Diploma

March, 2015

DECLARATION

I declare that this thesis entitled "ASPECTS OF THE ECOLOGY OF FRUIT BAT (*Eidolon helvum*) IN THE UNIVERSITY OF ENERGY AND NATURAL RESOURCES, SUNYANI" is the results of my own original work and that no part of it has been presented for another degree in this University or elsewhere.

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ABSTRACT

Aspects of the ecology of straw coloured fruit bats (*Eidolon helvum*), including population dynamics, seed dispersal and effect on the roosting trees, were investigated in the University of Energy and Natural Resources, Sunyani from January 2013 to July 2014. The Continuous Point Count Method was used to estimate the monthly population size of *E. helvum*. Using 64m^2 (4m x 4m) quadrats and 32 seed traps made from plastic sheets, the contribution of dispersed plant species to the total undergrowth plant cover in the area was sampled and catalogued to show the contribution of undergrowth from bat droppings in the area. Using six (20m x 20m) sample plots each for areas occupied by bats and areas unoccupied by bats, basal area, canopy, and heights of identified trees with DBH ≤ 1m were measured to show the impact of bats on the roosting trees. The results indicated that: (1) bats were present in the study area throughout the survey period, however, their numbers varied between months. The bat population estimates in 2013 were high in March (180,000) and December (240,000), but between the months of May to October their population were low, (12,400; 15990; 12,500; 18,500; 10,600 and 28,500) respectively, in the colony. This pattern is similar to the year 2014. The mean number of bats per month was estimated at 55,469.55 bats (S.E=4.34, CV=8.68%) for the study period. The mean population estimates in the dry season count was 85,955.5±87,272.3 whilst the mean population estimate in the rainy season count was 46,932.3±58,122.9. However, there was no significant difference between the mean dry and rainy season population count of bat in the study area, $t(8) = -0.922$, $p>0.05$(2) Undergrowth plant species sampled indicated that the percentage contribution of some of the species dispersed by bats were *Mallotus opposotifolia*,(16.1%), *Broussonetia papyrifera* (10.6%), *Ficus exasperata* (6.6%),

Solanum erianthum (6.2%) and *Morus mesozygia* (4.6%). These plant species altogether contributed 1.7% of the seedling composition in the undergrowth in the study area. These plants contributed to the ecological improvement by increasing the biodiversity in the study area through increased species cover and regeneration of dispersed species of the roost site.(3) Height and basal area of trees were the only factors that led to tree selection as roost by bats in the occupied zone. Trees in bat occupied areas, showed significant damages by bats through premature defoliation as well as loss of branches which resulted in reductions in canopy foliage of host trees, compared to the bat unoccupied areas. The main physical plant features that were affected are the tree canopy size and canopy cover. These bats have been known to have limited roost sites, so good management of their population to reduce threat to their survival is important. Sound strategies like monitoring population, roosting trees and habitat, in relation to the climatic conditions are required to be documented overtime to promote sound decisions and add to scientific knowledge to the study of bats.

DEDICATION

This Thesis is dedicated to Joyce, Ivy, Mordecai and Emmanuel Ohemeng

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ACRONYMS

BCA-	Bat Conservation Africa
BCI-	Bat Conservation International
CITES-	Convention of International Trade on Endangered Species
CV-	Coefficient of Variation
DBH-	Diameter at Breast Height
DDT-	dichlorodiphenyltrichloroethane
IUCN-	International Union of Conservation of Nature
SE-	Standard Error
UENR-	University of Energy and Natural Resources
USA-	United States of America

CHAPTER ONE

1.0 Introduction

1:1 Background Gaps

The straw-colored fruit bat, *Eidolon helvum* (Kerr, 1792), is a Frugivorous animal in the order Megachiroptera (Okon, 1974). Although traditionally not viewed as a charismatic species, bats are an invaluable natural resource. Except for the most extreme desert and Polar Regions, bats live in almost every habitat worldwide, just as they have for more than 50 million years. Nearly 1,000 different kinds of bats are known today, fully one-quarter of known mammal species. Despite their diversity, the world's only flying mammals remain among the least understood of animals (Vivian, 2007).

Centuries of myth and superstition have made bats among the world's least appreciated wildlife. Decades of unwarranted human fear, misinformation, and persecution of bats at their roosts have pressed populations into severe decline nearly everywhere in the world and endangered many species (BCI, 1989). While for some species of bats it may already be too late, sound management practices can potentially save others.

Besides the moral, ethical, and aesthetic justification for the conservation of bats, these species are ecologically and economically important. They are among nature's most beneficial animals, and undoubtedly, many are keystone species (BCI, 1989). Without them, thousands of other animal species, like mosquitoes would be abundant and spread diseases. Plant species, like *Milicia excelsa*, which is predominantly dispersed by bats, could die out, threatening entire ecosystems like rainforests.

Numerous factors have contributed to the decline of bats populations. The primary known causes are the direct and indirect actions of humans (Funmilayo, 1978). The whole world is changing at an unprecedented rate – habitat destruction, through the directly daily changing the face of our landscape and indirectly through climate change, are the biggest threats to wildlife conservation and for that matter bats.

Destruction of natural habitats and foraging areas also are responsible for decimating entire bat colonies, especially if the bat population has strong site fidelity (Tuttle, 1976). In addition, some bats have highly specific roosting requirements in terms of temperature, proximity to foraging areas, location and type of cave. For instance, it is believed that the endangered gray bat, *Plecotus austriacus*, has the most narrowly restricted cave habitat requirements of any U.S. mammals (Hall and Wilson, 1966; Barbour and Davis, 1969; Tuttle, 1976). Therefore, the unavailability of such roosting sites can decimate entire populations. Harvesting of roost trees, especially in areas where uncontrolled and illegal logging is rampant has also been responsible for declining populations. The bulk of rural African protein from meat comes from wild animals, ranging from rats, squirrels, monkeys, antelopes and also birds and bats, Funmilayo, (1978).

The straw-colored fruit bat, *Eidolon helvum*, inhabits forest and savannah, and is found up to an elevation of 2000 m in the Ruwenzori Mountains (Kingdon, 1974). It is gregarious and prefers to roost in tall trees by day, but has also been found in lofts and in caves in rocks (Nowak, 1991). In Nigeria, they select trees of particular species for roosting (Okon, 1974) and some tree species, even though common, are not used. Common trees for roosts include *Eucalyptus saligna* (Myrtaceae), *Cocos nucifera* (Palmae), *Elaeis guineensis* (Palmae), and three species of *Ficus* (Moraceae) (Jones, 1972).

Bats prefer dead trees that have bare branches; if living trees are used, the leaves are soon broken and the branches become bare. Trees used as day roosts are large with spreading branches, commonly found in dense groves with thick undercover. At night, roosts are chosen according to food availability. Trees are of various heights and sizes, some in groups, others widespread (Okon, 1974). Colonies can number up to one million; in sleeping groups of about one hundred (Nowak, 1991). Roosting clusters are located 6-20 m above ground on sturdy branches (Jones, 1972).

During periods of migration, colonies disperse into small groups and form temporary roosts from which they eventually form 'regular' roosts (Mutere, 1980). Baranga and Kiregyera (1982) reported a colony of 70,388 bats in Uganda. According to the same authors, the average number of bats per tree was 310; the average number of clusters per branch was 4; and the average cluster size 8.

Most colonies use the same roosts for many years, but because of local fluctuations in food, some colonies make regular seasonal migrations returning after a few months to their former roosting sites (Happold, 1987). In the Ivory Coast, it has been observed to migrate, from the tropical forest zone where it stays between June and December, to the Niger basin in the interior where it appears in January and stays until May (Happold, 1987).

In West Africa, there are over 120 species of fruits and nectar eating bats, however, in Ghana there are about fifteen (15) fruit eating bats, (Kankam and Oduro, 2009), feeding on a wide range of trees in the forest landscape. They feed on leaves, flowers, and large proportion on fruits of different families of tropical forest plant species. *E. helvum* is known to feed on the following fruits, both cultivated and wild, (Musaceae) *Musa sapientum*, (Caricaceae) *Carica papaya,*(Anacardiaceae) *Mangifera indica*, (Bignoniaceae) *Kigelia aethiopica* (Combretaceae) *Terminalia sp* (Fujita and Tuttle, 1991). In Nigeria, *E. helvum,* feeds almost exclusively at night, visiting only trees that have food resources, whereas trees visited during the day are only for roosting (Okon, 1974). At night, small groups of bats fly to foraging areas in straight lines. On many occasions, foraging area is not known, but the powerful flight suggests that these bats utilize food sources many kilometers from their roosts (Happold, 1987). Nowak (1991) suggested that foraging range may be at least 30 km for some of the larger colonies. They may assist in the pollination of the flowers of some trees (Ayoade, 1989), but probably not to the same extent as some of the smaller fruit bats (Happold, 1987). Vast quantities of fruits must be required to sustain large colonies; the daily foraging flights, and local seasonal migrations, are clearly related to the availability and abundance of food, the fruiting times of different tree species, and the size of the colony. Colonies do not appear to break up into smaller sub-colonies in times of food shortage, although individuals scatter and forage in smaller groups each night. The gregarious habits of these bats probably evolved in conjunction with their ability to forage on many types of food resource; obviously they feed on only one or two food items that could not be sustained in large numbers in one place for more than a short time (Happold, 1987).

Although predation is infrequent and seemingly poses little threat to populations, several animal species are known to prey on *E. helium.* Key predator species include (*Bubo africanus*) spotted eagle-owl, (*Corvus albus*) crows, (*Buteo buteo vulpinus*) steppe buzzards, (*Elanus caeruleus*) black kites(Kingdon, 1974), snakes, (*Paradoxurus hermaphroditus*) palm civets, (*Genetta genetta*) genets and (*Accipiter*) hawks (Funmilayo, 1979), (*Peridicticus potto*) pottos (Jones, 1972), (*Hieraaetus ayesii*) Ayers hawk eagle (Wolf, 1984), and (*Aquilla spilogaster*) African hawk eagle (Louette, 1975). On the other hand, Kingdon (1974) recorded *E. helvum* attacking (*Corvus albus*) a pied crow.

The straw-colored fruit bat, *Eidolon helvum*, is eaten in most West African countries (Funmilayo, 1979), but the hunting method is unsustainable. These animals are taken by catapults, snares, traps, guns, and in the case of bird's sticky plant latex. The meat is usually consumed at home with some occasionally sold on the local market. All these contribute to the population decline of wildlife including bats. Kamins *et al* (2011) notes that the peak season reported for hunting bats corresponds with the main dry season in Ghana. This means the bats provide an important food source during the "lean" agricultural season. In Brong Ahafo region, the current spate of hunting of the fruit bat for bush meat sold at Techiman market is very disturbing (Personal observation).

This thesis consists of six chapters. Chapter One comprises the Introduction, justifications, Problem Statement and Objectives. Chapter Two covers the available literature which throws light on the topic. Chapter Three deals with the Materials and Methods and constitutes a Description of the Study Area, Sampling Methods and how the Data was analyzed. Chapter Four has to do with the Results, whilst Chapter Five covers the Discussion, General Conclusions and Recommendations.

1.2 Problem Statement

Straw coloured fruit bat (*E. helvum*) is classified internationally as near-threatened due to overhunting (IUCN, 2010). Listed under the Migratory Species Convention and on Appendix II of CITES, it is protected under Ghana Wildlife laws and a subject of global animal tracking research. However, bats in Africa are under-studied, underappreciated, and under severe threat, despite their provision of essential ecological services across the continent (Ayoade *et al.*, 2012).

There is also a general lack of information on bat conservation in Ghana and Africa as a whole, limited expertise on bat conservation, and widespread absence of governmental policies on bat conservation in the sub region. Furthermore, straw coloured fruit bat populations are battered by loss of habitat and water resources, disturbances of crucial roosts, and, in some areas, by bush-meat hunting. Additionally, needless fears fed by long-standing myths and misinformation greatly complicate their conservation. Despite accounting for roughly 20% of mammals' species on the African continent, bats conservation and research is very limited.

In spite of ecological research into different species of fruigivores, of which bats are represented, there is very little knowledge into the general ability of bats as seed dispersers leading to forest regeneration.

In southeast Asia, several studies linked seed removal by a particular consumer to the fate of deposited seeds (Hamann and Curio 1999), but the few studies that have followed seeds and seedlings for long periods of time have been mostly conducted in the Neotropics (Russo and Augspurger 2004; Russo 2005).

Bats (*Bucerotidae*) are widely regarded as important seed dispersers in tropical forests in Africa and Asia (Kemp 2001). Their ability to swallow fruits (Leighton and Leighton 1983; Kitamura *et al.*, 2002) and to regurgitate or defecate viable seeds (Kinnaird 1998; Whitney *et al.*, 1998), large home ranges (Poonswad and Tsuji 1994; Suryadi *et al.*, 1998; Holbrook and Smith 2000), and gut passage times (Leighton 1982; Holbrook and Smith 2000) make them ideal dispersers, especially for seeded plants because of relatively fewer alternative dispersers (Becker and Wong 1985; Heindl and Curio 1999; Kitamura *et al.*, 2004a, 2006).

In Ghana, Kankam *et al* (2000) looked into the Role of the Fruit Bat (*Eidolon helvum*) in Seed Dispersal, Survival and Germination in *Milicia excels.* There is no documented evidence on the population, dispersal of different seeds by bats and the effect they have on the phenology of roosting trees.

1.3 Goal and Objectives

The goal of this study is to present an ecological impact of the presence of the bat population on their ability to disperse seeds for natural regeneration and how they affect the trees they roost. It is to provide us with a monitoring system to look into the ecosystem approach to conservation.

The specific objectives of the study are to:

1. Estimate the population size of *E. helvum* on UENR campus in Sunyani.
2. Catalogue plants eaten and dispersed by the *E. helvum* colony.
3. Determine the effect of *E. helvum* on roost tree morphology and phenology in the colony.

The following hypotheses will be tested to assist natural resources managers in the management of bat species on the University of Energy and Natural Resources and in similar natural forest ecosystems:

i) *E. helvum* are found in the University of Energy and Natural Resources, (UENR).

ii) *E. helvum* contribute to the dispersal of forest tree seeds in UENR from elsewhere.

iii) *E. helvum* roosting affect phenology of roosting trees.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Importance of Eidolon helvum

The straw colored fruit bat, (*E. helvum*), breeds in tropical forests in East and West Africa. They move outside into the savanna region in the north and south towards the Cape Province (Kingdon, 1984).

Changes in bat populations have ramifications for agricultural and forestry segments of the country's economy (because bats are consumers of farm and forest insect pests and disperse seeds), ecosystem function, and conservation of national biological diversity. There is therefore a need for status information on a wide range of bats, and bat population monitoring programs on a national or other broad scale.

Studies indicate that drops in abundance of bats at their roost sites may be accounted for by exposure to pesticides through the food chain (Clark 2001), and disturbance due to deforestation, illegal tree felling and hunting for bushmeat (Funmilayo 1978). Because of the lack of monitoring, however, McCracken (2003) pointed out that it is uncertain how representative population loss at identified locations may lead to the overall loss of a larger bat population.

2.1.1 The role of Bats in enhancing plant development

A colony of fruit Bats with a very large population is observed to have destructive impact on roosting trees and the environment (Ritcher, 2004). *Eidolon helvum* feeds entirely on flowering and fruiting trees (Wilson, 1973). Roosts sites selected during the day are in tall and large trees with scattered branches (Defrees and Wilson, 1988). These fruit bats help in pollinating and promoting out crossing in flowering plants, such as *Ceiba pentandra*.

It is well known among tropical ecologists that bats play important role in seed dispersal and pollination in tropical forest succession, distribution, and community composition (Fleming and Heithaus, 1981, Fleming, 1982). Most of these bat dispersed and pollinated plants have great economic and cultural significance to mankind (Howe, 1986).

Over 300 plants in the old world tropics are dependent on bats for pollination and dispersal (Bat Conservation International, 2002). The role of bats such as *Eidolon helvum* as major allies in ecosystem regeneration will be greatly compromised if no steps are taken to save their populations.

Many of these plants have traits that attract animal/bats. Some of these traits include bright colors, characteristic odors and in some cases their position on the parent plants are described as 'dispersal syndrome' (Howe, 1986). Studies have shown that there is a synchronization of fruiting functions which minimize intra and inter-specific plant competition for animal dispersers through resource partitioning (Fleming, 1986).

It has been argued that several factors, such as spatial distribution and temporal unpredictable germination sites have contributed to mutualism on animal and plants for dispersal (Howe, 1986). In some cases, Howe (1993), states that most dispersal agents may be less reliable and fail to establish their effect as special or general agents of dispersal. Thus it suggests that the dispersal agents do not harm seed, but remove seed from parent trees and deliver seed to a more suitable place for germination and growth. The regularity at which the agent visits the tree makes it a dependable agent.

Many bats are opportunists, switching between plants, depending on food availability (Fleming, 1982). *E. helvum* are noted to completely rely on fruit, pollen or nectar (Dumont, 2003).It has been explained by Fleming (1982) and Dumont (2003) that foraging strategies of *E. helvum* depends on risk of predation and distribution of fruit resources. Other factors may include colonialism, gender and age (Heithaus, 1982). Plants whose seeds are dispersed by bats are known to fruit seasonally (Fleming, 1982). This could influence their seasonal migration from roost site to other places where food resources are abundant.

The study is expected to add on to the existing knowledge on the role of bats especially *Eidolon helvum* in seed dispersal.

2.1.2 Challenges involved in Bat population monitoring

Populations of bats (Order Chiroptera) are difficult to monitor Westcott (2011). However, current recognition of the importance of bats to biodiversity, their ecological and economic value as ecosystem components, and their vulnerability to declines makes monitoring trends in their populations a much-needed cornerstone for their future management (IUCN, 2011).

Monitoring the size and distribution of bat population is challenging. Bats differ from most other species because they are:

i) Difficult to detect away from known roost sites,

ii) Extraordinarily mobile, with individuals change camp regularly and capable of moving hundreds of kilometers over periods of days, while,

iii) Behaviorally distributed based on their population, which appears to respond rapidly to changes in resource distribution with entire colony and regions being colonized or vacated in short periods Westcott *et al* (2011).

Monitoring is increasingly seen and promoted as necessary to ensure effective management in the face of growing anthropogenic impacts. Monitoring contributes to decision making through the establishment of a species' abundance, distribution and dynamics and allows for the assessment of management needs, management approaches and their effectiveness (Elinga 2001). Monitoring programs have provided critical information in a broad range of contexts including conservation management (Cadiou *et al.*, 2006), disease and invasion monitoring (Hochachka, *et al.*, 2000) and stock assessment (Hagen *et al.*, 2008) and form the basis of assessment for conservation listing under a variety of national and international frameworks.

Although rigorous estimation procedures and replicate counts over years are largely lacking, evidence for major declines in numbers of bats at their roosting sites over specific period of time is obviously absent.

Bergmans (1990) indicated that, bats are a heterogeneous group of mammals and require the application of multiple approaches to monitoring. Some species are essentially solitary and roost cryptically in foliage, whereas others aggregate in the millions at predictable locations. Many others occur in a range of intermediate situations. Bats are highly mobile, predominantly nocturnal, and generally roost in inaccessible or concealed situations. Their annual cycles can include seasonal long-distance migrations, and some species form colonies of different size, sex, and age compositions at different times of the year. They also are susceptible to disturbance (particularly during hibernation), which can reduce survival, Bergmans (1990).

With the possible exception of certain small colonies in which individual bats can be completely counted, attempts to estimate bat population trend have relied heavily on use of indices at local sites (Akite, *et al.*, 2009). The use of indices and "convenience sampling" to estimate population size and trends in animals in general is inferior to more statistically defensible methods and can lead to incorrect inferences (Thompson *et a1.*, 1998, Anderson 2001).

Bat conservation efforts are well founded, and current monitoring approaches, although provide scientifically less rigorous information than is desirable, have some merit for conservation if applied cautiously and conservatively (Decher, 1997).

Most animal populations are in alarming decline worldwide. Like most animals, bats suffer habitat loss through the decline and wanton destruction by humans in their habitats. *E. helvum* though not endangered, (IUCN, 2000), has been noted to be very vulnerable to habitat destruction. To manage wild populations, it is very important to monitor their population dynamics. This can contribute to decisions when establishing the abundance, distribution and dynamics for effective management activities (Marsh *et al.*, 2008). Monitoring populations of wild species have provided critical information in a broad range conservation management (Cadiou *et al.*,2006). The potential for tourism or eco-tourism and the economic benefits from conserving bat populations can certainly be the main incentive for protecting their populations. Their nightly foraging habits, when captured are a sight that can be regularly watched by bat lovers.

At the same time documenting the seasonal migration of tropical fruit bats is very important because of the role they play as seed dispersers in the tropical rainforests, pollinators of fruit crops and vectors of emerging diseases (Fleming *et al.*, 2003; Messenger, *et al.*, 2003).

A contributing factor in the reassessment of monitoring in recent times has been the recognition that significant resources and opportunities can be consumed by monitoring activities and that in some circumstances these resources may be more productively utilized elsewhere. Consequently monitoring programs must make justifiable, effective and efficient contributions to management. Of primary concern is the question of whether monitoring is actually necessary or even appropriate in any given circumstance (Mc Donald-Madden *et al.,* 2010).

2.1.3 Factors affecting Bat population

The reductions in bat populations in the world have been linked to human interactions. Most of the threats to bats are directly related to the increasing human population worldwide. An increasing population brings with it extra demands for land, resources, and food, which often results in the degradation or destruction of certain habitat types with a concomitant effect on bat populations (Westcott *et al.,*2011). The greatest pressure is often in tropical countries where a large proportion of the human populations live in rural areas and has incomes below the poverty line (Funmilayo, 1978).Habitat clearing and degradation are currently thought to be the main threats to bat population in Africa. Habitat modification in the form of land clearing for both urbanization and agriculture has occurred (Eby, 2002), leading to bat roosting sites and colonies losing their ecological significance to hold bat populations.

Bat populations in many countries are thought to have declined over the past 50–100 years, although the evidence for such reductions is often circumstantial (Stebbings, 1988). There are cases, however, where declines have been well documented. The rapid increase in human populations in many areas of the world poses the single most serious threat to bat populations. Fenton and Rautenbach (1998) use the example of Zimbabwe to illustrate the consequences of rapidly increasing human populations; since 1900, the population has increased from 0.5 million to over 10million (Cumming, 1991). This type of increase is likely to have a serious impact on bat populations in this area.

Major threats to bat populations include habitat loss or modification, roost site loss or disturbance, and disease (Mickleburgh *et al.,* 1992. In addition to this, bat meat is often consumed by humans, which can lead to subsistence hunting (Craig *et al.,* 1994) and over exploitation for commercial trade (Mickleburgh *et al.*, 2009).

The present killing methods are inefficient and wasteful (and cruel), many bats being merely wounded by guns that are commonly used, and dead or wounded bats are often not recovered because of the thick, tangled vegetation around the roosting trees (Funmilayo, 1989). All these cause decline in bat populations.

Shifting cultivation has been identified as one of the major cause of forest loss in South America. Trans-migration, particularly in Brazil, has compounded the effects of shifting cultivation. Large landowners have moved in after shifting cultivators and cleared the land for cattle ranching (UN Department of International Economic and Social Affairs, 1989). This state of land clearance has resulted in heavy pollution, deforestation, and loss of natural lowland vegetation, particularly in the last 20 years. Evidence suggests a severe decline in the local bat fauna. There is a trend towards habitat simplification and a reduction in the diversity and abundance of bats due to decline in fruiting trees that support their survival (IUCN, 2001).

The replacement of natural vegetation with cash crops such as oil palm, cocoa, rubber, and coffee is widespread in many tropical countries. These results in monoculture plantation, with very low species diversity; which affects the insect fauna and flora available for feeding bats (World Conservation Monitoring Centre, 1988).

Until recently in Zimbabwe, DDT was used to control tsetse flies, malarial mosquitoes, and agricultural pests. By comparing sprayed with unsprayed areas, McWilliams (1994) showed that spraying increased the mortality in some bats.

Fire plays an important role in some ecosystems, such as African woodlands, wooded grasslands, and grasslands. In Africa, humans have used fire as an ecological tool for at least 150,000 years. Here there are many fire-tolerant species, and many savanna species are dependent on fire for their survival in competition with larger species. Occasional fires may also be necessary for the germination of some species. Fire is now commonly used in agriculture as a way of clearing vegetation. While most burning is controlled, some fires can burn unchecked with the result that much of Africa outside the forests, deserts, and areas of densest settlement is regularly burnt. Even moist forests can be burnt; particularly during periods of drought (World Conservation Monitoring Centre, 1988) annual fires are a severe threat to fruit bats.

While major areas of forest, such as in Amazonia, remain relatively intact, destruction of rainforest is widespread and many forested areas worldwide are severely threatened. Much attention has been focused on tropical moist forests, but there are similar problems in other tropical forests (Ayoade,*et al*., 2012).

A combination of factors is thought to influence the decline in the population of bats. However, it is not possible to conclusively say which factor is taking the lead in bat population. Habitat destruction of previous roost sites can be said to have led to the break-up of the original bigger roosts, causing the bats to find alternative sites (Perpetra and Kityo, 2009).It has been identified that roost site loss or disturbance is the main threat to *Eidolon helvum in* Kampala, Baranga, (1979). This is not to rule out other threats such as habitat modifications including impacts of deforestation. Persecution of bats arising from a combination of ignorance and perceived risk of damage and lack of information makes accurate assessment of their status difficult.

Bats have been attributed to transmission of diseases ranging from rabies, tuberculosis and until recently Ebola virus. This has increased affected the interaction of these animals and human.

A comprehensive review of bats and rabies is given by Brass (1994), while Greenhall and Schutt (1996), Greenhall and Schmidt (1988), Greenhall *et al.*,(1983, 1984) and Turner (1975) focus specifically on vampire bats. The phylogeny of rabies viruses in the USA and the human incidents attributable to different strains is discussed in Smith *et al.*,(1995).

There is absolutely very little knowledge on the transmission of diseases from bats to humans, this lack of information is one of the least appreciated threats to bats in the tropic. Of the 834 bat species worldwide only a few has been well studied. This makes judging which species need special conservation effort difficult.

2.1.4 Frugivore and Importance of Fruit Bats as Seed Dispersal Agents

Many plants have traits that attract bats. Some of these traits include bright colors, as in *Ceiba pentandra*, characteristic odors as in *Azadiractha indica* and in some cases their position on the parent plants, as in *Musa sapientum*, are described as 'dispersal syndrome' (Howe, 1986). Studies have shown that there is a synchronization of fruiting functions which minimize intra and inter-specific plant competition for animal dispersers through resource partitioning (Fleming, 1986).

It has been argued that several factors, such as spatial distribution and temporal unpredictable germination sites have contributed to mutualism on animal and plants for dispersal (Howe, 1984b). In some cases, Howe (1993), states that most dispersal agents may be less reliable and fail to establish their effect as special or general agents of dispersal. Thus it suggests that the dispersal agents do not harm seed, remove seed from parent tree and deliver seed to a more suitable place for germination and growth. The regularity at which the agent visits the tree makes it a dependable agent.

In some cases behavior can influence seed dispersal by animals, especially the territorial attribute of the dispersal agent.

Animals, such as bats have been known to play important role in the distribution of some plant genera and species thus influencing floral composition within local communities (Fleming and Williams, 1990). This can lead to species distribution through such interactions. Connell (1971) explained that seed escape through dispersal from parent tree/plant will increase the probability of seedling establishment. Baobabs are affectionately known as the 'upside down tree' or the 'tree of life' - for good reason. These trees, which provide shelter, water and food for people as well as other animals, have been noted to be dispersed by fruit bats (Akite, 2008). In West Africa, *E. helvum* is a critically important seed dispersal agent for the economically important and threatened timber tree, the African Iroko (*Milicia excelsa*) (Omaston, 1965); Taylor *et al.,* (1999).

In Panama, Howe (1986) established that the dispersal pattern of animal dispersed trees have either small fruits which are scattered singly in scattered pattern with little chance of surviving high rate of predation or produce relatively large seeds that clump and fall below the parent tree and are dispersed by animals.

The passage of seeds through the guts of dispersal agents enhances seed germination (Thomas, 1982). Feeding trails with captive *E. helvum* found that germination rates of

Ficus capensis seeds from the bat excreta were significantly higher than seeds attached to the fruiting tree.

Many bats are opportunists, switching between plants, depending on food availability (Fleming, 1982).*E. helvum* are noted to completely rely on fruit, pollen or nectar (Dumont, 2003).It has been explained by Fleming, (1982) and Dumont, (2003) that foraging strategies of *E. helvum* depends on risk of predation and distribution of fruit resources. Other factors may include colonialism, gender and age (Heithaus, 1982). Plants whose seeds are dispersed by bats are known to fruit seasonally (Fleming, 1982). This could influence their seasonal migration from roost site to other places where food resources are abundant.

Ecosystem services are the benefits obtained from the environment that increase human well-being. Economic valuation is conducted by measuring the human welfare gains or losses that result from changes in the provision of ecosystem services. Frugivory is an ecosystem function that is beneficial to mankind and helps in improving ecosystem through spatial dynamics of plant population (Howe, 1986).

Fruigivores are animals that feed primarily on fruits or any animal that subsists totally or primarily on fruit. Although the diets of many animals include fruits, many species practice Frugivory exclusively, *E. helvum*, the straw colored fruit bat is no exception.

Frugivory is thought to have evolved as a mutualism to facilitate seed dispersal in plants. In general, an animal benefits by receiving sustenance from the plant by consuming the fruit. If the animal swallows the seeds of the fruit and later travels to a new area, it assists the propagation of the plant by dispersing the seeds when it defecates.

During their feeding, these frugivore swallow small seeds and so disperse them in their feces great distances from the mother tree. When fruits are too large to be eaten rapidly, frugivore typically carry them off to distant trees where they can feed safely, thus dispersing even large seeds tens to hundreds of feet away. By dispersing seeds away from the mother tree, frugivore renders at least two important services(Thomas, 1991).The role of bats in rebuilding tropical forest ecosystems have received little attention (Marshall, 1983), despite their relevance in understanding the role of frugivore in landscape ecology. *E. helvum* feed on several fruits ranging from shrubs, trees and figs (Ayoade, *et al.,* 2012), this makes them prolific dispersers of seeds in the forest landscape. Their nightly foraging tour to feeding roosts, and their return to their day time roosting sites, makes them active seed dispersal agents.

Several studies have indicated that bat feces literally rained down on collecting sheets, accounted for over 92% of all seed precipitation in a bat colony (Thomas, 1991), the seed precipitation also accounted for 90% of regenerated seedlings in the colony.

Seeds that passed through a bats' gut obviously had a highly beneficial effect on seeds, leaving them viable and primed to germinate (Thomas, 1991).

2.1.5 Bats as Seed Dispersal Agents

Bats have long been found to play important roles in arthropod suppression, seed dispersal, and pollination; however, only recently have these ecosystem services begun to be thoroughly evaluated (Ayoade *et al.,* 2012).

More than 250 species (29%) of bats eat some fruit, pollen, or nectar (Marshall 1983). These bats belong to two main families, the Neotropical Phyllostomatidae (suborder

Microchiroptera), and the paleotropical Pteropodidae (suborder Megachiroptera). The phyllostomids developed the ability to echolocate, allowing them to exploit invertebrate and vertebrate prey in addition to plant resources, resulting in a greater radiation than the pteropodids.

Many bats in the Phyllostomatidae are opportunists, switching between plant and other food sources depending on resource availability (Fleming 2007).Feeding roosts may be far from the food source. African fruit bats typically process fruits and seeds at feeding roosts within 100 m from fruiting trees (Kankam & Oduro 2009).

Seed size has been shown to be an important influence on how seeds are handled and dispersed (Wheelwright 1985), because bats can swallow small seeds while ingesting fleshy pulp.

Africa is home to 12 families of bats (Nowak, 1997), the high human population in Africa combined with poverty, minimum education, and pervading stigmas about bats, makes the conservation of bat species a significant challenge (Fenton and Rautenbach, 1998).

Bats are almost exclusively night active and airborne, thus their presence, behavior and species richness is not as obvious and easy to observe and study as that of many day active animals. About one quarter of all bats, some 250 species, are mainly vegetarians, living on fruits, fruits and nectar or exclusively on nectar and pollen (Cotterill, 2001).

Fruit and nectar feeding bats are found in most tropical and subtropical areas of America, Africa, Asia and Australia and on islands in the Pacific, Indian and Atlantic Oceans.

However, the Old and New Worlds fruit and flower visiting bats belong to two different families of Chiroptera, Pteropodidae and Phyllostomidae, respectively. The Old World's pteropodid bats are exclusively fruit and/or nectar feeding and include some 173 species distributed from Africa to the Pacific (Marshall1983). The Phyllostomidae, endemic to the New World, is an ecologically very diverse family with species feeding on insects, fruit, nectar, and pollen (Nowak 1994).

Pteropodid bats are known to eat fruit from at least 139 genera in 58 families (Ayoade *et al.*, 2012). In the case of flowers, most fruits eaten by pteropodid bats are produced by trees or shrubs, whereas those eaten by phyllostomids include fruits produced by epiphytes and vines as well as trees and shrubs (Aladetuyi, 1984).

Large-scale cash crops produced by plants either(originally) pollinated or dispersed by bats include non native bananas and mangos in the New World and native bananas (*Musa sp*), breadfruits (*Artocarpus artilis*), durians (*Durio zubethinus*), mangos (*Mangifera indica*), and petai (*Parkia speciosa*) in the Old World (Aladetunyi, 1984). Of these, only durians and petai currently rely on bats (among other animals) for pollination.

The same is true for trees such as *Ceiba pentandra*, the kapok tree, and *Ochroma lagopus*, the balsa tree. Other fruits that are harvested and sold locally include sapodilla and organ pipe cactus (*Stenocereus*) in the New World (Lobova, 2009). Although bat pollination is relatively uncommon compared with bird or insect pollination in angiosperms, it involves an impressive number of economically and/or ecologically important plants (Aladetuyi, 1984).

In arid habitats in the New World, two families, Agavaceae and Cactaceae, have enormous economic and ecological value. Many species of paniculate *Agave* rely heavily on phyllostomids bats for pollination, and many of these same bats are also major pollinators and seed dispersers of *Columnar cacti* (Fleming *et al.*, 1990). Three species of *Leptonycteris* bats are especially important in this regard in the south western United States, Mexico, and northern South America. The bat-pollinated *A. tequilana* is the source of commercial tequila, a multimillion dollar industry in Mexico; other species of *Agave* are used locally to produce similar alcoholic beverages such as pulque, mescal, and bacanora. Agaves are also important sources of sisal fiber in many tropical localities. Although bats are not the exclusive pollinators of most species of Agave, *Agave tequilana*, they are critically important pollinators in tropical latitudes in the New World (Rocha, *et al.*, 2006). This is also true of bats pollinating *Columnar cacti*. For example, bats are minor pollinators of the two northernmost columnar cacti, *Carnegiea gigantea* and *Stenocereus thurbei* (Fleming, *et al* 2002).

Bats provide ecological services for wild plant relatives by preserving genetic diversity in these plants. In India, the Mahwa tree (*Madhuca indica*), also called the honey tree, sugar tree, or Indian butter tree, is pollinated by *Pteropus giganteus, Rousettus leschenaulti*, and *Cynopterus sphinx* (Isaac, *et al.*, 2010). The timber of this tree is used for making wagon wheels in India. The flowers, also called honey flowers, are used as food and for preparing a distilled spirit (matkom duhli). Sun-dried fruits are directly consumed by humans, and the oil extracted from flowers and seeds, known locally as *mahwa*, *mowrah butter*, or *yallah*, is incorporated into soaps, candles, cosmetics (e.g., lipstick, lotions), and lubricants, and used medicinally as anemetic, an anti rheumatic, and in the treatment of leprosy. Extracts from the fruits are also thought to prevent wrinkles and restore skin flexibility (Panda, 2002).Seedcakes made from *M. indica* are used as food for cattle and goats (Kunz, 2002), and are known to increase their milk production (Devendra, 1988).

The shea butter, *Vitellaria sp.*(*Butyrospermum) parkii*), a highly economical tree in Africa, is dispersed by bats (Richter, 2004; Richter *et al.*, 2006).

It is well known among tropical ecologists that animal/bats play important role in seed dispersal and pollination in tropical forest succession, distribution, and community composition (Fleming and Heithaus, 1981, Fleming, 1982). Most of these animals dispersed and pollinated plants have great economic and cultural significance in our everyday life (Howe, 1986).

With over 300 plants in the old world tropics are dependent on bats for pollination and dispersal (Bat Conservation International, 2002). The role of bats such as *Eidolon helvum* as major allies in ecosystem regeneration will be greatly compromised if no steps are taken to save their populations.

Many of these plants have traits that attract bats. Some of these traits include bright colors, characteristic odors and in some cases their position on the parent plants are described as ‘dispersal syndrome’ (Howe, 1986). Studies have shown that there is a synchronization of fruiting functions which minimize intra and inter-specific plant competition for animal dispersers through resource partitioning (Fleming, 1986).

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The passage of seeds through the guts of dispersal agents enhances seed germination (Thomas, 1982). Feeding trails with captive *E. helvum* found that germination rates of *Ficus capensis* seeds from the bat excreta were significantly higher than seeds attached to the fruiting tree. Izahki (1995) compared the germination rates of seeds from bat excreta, ejected pellets and uneaten fruit (control) and found that the germination rates were higher in the ejected fruit.

Many bats are opportunists, switching between plants, depending on food availability (Fleming, 1982). *E. helvum* are noted to completely rely on fruit, pollen or nectar (Dumont, 2003).It has been explained by Fleming (1982) and Dumont (2003) that foraging strategies of *E. helvum* depends on risk of predation and distribution of fruit resources. Other factors may include colonialism, gender and age (Heithaus, 1982). Plants whose seeds are dispersed by bats are known to fruit seasonally (Fleming, 1982). This could influence their seasonal migration from roost site to other places where food resources are abundant.

2.1.6 Impact of Fruit Bats on Roost Trees

Ecological theory makes a number of predictions about the timing of migration and the behavior of migratory bats upon arrival in a new location. If food availability is an important driver of migration in *E. helvum*, the colony should arrive at its new habitat when food abundance is high or increasing, and depart when food availability starts to decline (Katz, 1974, Charnov, 1976; Pyke *et al*., 1977).

It has been suggested that *E. helvum* migrate to take advantage of variations in food supplies to increase its reproductive success (Jones, 1972).

The impact migratory fruit bats have on their environments, particularly their seasonal roost sites, needs to be studied because of their gregarious behavior. They often defoliate and break branches of roost trees, resulting in reduced canopy foliage (Jones, 1972; Bonoccorso, 1998; Richter, 2004).

E. helvum is highly gregarious and often defoliate and break branches of roost trees, resulting in reduced canopy foliage (Jones, 1972; Bonaccorso, 1998; Richter, 2004). Bonaccorso (1998) suggested that such defoliation might aid visual observations between bats and detection of approaching aerial predators or could be related to thermoregulation. Severe defoliation of roost trees could affect tree growth, composition and structure of roosts which may affect their long term viability (Richter, 2004) and play an important role in forest dynamics (Zielinski & Gellman, 1996).

Large aggregations of bats are also likely to move significant amounts of energy and nutrients around their foraging areas (Polis, *et al.*, 1997) and into roost sites. They often defoliate and break branches of roost trees, resulting in reduced canopy foliage (Jones, 1972; Bonoccorso, 1998; Richter, 2004).

Eidolon helvum feeds entirely on flowering and fruiting trees (Wilson, 1973).Large roosts cause damage to smaller branches and twigs. *E. helvum* will eat any sweet, juicy fruit, bud and young leaves of certain trees, flowers, nectar and pollen (Kingdon, 1974). They also chew into soft wood to obtain moisture (Nowak and Paradiso, 1983).

Bats induce premature shedding of leaves which could result into the destruction of such trees (by the loss of photosynthetic ability); depending on how long the trees serve as their roost site or camp. This deprive the immediate environment of the complement of such landscape feature i.e. shade and evapo-transpiration, humidity (Wund and Myres, 2005). The aftermath of their camping is an aesthetically unpleasant sight or defacement of such landscape feature (trees). An evaluation of the ecological consequences of the presence of any animal life, such as bats on the urban environment reveals that the main victims are the trees and a few associated features, Bonoccorso, (1998).

E. helvum are particularly fond of *Ceiba pentandra* and their habit of moving about in large flocks promotes crossing in this widespread and common tree species (Aladetuyi, 1984). Joel, (2004) indicated that bats roost on tall trees at very high density where they completely defoliate all trees within the first week after occupation. Their activities make the branches of many trees to crack and fall off due to the weight of the roosting bat population.   These phenological events are not mutually independent in woody species, and flowering may be partly or wholly dependent on leafing activity (van Schaik*et al*., 1993).

The analysis of phenological events and strategies is a complex issue, because several factors comes into play ranging from an interacting set of environmental conditions, plant-animal interactions and plant attributes (Armbruster,1995). Seasonality exposes plants to regular, periodic changes in the quality and abundance of resources (Fretwell, 1972). However, the roosting behaviors of *E. helvum* who are found all year round on trees have an effect on the tree phenology.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Sunyani is 400 m above sea level, and the University of Energy and Natural Resources is located in the Sunyani West District Assembly. The Wildlife Sanctuary is located in the eastern corner of the University of Energy and Natural Resources. The vegetation is dry-semi-deciduous forest type, with some portions re-planted with teak *Tectona grandis* (Antwi, 1999). The climate is characteristic of the tropical humid zone with two seasons, namely, harmattan and rainy season. Rainfall is bimodal with maximum occurring in May-June and September – October, (Meteorological Services, 2014).

Sunyani Municipality is one of the twenty-two administrative districts in the Brong Ahafo Region of Ghana. It lies between Latitudes 7^0 20'N and 7^0 05'N and Longitudes 2^0 30'W and $2^0$10'W (Figure 1) and shares boundaries with Sunyani West District to the North, Dormaa District to the West, Asutifi District to the South and Tano North District to the East. There are effective economic and social interactions with the neighboring districts which promote resource flow among these districts.

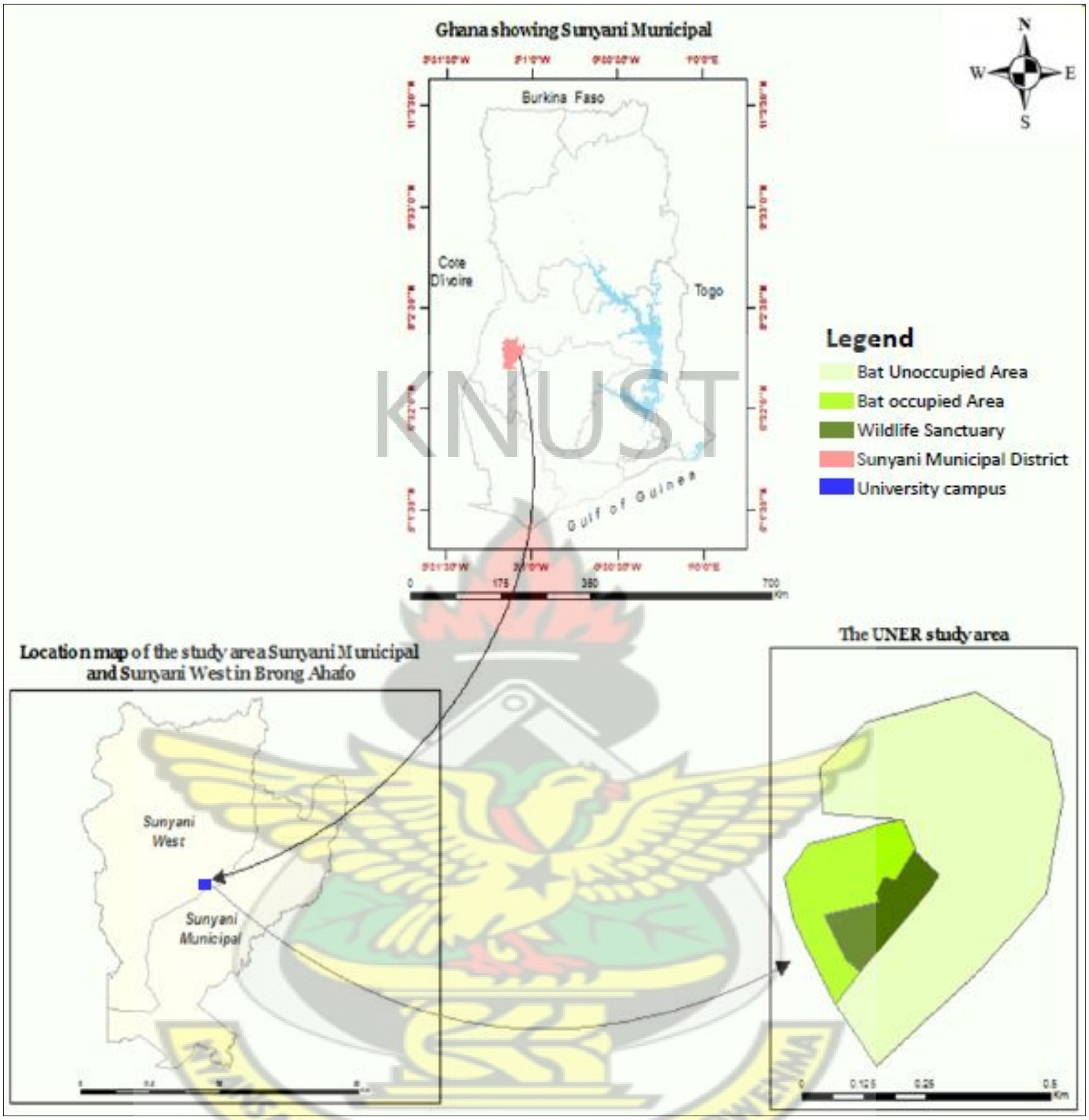

Figure 1: Map of Study Area

3.1.1 Location

The municipality has a total land area of 829.3 Square Kilometers (320.1square miles). 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)

3.1.2 Biophysical Setting

The municipality falls within the wet Semi-Equatorial Climatic Zone of Ghana. The mean monthly temperatures vary between 23ºC and 33ºC with the lowest around August and the highest being observed around March and April. The relative humidityis 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 (Meteorological Services 2014).

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 (www.molgrd.org)

3.1.3 The Environs of UENR

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 7^0 20′N and 7^0 05'N and Longitudes 2^0 30'W and $2^0$10'W (Figure 1) with a total area of 3.6ha and occupies 7.3% of the University Campus. The purpose of the establishment of the sanctuary is to serve as an educational site for students as well as visitors to the University. It was also established to provide natural conditions for animals (purely forest animals) which would be used for research purposes (Antwi, 1999) it is currently managed by the School of Natural Resources as a research station. There are sixty eight species of plants representing thirty families. The dominant Families are Apocynaceae, Papilioniaceae, and the least dominant are Ulmaceae, Ebenaceae, and Sapotaceae. The dominant tree species is *Newbouldia laevis* and the least abundant is *Triplochiton scleroxylon.* The dominant undergrowth is the *Psychotria spp*. which can support duikers.

3.2 Description of the Study Species and Population

Megachiroptera, or flying foxes, are known to feed on at least 188 plant Genera in 16 Families in Asia and Africa (Marshall, 1983). Around the world at least 289 plant species, producing more than 448 economically valuable goods, rely on fruit bats to some degree (Fujita and Tuttle, 1991). Africa is home to 12 families of pteropodid bats (Nowak, 1997), but the lack of even basic knowledge about them constrains conservation efforts (Fenton and Rautenbach, 1998; Racey and Entwistle, 2003). Furthermore, the high human population in Africa combined with poverty, minimum education, and pervading stigmas about bats, makes the conservation of bat species a significant challenge (Fenton and Rautenbach, 1998).

The University of Energy and Natural Resources in Sunyani, is unique in that it has a large resident fruit bat colony in its Wildlife Sanctuary. Despite the presence of the bats on the site since 2008, no sampling has been conducted to establish the size of the bat population and other related characteristics of the colony. Similarly, no study has explicitly examined the factors that influence migratory timing in African fruit bats or the effects migratory bats have on resident fruit bat populations. Although there are some information on similar bat fauna in Kumasi and Accra in Ghana (Fenton, 1975), virtually nothing is known about the fruit bat assemblage in the Wildlife Sanctuary. Information on their seasonality, roost sites, migration habits, food sources, foraging patterns, or timing of parturition have not been documented. This study addresses the lack of information about some aspects of population dynamics of the fruit bat assemblage in the Wildlife Sanctuary. This information is vital for their effective conservation and management, especially in human dominated landscapes like the one that exist on the UENR campus.

3.3 Experimental Procedure

Three different experimental procedures were adopted to meet each objective.

1. Direct roost counts were carried out between January 2013 and July 2014, using the continuous Point Count Method (Huff*et al.,* 2000). This method is a common way of estimating bird populations by tallying at a fixed location during specific and repeated observation periods. Observers were stationed at designated positions relative to the study area using GPS and all bats on trees within a plot of 20m x 20m were recorded.

In all 30 sample plots were systematically laid and monthly estimates of bats on each tree within the plots were counted continuously during the period. This was used on the assumption that the trees were randomly distributed. The counts were done on the 7th day of each month of the study period and the same observers were used throughout the counts to ensure consistency. The 7th day of the month was chosen arbitrary, it could have been any other day but it was for our convenience. Counts of tree roosting bats were made during the late morning when wind velocity is low and cloud cover is minimal to increase reliability and accuracy in counts (Mutere, 1967).

The only limitation in this method is the movement of bats during counting.

The number of bat clusters on a branch is counted, and the number of branches with bats is then estimated from the number of clusters on the particular tree, which is considered as a sampling unit. The sampling unit was defined as the tree on which the bats were found in the sample plot. The number of bats found in a sampling unit in a sample plot therefore represents the number of bats for that plot. The total number of bats for the month represents the sum of all bats in all the 30 sample plots.

2. i) Thirty one roost trees were randomly selected in the study area and seed traps were placed under each tree to collect seeds dispersed through bat droppings at the bat roosting site. Each seed trap was constructed under the tree canopy using a plastic sheet measuring 4m x 6m **(Plates 2a and 2b)**.

ii) Seeds dispersed through bat droppings on the sheets were identified with a handheld magnifying glass based on methods employed by Irvine and Roberts (1961).

iii) Fifty two quadrats, each 2m x 2m, were randomly laid in the study area and some outside roost trees to compare diversity. All seedlings were identified using methods employed by Hawthorne (2006). All seedlings were defined as any plant form that is below 30 centimeters high.

3. 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 x 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 of tree 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* non-parametric 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 tree canopy 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 analyses were conducted using InfoStats v 1.4. (Infostat, 2004).

The main limitations in the laying of plots were that, it required skills and it was assumed that all the technicians employed in the field work were experts.

3.4 Data Analysis

All data sets collected were carefully separated and analyzed separately using different tools and were analyzed one at a time.

1. The population data was analyzed using time series to represent the twenty months population data. A t-test was used to detect any monthly and seasonal differences in the population of bats during the study period.

2. All vegetation sample analysis was done using the Minitab computer package. Descriptive analysis using tables, charts and histogram were used to show the types and quantity of fruits eaten and dispersed by bats. Shannon-Wiener's diversity index was used to estimate fruit seed and seedling diversity. A t-test was also used to detect monthly differences in the quantity and diversity of fruit seeds and seedlings dispersed by bats during the study period.

3. The impact of bats on trees data was analyzed using the DBH measurements which were used to calculate the basal area for plant species. Estimates Win800 Version 8.0.0 (Colewell, 2006) was used to determine indices of tree 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* non-parametric 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 tree canopy 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 analyses were conducted using InfoStats v 1.4. (Infostat, 2004)

CHAPTER FOUR

4.0 RESULTS

4.1 Population size of bats in UENR

E. helvum, normally aggregate in relatively small clusters in their roost site. Following methods described by Defrees and Wilson (1988), the number of bats, with its standard error and coefficient of variation was estimated to be 5.6 (S.E=7.88, CV=0.047%) for the dry season and 6.2 (S.E=7.98, CV=0.034%) for the wet season. This gave an overall estimated mean number of bats per cluster as 5.9 (S.E=7.63) for the entire survey period (Table 1).

It was found out that number of bat clusters for each tree was estimated between 9-10; number of bats per tree per month was estimated to be 121; the variation in the number of branches occupied for each tree per month was between 2 and 20+; and the mean monthly bat population for the period under study was estimated to be 55,469.55 in an area of 3.566ha. According to Defrees and Wilson (1988), *E. helvum* roost in clusters and the average cluster sizes depended on the population size in the colony at a time. When the population in a colony is high, they cluster between an average of 5-10, but when the population is low the cluster sizes decrease to 1-5. The highest number of counts was in December (240,000) S.E=8.56, C.V=13.56%) and March (180,000) S.E=5.67, C.V. =8.6% the lowest counts were in March to October for the year 2013 (Figure 2) and decreased from May to October in 2013.In 2014, the population showed similar trend between May to July with high in March (90,000) and in July (1,900) (Figure 2), what triggers this pattern is not known and should be investigated.

Table 1: Monthly bat estimate counts in the study area

Month	Total No. of bats	Mean No. of bats	No. of trees with bats	S.E	CV (%)
Jan	15,000	500	45	19.6	22.2
Feb	56,000	1,867	85	16.2	23.4
Mar	180,000	6,000	189	5.67	8.67
Apr	69,000	2,300	108	14.2	22.3
May	12,401	413	40	17.2	23.4
Jun	15,990	533	98	19.6	22.3
Jul	12,500	417	40	17.2	23.4
Aug	18,500	617	88	16.4	24.2
Sept	10,600	353	39	16.8	25.5
Oct	28,500	950	95	20.1	16.4
Nov	140,000	4,667	122	10.3	9.3
Dec	240,000	8,000	321	8.56	13.56
Jan	12,000	400	69	17.2	23.4
Feb	156,000	5,200	125	12.7	15.2
Mar	90,000	3,000	102	14.3	24.2
Apr	30,000	1,000	99	20.5	17.2
May	11,000	367	48	16.3	21.5
Jun	1,500	50	36	0.06	1.06
Jul	1,900	63	49	0.05	1.02
Total	**1,100,891**	**36,696**	**1798**		
Mean	**122,321**	**1,931**	**98.63**		

The bat estimate throughout the study period was estimated as One million one hundred thousand, eight hundred and ninety one (1,100,891) individual bats recorded in the thirty (30) sample plots. This gave us a mean number of bats as 36,696.4bats/plot (Table 1).

The mean population estimates in the dry season count was 85,955.5±87,272.3 whilst the mean population estimate in the rainy season count was 46,932.3±58,122.9 (Table 2a). However, there was no significant difference between the mean dry and rainy season population count of bat in the study area, *t* (8) = -0.922, p>0.05 (Table 2b).

Bats were present in the study area throughout the survey period, with their numbers varying between months (Figure 2). The estimated mean number of bats per month, with its standard error and coefficient of variation was estimated at 55,469.55 bats (S.E=4.34, CV=8.68%) throughout the whole year.

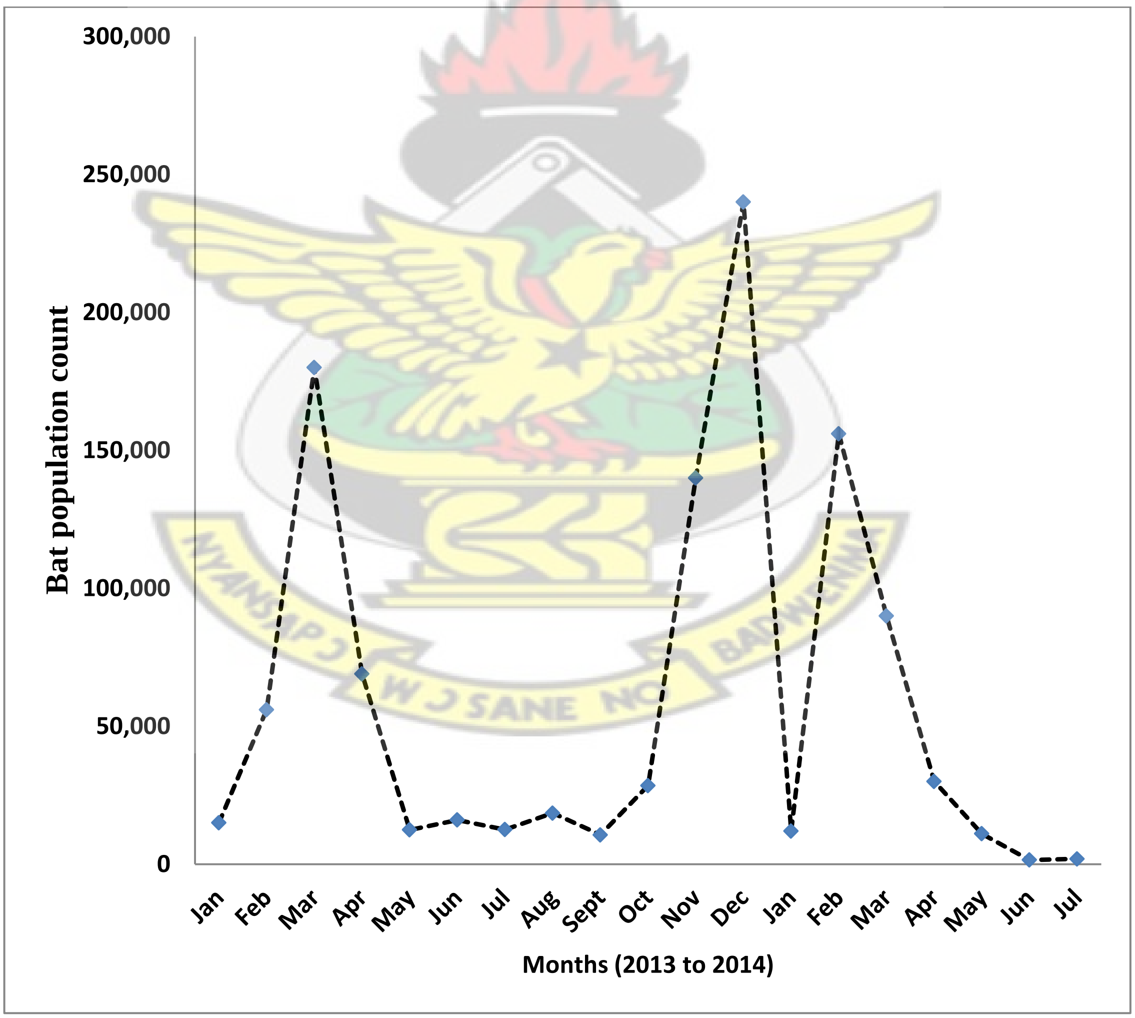

Figure2: Time series Plot of Bat Population from January 2013 to July 2014

Table 2a: Paired Sample Statistics

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	rainy	46932.33	9	58122.89	19374.29
	dry	85955.55	9	87272.31	29090.77

Table 2b: Paired sample Test (t)

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
rainy - dry	-39023.22	126990.48	42330.16	-136636.74	58590.30	-.922	8	0.38

4.2 Plants eaten and Dispersed by E. helvum in the study area

4.2.1 A list of food plants eaten by straw-colored fruit bats in UENR

A survey in the study area showed that there are 68 plant species, made up of 45 trees species (66.2%) and 23 species of herbs, shrubs and climbers, (43.8%). Seven tree species (15.6%) had their fruits eaten by *E. helvum*.

These tree species had their fruits eaten by bats in the study area. Two hundred bat droppings were examined and seven seeds were found to correspond to trees found in the study area and four were found exclusively outside the Study area (Table 3a). Monthly number (percent) of fruits eaten by bats in the study area (Table 3b).

Table 3a: Plants Eaten by bats in the study area

Botanical Name	Family	Frequency	Notes
Azadiractha indica	Meliaceae	10	Present in bat area
Ceiba pentandra	Bombacaceae	15	Present in bat area
Deloniix regia	Caesalpinaceae	18	Present in bat area
Holarrhena floribunda	Apocynaceae	16	Present in bat area
Newbouldia laevis	Bignoniaceae	10	Present in bat area
Albizia zygia	Mimosaceae	10	Present in bat area
Triplochiton scleroxylon	Sterculiaceae	12	Present in bat area
Ficus exasperate	Moraceae	17	Not present in the study area
Mallotus opposotifolius	Euphorbiaceae	19	Not present in the study area
Solanum erianthum	Solanaceae	11	Not present in the study area
Broussonetia papyrifera	Moraceae	40	Not present in the study area
Morus mesozygia	Moraceae	22	Not present in the study area
TOTAL		**200**	

The plant families found to be frequently eaten in the study area were Caesalpinaceae (18), Apocynaceae (16) and Bombacaceae (15) with Sterculiaceae (12). Meliaceae, Bignoniaceae and Mimosaceae were all (10).

The percent monthly seeds collected during the study period were computed out of the total seeds examined during the study period (Table 4).

Table3b: Monthly number (percent) of fruits eaten by bats in the study area

	MONTHS					
Fruit Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Azadiractha indica	23 (12.0)	6 (4.9)	62 (39.1)			
Ceiba pentandra	22 (11.0)	12 (9.7)				
Deloniix regia	1 (0.5)	10 (8.1)	13 (8.2)	4 (6.6)	7 (18.9)	12 (26.0)
Holarrhena floribunda		2 (1.6)	8 (6.5)	4 (6.6)	6 (5.2)	
Newbouldia laevis	8 (6.5)	8 (6.5)	15 (9.5)	17 (27.2)	12 (32.4)	15 (32.6)
Albizia zygia				8 (4.2)	6(6.2)	
Triplochiton scleroxylon	31 (15.5)	11 (8.9)				
Ficus exasperate	23 (12.0)	6 (4.9)	6 (3.8)			
Mallotus opposotifolius	22 (11.0)	12 (9.6)				
Solanum erianthum	39 (19.5)	34 (27.5)	18 (11.3)	12 (19.7)		
Broussonetia papyrifera	30 (15.0)	22 (17.8)	34 (8.2)	18 (29.5)	12 (32.4)	15 (32.6)
Morus mesozygia			2 (1.3)	6 (9.84)		4 (8.68)
TOTAL	**199 (99.5)**	**123 (61.5)**	**158 (79.0)**	**61 (30.5)**	**37 (18.5)**	**46 (23.0)**

Table 4: Monthly number (percent) of fruits eaten by bats in the study area

	MONTHS					
Fruit Species	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Azadiractha indica			28 (15.1)	14 (2.1)	16 (13.1)	33 (33.0)
Ceiba pentandra				12 (1.4)	12 (9.8)	14 (14.0)
Deloniix regia	13 (28.2)	20 (51.2)	20 (10.8)	8 (0.3)	6 (4.9)	2 (2.0)
Holarrhena floribunda			17 (8.5)	10 (1.0)	12 (9.8)	
Newbouldia laevis	20 (43.4)	19 (48.6)	14 (7.6)	12 (0.4)	12 (9.8)	8 (8.0)
Albizia zygia	16 (13.1)					
Triplochiton scleroxylon				3 (0.1)	3 (2.5)	
Ficus exasperate			54 (29.2)	26 (0.9)	16 (13.1)	12 (12.0)
Mallotus opposotifolius				6 (1.0)	13 (10.7)	
Solanum erianthum			18 (9.7)	25 (0.8)	16 (13.1)	8 (8.0)
Broussonetia papyrifera			24 (13)	13 (0.5)	16 (13.1)	23 (23)
Morus mesozygia	13 (28.2)		10 (5.4)			
TOTAL	**46 (23.0)**	**39 (19.5)**	**185 (92.5)**	**129 (64.5)**	**122 (61.0)**	**100 (50.0)**

The number of seeds in the seed rain per month ranged from 37 to 199 (Tables 5a and 5b). However, the monthly variety of fruits eaten by bats was least (37) in the month of May and highest (199), (185) and (158) in the months of January, September and March. The most frequently eaten species (Throughout the year) were *Newbouldia laevis* and *Broussonetia papyrifera* and *Delonix regia* species (Tables 5a and 5b). However, *Morus mesozygia* and *Triplochiton scleroxylon* were less frequently eaten.

Seedling diversity at the study area was assessed and the results were shown in the histogram below in Figure 6. The results indicated the relative abundance of each plant species sampled in the roosting area. There was a high seedling Species Diversity in the study area as revealed by the indices of Simpson's diversity index (D) of 0.92 ± 0.004, coefficient of variation 1.05%; Shannon- Wiener's index (H) of 2.83 ± 0.046%, coefficient of variation 3.50; Evenness (E) was 0.82 ± 0.012, coefficient of variation 3.75% and species richness of 31 in the study area.

$t(6)=0.23$, $p<0.05$ shows that there was no significance difference in the undergrowth plant population in the bat occupied and bat unoccupied areas in the study area. The dispersed plat seedlings might take a long time to dominate the plants in the study area.

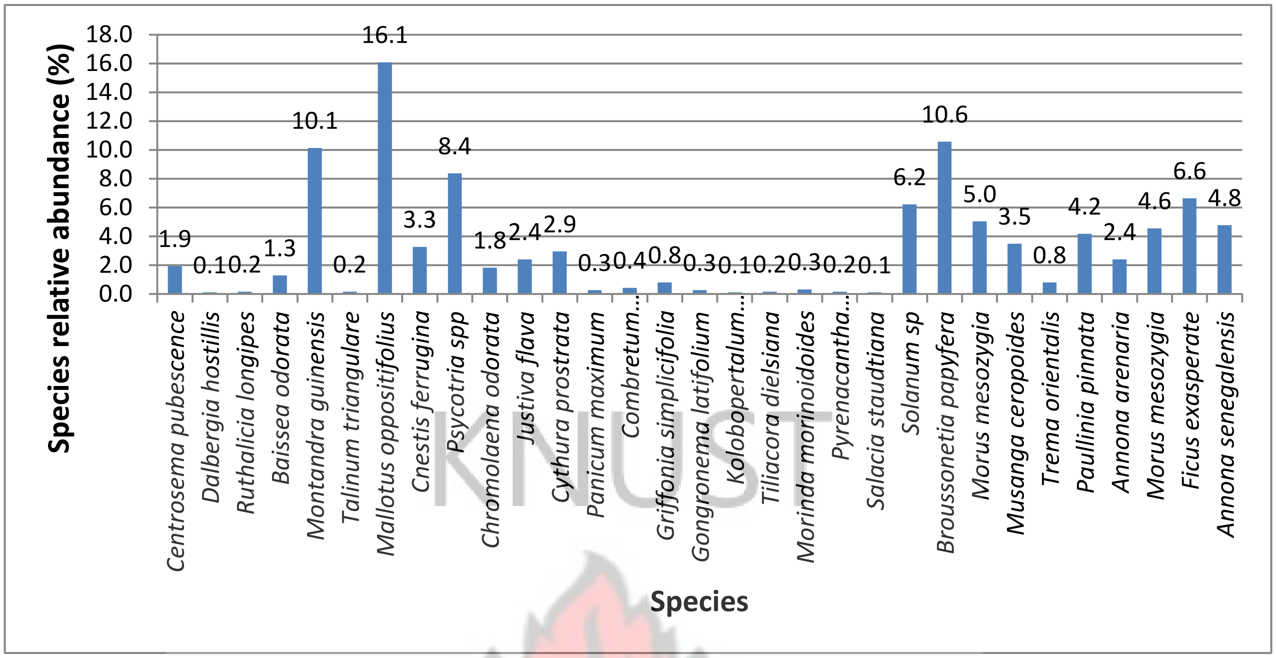

Figure 3: Histogram of relative abundance of seedlings in the study area

The mean population estimates of undergrowth seedlings in the occupied area were 32.3 and 25.5 in the unoccupied area. However, Paired Sample Statistics of bat occupied and unoccupied areas were done using the t-test andthere was no significant difference between the undergrowth seedling compositions in the bat occupied area and the unoccupied area, $t(6) = -0.23$, $p>0.05$ (Table 5b).

Table 5a:Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	occupied	32.3	7	122.8	74.2
	unoccupied	25.5	7	72.3	90.7

Table 5b : Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 2 a. Occupied b. Unoccupied	16.8	78.2	50.5	36.9	98.4	0.23	6	0.034

4.3 Impact of E. helvum on roost trees in UENR

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 6).

Table 6: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 elastica	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 6 and 7).

Table 7: 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	0.20
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* (0.22m^2/ha) contributed the largest basal area (32.94% of the total basal area) whilst *Senna siamea* (0.01m^2/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. 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 6).

Table 8: 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	**14.0**	**7.6**

Estimates of canopy cover were significantly lower in many bat-occupied trees (Table 8) in contrast to their relative larger basal areas and taller tree heights (Tables 7 and 8). 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.

Table 9: 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	34.70
Alstonia boonei	4.1	*
Antiaris toxicaria	10.2	56.80
Azadiractha indica	3.8	65.70
Bombax buonopozense	18.8	*
Ceiba pentandra	8.6	*
Cordia senegalensis	5.6	*
Deloniix regia	10.8	*
Funtumia elastic	4.3	*
Holarrhena floribunda	24.6	54.80
Morinda lucidia	1.5	56.90
Newbouldia laevis	11.7	*
Pycnanthus angolensis	40.6	*
Senna siamea	*	24.90
Sterculia tragacantha	2.4	87.30
Tectona grandis	4.7	*
Total	**184.1**	**381.1**
Mean	**10.8**	**54.4**

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 9).

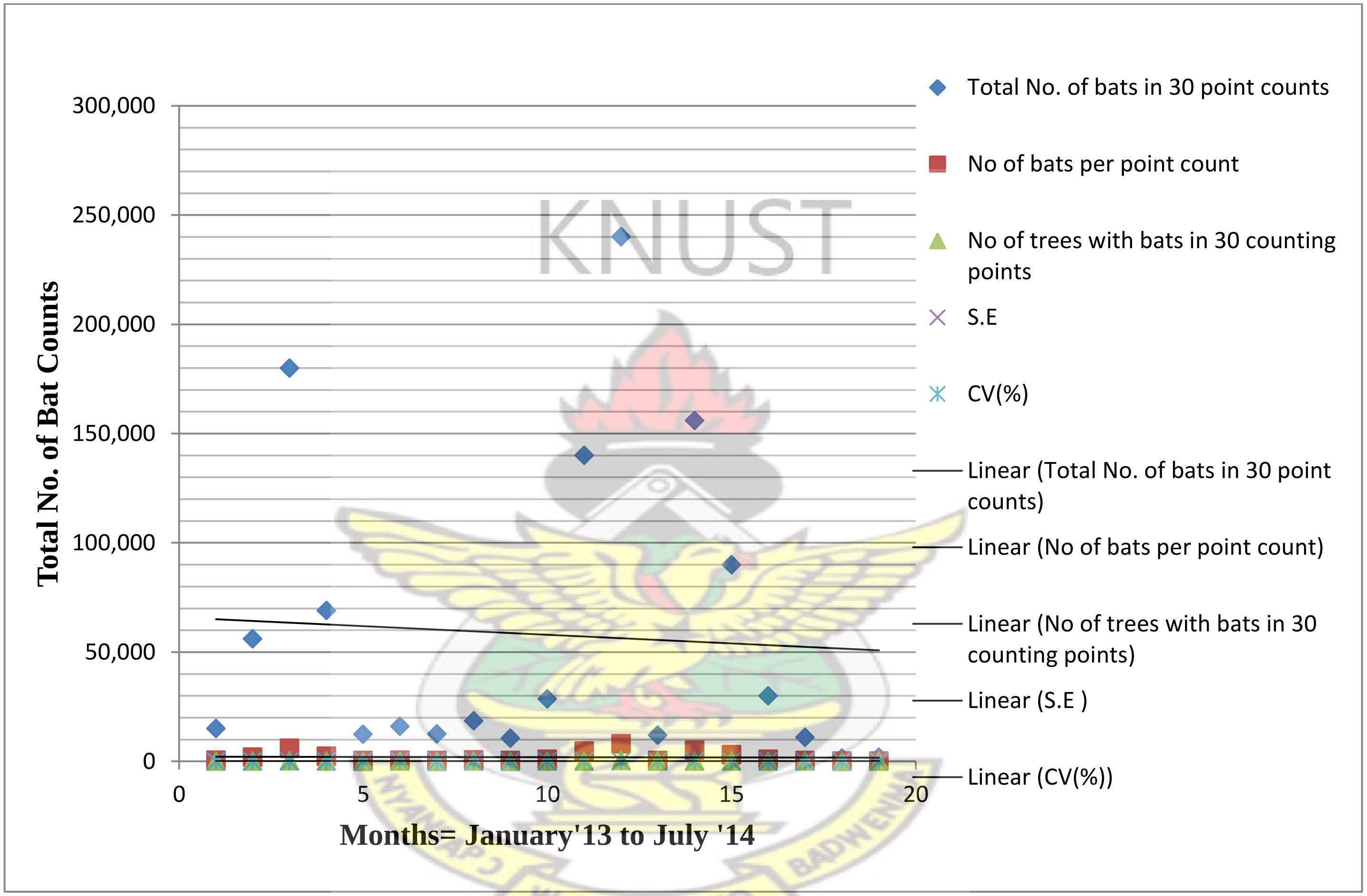

Figure 4: Graph showing the distribution of bat counts per point and tree distribution

The graph in Figure 4 generated five negative linear equations (1 to 5) below. The number of trees with bats varied according to the population, the higher the population, the higher the number of trees occupied by bats. The linear equations below suggest that with increasing months the bat population can decrease with decreasing roosting trees. In all cases, the coefficient of determination R^2 is very low and indicates that other factors could be involved but was not accounted for by the data collected.

$y = -792.9x + 65871$

$R^2 = 0.004$ ……………………………………………………………………Equation 1

2. No. of bats per point count

$y= -0.652x +24.32$

$R^2 =0.223$…………………………………………………………………...Equation 2

3. No. of trees with bats in 30 point counts

$y = -0.451x + 18.35$

$R^2 = 0.165$ ……………………………………………………………………Equation 3

4. SE

$y = -0.601x + 100.6$

$R^2 = 0.002$ …………………………………………………………………..Equation 4

5. CV%

$y = -26.43x + 2195.$

$R^2 = 0.004$ …………………………………………………………………..Equation 5

CHAPTER FIVE

5.0 Discussion

5.1 Fluctuations in Population Size

The population of *E. helvum* in the colony is quite high and deserves conservation priority as far as the status of the fruit bats are concerned ecologically. This study is a bold attempt to generate critical data on the population of bats for monitoring and protecting the roosts site of *Eidolon helvum* on the University campus. The population of *E. helvum* in the colony at the University of Energy and Natural Resources was high in March and December during the study. In this colony, the average cluster sizes followed the same pattern. The population build up may be due to several factors, ranging from food availability, seasonal changes to migration and even disturbance in the colony (Nelson 1965), which this study did not consider.

Frugivorous species of bats in Australia and Africa (Ratcliffe 1932; Nelson 1965; Mutere 1967; Kingdon 1974), and two nectarivorous species in the neotropics (Hayward and Cockrum 1971) migrate seasonally. Since even the most stable tropical environments exhibit marked seasonal fluctuations in food abundance it could provide the impetus for regional movements. *Eidolon helvum* is commonly acknowledged as a migratory species, but the details of its movements are unknown. Where colonies have previously been observed in the Congo (Allen *et al.*, 1971), Equatorial Guinea (Jones 1971, 1972), Ivory Coast (Huggel-Wolf and Huggel-Wolf 1965), Nigeria (Okon 1974; Fayenuwo and Halstead 1974), and Uganda (Mutere 1967, 1980), they undergo seasonal fluctuations in size, reaching their peak of the rains can trigger decline in size of colonies (Mutere, 1967) and (Fayenuwo, *et al.*, 1974 during the latter half of the dry season and numbering in some cases over 1,000,000 individuals (Okon 1974).

If this assertion is true, then the population *E. helvum* in the University of Energy and Natural Resources could follow the same pattern. Some reasons have been adduced to the period of low population counts of *E. helvum* in the study area.

Firstly, parturition which occurs just prior to the onset (Allen, *et al.,* 1971) noted that the Avakubi colony (Congo) reached its minimum in July-August, corresponding with the middle of the wet season and also noted that other colonies fluctuated out of phase with this one. However, they were unable to discern any relation between the fluctuations and suggested that *E. helvum* was a local migrant.

The colony under study also showed the same low pattern of population between May (12,400) to September (10,600) during the study. Factors that triggers the movement of the *E. helvum* between May and September, is not known and needs to be looked into. The *E. helvum* population on the University of Energy and Natural Resources' Wildlife Sanctuary fluctuate monthly throughout the year (Fig 1). However, there is E. helvum presence in the study area all year round.

Secondly, Kingdon, (1997) and Thomas, (1983) documents periods of absence of *E. helvum* from their breeding colony for a period lasting three months and six months in Uganda and Cote d'Ivoire respectively. In eastern part of the Democratic Republic of Congo, Allen, *et al* (1971) recorded concentrated movements in September and again early May to early June, but did not conclude that large migrations take place at definite seasons. In Uganda, Kingdon (1974) reports from a large colony that there is a significant reduction in number by as much as one-third towards the end of the year, this reduction is caused by all non-breeders leaving. Such behavior benefits the breeding colony to reduce competition.

Lastly, the primary habitat of *E. helvum* is tropical forest, but move annually to savannah regions (Thomas 1983). Current observations suggest that fluctuations in food availability are the primary driver of *E. helvum* movement to other habitats (Richter and Cumming 2006). Food (fruit & flower) resources fluctuate seasonally in their habitat, but amplitudes are larger in the savannah than in the forest biome. Wet season surplus in the savannah cannot be fully exploited by resident bat populations and provides opportunities for migration from the forest biome. Any of these reasons could be seen to prevail in this colony and requires further research into.

5.2 Frugivory and Dispersal

E. helvum is a frugivore that feeds on varieties of fruits at their foraging site. In the UENR campus they feed on fruits of *Azadiractha indica*, *Ceiba pentandra*, *Deloniix regia*, *Holarrhena floribunda, and Newbouldia laevis.* They also introduce seeds of other plant species like *Mallotus opposotifolius*, *Solanum erianthum*, *Broussonetia papyrifera*, *Morus mesozygia*, and *Ficus exasperate* into the study area. This dispersal process can lead to heterogeneity in the biodiversity of the study area. It can also produce mixed stands of reproductive plants which can serve as regeneration for succession and forest recovery.

Newbouldia laevis and *Deloniix regia* found among the roost trees and *Broussonetia papyrifera* not found among the roost trees were common seeds found throughout the year in the seed trap (Tables 3a and b).

The influx of seeds from other places was notable; because they constitute fruits eaten by bats during the dry and wet season and can evidently serve as recruitment species for regeneration of the landscape. Majority of these trees fruit from October to December, and they are readily available as food sources for *E. helvum*. *Azadiractha indica, Ceiba pentandra, Deloniix regia, Holarrhena floribunda, Newbouldia laevis,* are all fruit trees that are available in the study area.

The seasonality in the food resources availability and the movement of bats is an indication that food resources can be used to determine the presence of bats in study area. The seed collected in study area was very high in January, (199) March (158) and December (100); these trends coincide with the population in the area. Therefore apart from other unknown factors it can be predicted that food resource availability accounts for the presence of bats in the study area.

The high species diversity of the bat area as compared to the non bat occupied area also attest to the fact that the bats are attracted by available food resources. There are more trees for occupation in the bat occupied area than the area not occupied by bats. This suggests that bats find food resources in areas where there are more trees that produce fruits than areas where there are few trees.

5.3 Impact on trees

E. helvum selects and occupies all trees with larger basal areas (Tables 7 and 8). *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) m^2/ha respectively. These trees are absent in the unoccupied bat zone. The bats also select dense tree cover than open areas (Table 9). Despite the larger mean canopy cover of trees in the areas not occupied by bats, the bats prefer more open areas.

In Table 6, 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 10).

Table 10: Descriptive observations of some trees damaged and type of damage in the study area

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*	215	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	*Deloniix 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

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Throughout the study there were bats presences in the study area. However, their numbers varied with the months. This could be used to study the life cycle of these bats and at the same time help to design appropriate conservation strategies that will focus on bat population at a particular period. Their night flight can attract bat lovers and the high population months could be used to attract viewing bats in flight.

Seed rain of seeds collected indicated that the bats have introduced other plant species into the study area. These plants can for a very long time to come affect the succession of the plants in the study area while improving biodiversity of plants. Introduced species can positively or negatively affect the ecological balance of the study site.

The study showed a negative impact of bats on trees through suppression of flowering, fruiting and defoliation. If this continues the forest cover may not be able to support the increasing population of bats in the study site for some time to come. *E. helvum* feed on the flowers and nectar of many indigenous trees, such as *Azadiractha indica, Ceiba pentandra, Deloniix regia, Holarrhena floribunda, Newbouldia laevis, Solanum erianthum, Milicia excelsa, Broussonetia papyrifera. Ficus exasperata, Morus mesozygia, Triplochiton scleroxylon,* which they also pollinate.

The *E. helvum* population had some effect on the trees but with time, during the period of low population from the roost, May-August; the trees may have time to recover even though the period is short. Trees like *Ceiba pentandra,* and *Triplochiton sp.* had never seen flowers and fruits throughout the study period, even though their counterparts flower and bear fruits.

6.2 Recommendations

These bats have been known to have limited roost sites, so to forestall a reduction in their population and threat to their survival and their ecological significance; very sound management strategies like monitoring of population in relation to the environment is required. Therefore a continuous monitoring of the population through monthly counts is recommended to establish their status in the colony.

In order to evaluate a possible control measures on their population, knowledge of *E. helvums*' biology is essential. Their annual cycle, based on weather patterns, is recommended to check the local movement and migration in Ghana as well as their feeding habits. A fuller knowledge on the ecology and behavior of *E. helvum* may permit an understanding of its selection of roost site. This could permit the identification of potential vulnerable roosting trees that they colonize. There is the need to monitor the interaction between the introduced plants and other plant species in terms of their association to see if they are compatible with the environment.

The presence of the *E. helvum* colony on the campus provides a research tool for further investigations into the ecology/diseases associated with *E. helvum*. It is a huge ecotourism potential for the University to fit into the Green Economy of Ghana, where environmental resources will provide the needed financial inputs through the creation of appropriate platform.

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PLATES

Plate 1: *E. helvum*1-10 or more clusters on tree branches in the Sanctuary

Plate 2a: Seed trap under the canopy **Plate 2b: Seeds dropped on plastic sheet.**

Plate 3: Cluster sizes of bats on the same tree on different months during the study period

Plate 4: Different cluster sizes of E. helvum on different trees

Plate 5: *E. helvum* suppressing leafing, flowering on a *Newbouldia laevis* in the colony

Plate 6: Tree fall, debarking, suppression of leaf formation and flowering on *Tectona grandis* at the roosting site

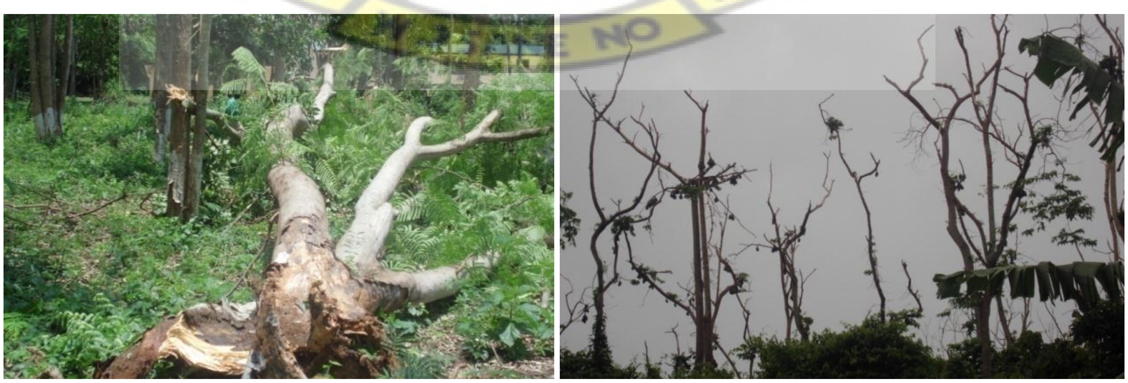


Plate 7: ***Ceiba pentandra*** **at different stages of bat occupation during the study period a. December and b. February respectively**

a

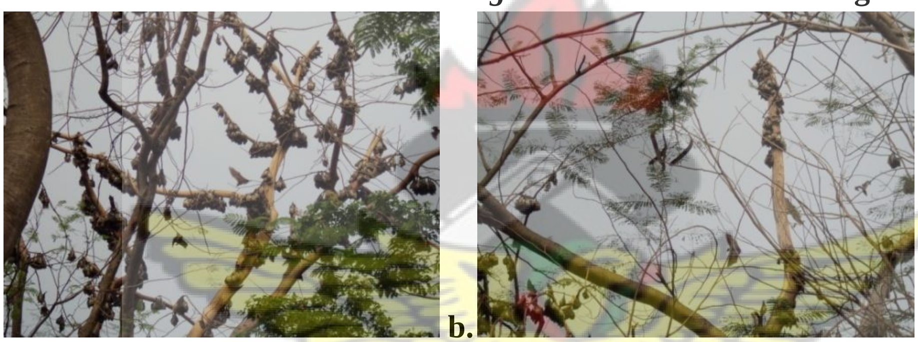
b

Plate 8: ***Tectona grandis*** **in the roosting site**

Plate 9: ***Deloniix regia*** **branches breaking in the roosting site**

Plate 10: Branch breaking of *Deloniix regia* in the roosting site

Plate 11: Debarked stem of *Deloniix regia* with bats in the roosting site



a. b.

Plate 12: *Newbouldia laevis* trees defoliated during bat roosting

APPENDIX

Seasonal Phenological features

1. March-July (long Wet Season)			
Event	**Leaf formation**	**Flowering**	**Fruiting**
Mean No. of Trees	45	23	12
2. August (Short dry season)			
Event	**Leaf formation**	**Flowering**	**Fruiting**
Mean No. of Trees	0	12	6
3. September- November (Long Wet season)			
Event	**Leaf formation**	**Flowering**	**Fruiting**
Mean No. of Trees	60	23	52
4. December-February (Long Dry season)			
Event	**Leaf formation**	**Flowering**	**Fruiting**
Mean No. of Trees	0	20	23