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EFFECTS OF HUMAN DISTURBANCE ON BUTTERFLY DIVERSITY AND ABUNDANCE IN ATEWA RANGE FOREST RANGE FOREST RESERVE, GHANA

BY

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THIS THESIS IS PRESENTED TO THE DEPARTMENT OF ENVIRONMENTAL SCIENCE IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR M.Sc. OF ENVIRONMENTAL SCIENCE

DECEMBER

2012

ACKNOWLEDGEMENT

First of all, I will give thanks to the Almighty God for helping go through such a study successfully. Secondly, my sincere gratitude should go to my supervisor Mr. Addo-Fordjour Patrick for his assistance and guidance given me throughout the study. God richly bless you. I will also thank my mother Agnes Dankwah Adjei, my siblings and friends. The rest goes to the staff of Bobiri Forest Reserve especially Mr. Zap. As well as the managers of FORIG Eastern region and Ashantiregion.

DECLARATION

I hereby declare that the thesis entitled: The effect of human disturbance on Butterfly diversity and abundance in Atewa Range Forest Reserve was done by me with the guidance and supervision by Mr. Addo-Fordjour Patrick. Exceptions are the sections where previous knowledge is stated in which references have been duly provided.

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ABSTRACT

In the face of increasing human disturbance in tropical forests, it is important to understand how disturbance influence species assemblages. Though butterflies respond dramatically to disturbance, only a limited number of studies have examined the effects of varying levels of disturbance intensities on butterfly diversity and abundance. This study was conducted in Atewa Range Forest Reserve (ARFR) to determine butterfly diversity and abundance in forests which differed in plant diversity and structure as a result of different disturbance intensities (i.e. non-disturbed, moderately disturbed and heavily disturbed forests). Vegetation characteristics and butterflies were sampled within ten 50 m × 50 m plots in each forest type. The results revealed that butterfly diversity and abundance were similar in the non-disturbed and moderately disturbed forests although they were significantly lower in the highly disturbed forest ($p < 0.001$). There were significant relationships between vegetation characteristics, and butterfly diversity and abundance ($p < 0.001$) which indicate that changes in vegetation following human disturbance influenced butterfly assemblages in the area. Based on butterfly species composition in the forest types, certain butterfly species were classified as disturbance-avoiding, moderately disturbance-adapted and highly disturbance-adapted species. The findings of the study indicated that butterfly diversity and abundance were comparable in the non-disturbed and moderately disturbed forests but significantly lower in the heavily disturbed forest. Thus, intermediate form of human disturbance could maintain butterfly diversity and abundance in the forest reserve. Consequently, management efforts aimed at butterfly conservation should be geared towards protecting forests from excessive human disturbances; selective logging could be preferable.

TABLE OF CONTENT

CHAPTER 3

CHAPTER 4

CHAPTER 5

CHAPTER 6

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

INTRODUCTION

The tropical forest ecosystem is home to many animal species, including a lot of threatened and endangered species in the world. Butterflies depend on the forest for survival due to the provision of favourable habitats and resources such as cover, camouflage, litter, moderate temperature and humidity, and food sources (Humpden and Nathan, 2010). Tropical forests also support most endemic butterfly species (Hill, 1999). Given the important role tropical forest ecosystems play in maintaining butterfly diversity, any disturbance agents that impacts forest structure and composition may also exert enormous pressure on butterfly assemblages in the tropics. In fact, butterflies are considered as a useful insect group in environmental monitoring and evaluation (Brown,1997; Larsen, 2005) due to their sensitivity to anthropogenic disturbance(Koh,2007).

As butterflies may respond dramatically to disturbances in the forest, it is imperative that regular ecological studies are conducted to determine the effects of various human disturbances on them. Such studies may provide information about the conservation needs of the butterfly species, and indirectly reflect the needs for protection of other species within the ecosystem. Thus, studies relating to human disturbances to butterfly assemblage could be useful for conservation (Gardner*et al*.,2009). While many studies have suggested decreasing trends of butterfly diversity following disturbance, reports of increase in butterfly diversity are not unknown in the ecological literature (Hill, 1999;Hamer *et al*.,2003). Butterfly diversity and abundance may track changes in plant diversity and forest structure resulting from different disturbance regimes such as logging, farming and mining. Differences in intensity of disturbance may lead to differential effects on plant community diversity and structure, with significant implications for butterfly composition and abundance. However, there is little information about how differences in disturbance intensity influence butterfly diversity and abundance in most tropical forests.

PROBLEM STATEMENT AND JUSTIFICATION

The Atewa Range Forest Reserve (ARFR) is an important forest in Ghana and West Africa because it harbours many endemic and rare species including several endemic butterfly species (McCullough *et al*., 2007). Many of the endemic butterfly species in Ghana and West Africa as a whole are found in the ARFR. Consequently, the ARFR has been designated as a Globally Significant Biodiversity Area (Abu-Juam *et al*., 2003). Biodiversity in the Atewa Forest Reserve is threatened by different forms of human disturbances. Major anthropogenic activities such as bauxite mining, farming and logging are currently taking place in the forest reserve. Though some studies have been conducted in the ARFR (Larsen,2006;McCullough *et al*., 2007), which demonstrate the significance of the forest reserve in maintaining butterfly diversity in West Africa, none of these examined the impact of human disturbance on butterflies in the area. As a result, there is no information on the influence of human disturbances on the patterns of butterfly abundance and diversity in the forest.

MAIN OBJECTIVE

The purpose of this study was to determine the impact of human disturbance on butterfly diversity and abundance in the Atewa Range Forest Reserve, Ghana.

SPECIFIC OBJECTIVES

The specific objectives were to:

1. determine plant diversity and community structure of forests with different disturbance intensities,
2. identify butterfly species in the forest types,
3. determine the abundance of butterfly species in the forest types, and
4. determine the effects of plant diversity and forest structure on butterfly diversity and abundance.

The following research questions were addressed by the study: (a) Do butterfly diversity and abundance differ in forests differing in disturbance intensities? (b) Does butterfly composition differ in forests of differing in disturbance intensities? (c) Do changes in vegetation characteristics affect butterfly diversity and structure?

CHAPTER TWO

LITERATURE REVIEW

Butterflydiversity

Insects constitute about 70% of all life forms on the earth (Scott, 1999). Approximately 18,000 butterfly species exist on the earth (Emmel and Larsen, 1996).Africa is second only to the Neotropical Region as the world's richest place for butterflies. About 3,600 butterfly species have been identified in the Afrotropical Region, which represents 20% of the butterflies across the world (Larsen,2006). Butterfly diversity of Africa is wide spread from one region to another (Emmel and Larsen, 1996).About 890 butterfly species are found in Ghana (Larsen, 2006). These species are spread in families of Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae and Pieridae (Larsen, 2006; McCullough *et al.*, 2007). Butterfly species in Ghana are distributed in the dry coastal region, drier tropical deciduous forest, evergreen rainforest and tropical semi deciduous forest (Larsen, 2006). The evergreen rainforest and the tropical deciduous forests have abundant rainfall and more widespread butterfly species (Larsen,2006). Thus Ghana's butterflies are overwhelmingly forest dwelling, where the forest butterflies refuse to migrate into non forest area after their adaptation to the forest. The butterflies dwell at such places due to availability of food resource from flower nectar. Others can get easily access to pollen, tree sap, rotting fruit, and dung dissolved minerals in wet sand or dirt for nourishment (Brakefield *et al.*, 1984). Also butterflies are threatened especially in the early stage by parasitoids or their predators, and they are able to defend themselves by means of chemicals which are of plants origin (Warren, 1998). In view of this, savanna areas or open habitats in Ghana are with less butterfly species (Larsen, 2006). Therefore in general, butterfly species are more widespread at most places with forest (Griffis *et al.*,2001).The forest reserves such as Atewa range forest and Aburi botanical Gardens located in the Eastern part of Ghana have many butterfly species

(Larsen, 2006). This is because they have attributes of forest that support lives of butterflies (Brown,1997).

More than 700 different species of butterfly are now estimated to occur on the Atewa Range (Larsen 2006, McCullough *et al*., 2007). This is more than in any other single locality in Ghana, and for that matter anywhere in Africa west of the Dahomey Gap (Larsen, 2006). In terms of endemicity, there are 16 endemic species in Africa, where two species (*Euphaedramariaechristinae*(Hecq and Joly, 2003) and *Ceratriculuamaesseni*(Joly, 2003)) are endemic to Ghana sub-region.The remaining 14 species are endemic to West Africa sub-region as well as Atewa forest. In all, Atewa possess at least 66% of the known West Africa endemic species. Thus, ten of such endemic species are so far known in Ghana only and are mostly from Atewa (McCullough *et al*., 2007). Examples of the endemic species to Atewa forest are *Mylothrisatewa*(Suffert, 1904), *Papilioantimachus* (Drury, 1782) and *Acraea kibi*(Larsen, 1998) Larsen (2005), *Tetrarhanis baralingam*(Larsen, 1998),*NeaveiaLamboni* (*Druce, 1910)* and *Bicyclusauricruda (*Butler, 1868) Larsen (2006) andMcCullough*et al*. (2007). There is the presence of a large number of very rare butterfly species in Atewa which include some rare species in Africa (McCullough *et al*., 2007). Almost half of rare species in Africa can be positively found either exclusively from Atewa (Larsen, 2005;McCullough *et al*., 2007).

Ecological and economic importance of butterflies

Insects contribute about 60% of the animal population worldwide (Erhardt, 1985). Among the insects, butterflies occupy an important position in the ecosystem (Triple *et al*., 2006), showing significant roles (Griffis *et al*., 2001). Among the significant roles of the butterfly in the ecosystem is pollination associated with regeneration of forest (Bailowitz and Sitter,2005). At the larvae stage during their life cycle, the caterpillar (cocoon) spins on plants which results in silk production which can be used for making clothing (Mader,2003). However, the caterpillars feed ferociously on leaves and cause serious damage to plants especially the citrus trees (Bailowitz and Sitter, 2005).The cutworm which is butterfly larvae destroys the roots of many different crops including cabbage, corn, cotton and tomatoes. Some butterfly species are also considered destructive. For example, butterflies of the cabbage feed and damage cabbages, broccots and other related crops (Pyle,1992). Other butterfly species such as the giant Swallowtail and some species of Papilio feed on citrus and sometimes destroy commercial citrus crops (Pyle,1992). In view of global destruction of tropical forest, the measurement of butterfly species diversity is critically important to the understanding of the state of tropical forest communities and conversation (Devries, 1997). Therefore in many regions of the world, Lepidoptera are widely accepted as ecological indicators of ecosystem health (Rosenberg *et al*.,1986; New *et al*., 1995;Beccaloni and Gaston, 1995; Oostermeijer and van Swaay, 1998). This important role of butterflies is possible, due to many of their physiological tolerances, such as light, temperature and habitat requirements (Warren, 1998; Erhardt and Thomas, 1995;Oostermeijer and van Swaay, 1998) and correlations with changes in ecosystem conditions (Bowman *et al*.,1990; Pollard *et al*.,1998). In addition butterflies are small and have high reproduction rates and are at low trophic levels that allow them to quickly respond to environmental stress (Griffis *et al*.,2001). Apart from their function as indicator for environmental changes, butterflies are used to monitor changes in the abundance and distribution of other species, both plants and animals (Thomas,2005). The signaling of other species in ecosystem is by either their presence or abundance (Landre *et al*., 1988; Simberloff,1998). In the forest ecosystem, many butterflies specialize on a specific plant species for oviposition or feeding (Ehrlich, 1995; Oostermeijer and van Swaay, 1998). Due to such behavior and their aesthetic appearance, they attract tourists to tourist centers (Griffis *et al*., 2001).

Factors affecting butterfly diversity and abundance

Climatic factors

Butterfly diversity and abundance are influenced by climatic conditions such as sunshine and temperature (Kremen,1992). Butterfly diversity is said to be strongly influenced by the amount of energy available during favorable season (Grimaldi and Engel, 2005). This is due to the extreme ectothermic behavior of adult butterflies which depends on both warm air and direct sunshine (Gibson *et al*., 1992). This is supported by the species-energy hypothesis which states that diversity within terrestrial habitats is more or less directly controlled by the amount of solar energy available, and declines with latitude as input from the sun to the earth's surface decline and this affect species diversity (Wright, 1983). Butterfly diversity and distribution are affected by low temperature (Stefanescu*et al*., 2003). The metabolism of butterfly depends strongly on climatic condition (Kukal*et al*., 1991; Watt 2003; Dennis and Sparks, 2006). Therefore warmer temperatures instead of low temperature directly benefit butterflies because, it enables individuals may be to spend more time acquiring resources (Turner e*t al*., 1987; Boggs and Murphy, 1997). Thus many butterfly species are limited by tolerance to minimum temperature (Kukal*et al*., 1991). On the other hand, the release and accumulation of excessive temperature through global warming affect the diversity, abundance and distribution of butterflies (Microsoft Encarta, 2008). The global warming changes the quantity and quality of habitats available to species and the climate envelope of butterfly species, the range of temperature, rainfall and other climate related parameters in which the butterfly species exist (James *et al*., 2003).

Several environmental factors including climate affects resource availability and habitat diversity (Currie,1991). This means that climate does not only affect the butterflies directly but also affect resource availability and habitat diversity at their disposal (Connell,1978). Rainfall and temperature affect butterfly assemblage in many parts of the world especially in the temperate regions (Pollard and Yates, 1993). The effects of rainfall and temperature on butterfly diversity is less pronounced in the tropical regions because they experience little variation or changes in temperature and rainfall which are most important factors affecting wet and dry seasons (Owen 1971; Spitzer *et al*., 1993). Changes in the temperature and rainfall could affect the diversity and abundance of butterflies (Kremen, 1992). For instance, the distribution and abundance of butterflies was found to reduce significantly due to less rainfall and high temperature, but increased during abundant rainfall (Hill and Hamer, 2004). The rainfall affects the butterflies due to their positive effects on the vegetation growth which serves as resource for butterflies (Hill, 1999).

Human disturbance

The effect of human disturbance on butterfly diversity and abundance is not based on the disturbance affecting the butterflies directly. Rather the disturbance on the forest ecosystem which results in large scale modification and destruction of the forest (Fahrig, 2003). This leads to colossal losses of forest biodiversity which may affect butterfly species diversity and abundance (Kremen, 1992; Spitzer *et al*., 1993; Griffis *et al*., 2001). Many disturbances affect butterfly diversity and abundance by removal of the larva of butterflies (Culin, 1997; Solomon *et al*., 2004).

Habitat quality

Butterflies feed on nectar from flowers and other plants sources such as pollen, trees sap and rotten fruits (Brakefield *et al*., 1984). In their normal activities, they need conditions of temperature as climatic condition for their survival (Currie,1991). The conditions for survival for butterflies are existed in their habitat structure which is not disturbed (DeVries *et al*., 1997), eventhough, butterflies are extremely sensitive to changes in vegetation composition and structure (Dennis *et al*., 2006). As butterflies are found in the forest, they obtain conditions for their survival, and when the conditions for butterflies in the forest ecosystem changes this affect their diversity (Wettstein and Schmid, 1999). Human disturbance on the forest cause destruction and deterioration of natural habitat of butterflies which even leads tonaturalhabitat being loss (DeVries *et al*., 1997). This habitat loss and fragmentation is the breaking apart of habitat which leads to loss of biodiversity (Hutchison, 1975). The loss of habitat through fragmentation removes some specific plants species that provide the trophic resources for caterpillars of butterflies as well as nectar which also supply the adults with food to survive (Brown, 1997). The loss of biodiversity as result of destruction of habitat also affects conditions that affect species (Webster, 1979). Therefore habitats of butterflies that are destroyed affect conditions that support the survival of them. Examples of them are climate (Currie, 1991), rainfall and light (Guison *et al*.,1995). On the other hand, the habitats which are mostly vegetation where butterflies dwell have good composition of plant species (Gaston,1992). Their threat both in the early stages by parasitoid and adult stage by predators, diseases and environmental condition are reduced with good habitat. For example parasitoids and predators are defended by butterflies based on chemicals released from body parts which are obtained from plants toxins and they use them instead of their own defense (Nishida and Ritsuo, 2002) and the chemicals obtained for their defense are plants based which in turn are based on the habitat with enough plants species. The vegetation can also play an important role for butterfly survival offering particular structural elements for sun-basking, mating and even suitable microclimates production (Dover *et al*., 1997). For example, the act of grazing by farm animals has threatened many species of plants and this in turn affects the butterfly species richness.The continuous grazing result in year-to-year variation in temperature that kills certain butterfly species (Hoyle and James, 2005). The continuous grazing resulting in temperature variation can lead to extinction of whole populations of certain butterfly species (James *et al*., 2003). It is believed that many butterflies adapted to migration as a result of habitat destruction and loss because their habitat that was forest became semi-arid areas where breeding seasons are short (Southwood, 1962). Generally, the relation between butterfly diversity and distribution is in relation to the habitat suitability (Brown, 1984) which is based on variety of plant resources (Gaston, 1992).

Competition

Butterflies play crucial role in food chain as secondary producers, and they are affected by consumers during energy flow through food chain (Mader, 2003).This affects the butterfly diversity and abundance in its habitat (Bailowitz and Sitter, 1995). The loss of butterflies occurs mostly when the eggs are eaten and the hatched eggs into larva are fed on by birds and other species (Thomas,2005). There have been many explanations through theories by many authors in terms of competition and its influence on species diversity (Paine, 1971). As species diversity is dependent on competition among species occupying a habitat, where competition leads to predation among species (Pianka, 1966). The butterfly diversity is intensely affected especially during limited resources, and when there are many predators (Fahrig,2003). Also high species diversity in a particular habitat may lead to intense competition which brings niche restriction (Dobzhansky,1950; MacArthur and Wilson, 1967), example is predation (Fahrig, 2003). The predation may affect the adults to breed because parts of the mates are reduced during the predation. The larva that continue the generations are fed on by consumers to create a gap in the growth cycle which affect the diversity (Mader, 2003).

CHAPTER THREE

METHODOLOGY

Description of study area

The Atewa Range Forest Reserve (ARFR) is located betweenlatitude 0^{o}, 36.00' W and latitude 6^{o} 10.00' N) is one of the most important and largest forests in Ghana (Fig. 1). It covers a total area of 23,663 ha and stretches over several towns and villages in the Eastern Region of Ghana. Part of the forest has been disturbed by various human activities such as farming, logging and mining. The reserve has distinctive upland forestvegetation which is rich in biological resourcesand bauxite deposits (McCullough *et al*., 2007).

The study was conducted in three forest types determined by their different intensities of human disturbance (Addo-Fordjour *et al*., 2012) from January to June 2011. The disturbance intensities which were calculated as the ratio of the number of cut stumps to total number of individual trees including cut stumps were based onAddo-Fordjour *et al*., 2012- the non-disturbed: 0; moderately disturbed: 0.23; heavily disturbed: 0.65. The heavily disturbed forest has undergone major disturbances in the form of logging and faming activities, whereas only selective logging activities have taken place in the moderately disturbed forest. The non-disturbed forest, which has been protected from human activities, remains free from human disturbance (Addo-Fordjour *et al*., 2012)

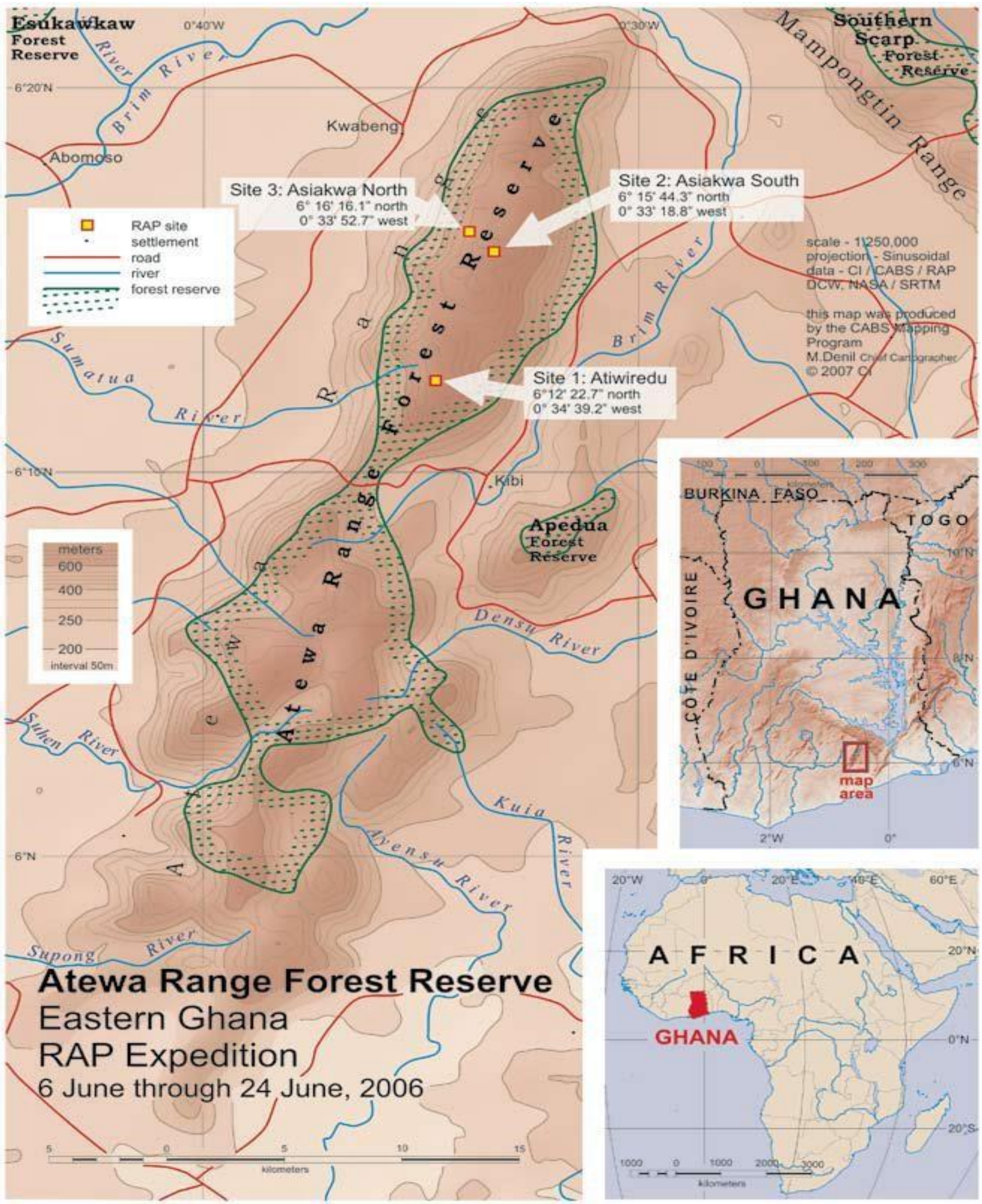

Fig. 1.Map of Atewa Range Forest Reserve (McCullough *et al*., 2007)

Vegetation sampling

Each forest type was represented by two forest stands, and within each stand five 50 m × 50 m plots were demarcated for vegetation sampling. Thus a total of ten 50 m × 50 m plots were studied in each forest type. In the plots, trees and shrubs with diameter at breast height (dbh) ≥ 10 cm were identified and counted, whereas lianas with dbh ≥ 1 cm were enumerated. Liana diameter was measured at 1.3 m from the soil surface. Diameter of plants was measured with a diameter tape and canopy cover of the plots was determined by a spherical densitometer. Plants were identified with the assistance of a plant taxonomist, and cross-checked with local manuals and FlorasArbonnier(2004),Hawthorne (1990), Hawthorneand Jongkind (2006), Poorter*et al*.(2004). All identifications were confirmed at the KNUST, Kumasi and the Forestry Commission, Kumasi herbaria.Vegetation sampling took place from January to March 2011.

Butterfly sampling

Although most butterfly studies use line transect for sampling, the quadrat sampling method was employed in this study because it allows for greater sampling effort in a given location (Levanoni*et al*., 2011). Butterflies were therefore, sampled within the 50 m × 50 m plots used for the vegetation sampling.

Fruit baited traps were used to trap butterflies in the study areas. In each plot, two traps, stocked with bait made by mixing of over-ripped banana mashed with fermented palm wine, were hanged on trees at the canopy and under-storey layers(DeVries *et al*., 1997). The trap was inspected for butterflies and re-baited every 24 hours between 7:00 and 12:00 h. Butterflies which are not fruit-feeding as well as fast or swift moving types were trapped with a sweep net during the same period of the day. A total of 70 sampling days were used for the study (between April and June 2011). Butterflies were identified by entomologists, and with recourse to zoological specimens at the Bobiri Forest Reserve butterfly sanctuary, and identification guide(Larsen, 2005).

Plate 1. *Papilio cyproeofila*(Butler, 1868) surrounded by white *Belenois* sp.identified in Atewa Range Forest Reserve

Plate 2. *Mylothis atewa*(Berber, 1980) identified in Atewa Range Forest Reserve

Plate 3. *Charaxes* sp.identified in Atewa Range Forest Reserve

Plate 4.*Kallamoides rumia*(Fox, 1968)identified in Atewa Range Forest Reserve

Data analyses

Diversity of plant and butterfly species in each of the three forest types were computed using the Shannon diversity indexfollowing the method of Magurran (1988). Plant diversity (species richness and Shannon diversity) and forest structure (abundance and canopy cover) were compared between the forest types using the analysis of variance (ANOVA). To determine the effects of forest type (used as surrogates of disturbance intensity) on butterfly species richness, diversity and abundance, ANOVA was conducted. Fisher's LSD pair wise comparison tests were used to determine differences of means among forest types. Normality and homogeneity of variance tests were conducted on the data prior to the ANOVA. All the data were normally distributed except butterfly abundance and species richness which were square root transformed.

The ANOVA was conducted at a significance level of 5 % using the 11^{th} edition of the GenStat Software 2011 version (VSN International Ltd, Hemel Hempstead, UK).

Similarity in butterfly species composition among the forest types was determined according to the Sørensen similarity index, S (Magurran, 2004):

$$S = 2C/ (a+b)$$

Where C = number of species of the two forest types being compared share in common

a = number of species in forest type A b

= number of species in forest type B

In order to determine vegetation characteristics influencing butterfly abundance and diversity, stepwise multiple regression analysis was performed between butterfly diversity (Shannon diversity and species richness) and abundance, and vegetation characteristics (plant species richness, Shannon diversity, plant abundance, canopy cover). The forward selection procedure was used to eliminate redundant vegetation variables and also reduce collinearity. The stepwise regression analysis was conducted at a significance level of 5 % using the Minitab 15 software (Minitab Inc. 2011).

CHAPTER FOUR RESULTS

Plant diversity and forest structure

The vegetation characteristics of the three forests types are presented in Table 1. Overall plant species richness was highest in the non-disturbed forest and lowest in highly disturbed forest (Table 1). Mean species richness and diversity of plant species decreased significantly (P = 0.005 and 0.004 respectively) with increasing disturbance intensity. Similarly, mean plant abundance and canopy cover per plot decreased significantly from the non-disturbed forest through the intermediately disturbed forest to the heavily disturbed forest (p = 0.002 and 0.001 respectively).

Table 1.Vegetation characteristicsin the non-disturbed (NDF), moderately disturbed (MDF) and highly disturbed (HDF) forests in the Atewa Range Forest Reserve(± Standard error of mean)

Parameters	NDF	MDF	HDF
Total species richness	107.00	59.00	33.00
Mean species richness/plot	$23.50^{a} \pm 1.23$	$12.17^{b} \pm 1.00$	$6.25^{c} \pm 0.47$
Shannon diversity	$2.88^{a} \pm 0.10$	$1.99^{b} \pm 0.12$	$1.12^{c} \pm 0.11$
Mean plant abundance/plot	$51.31^{a} \pm 1.64$	$30.45^{b} \pm 2.12$	$17.44^{c} \pm 2.00$
Mean canopy cover/plot (%)	$86.74^{a} \pm 2.42$	$68.55^{b} \pm 3.32$	$44.72^{c} \pm 2.26$
Total number of individuals	476	382	220

Means in the same row that have different superscripts are significantly different at α = 5 %.

Butterfly diversity

Species richness, composition and abundance of butterflies in the three types of forests in the Atewa Range Forest Reserve are shown in Table 2. A total of 79 species of butterflies belonging to 29 genera and 4 families were sampled in the 7.5 hectare forest (Table 2; Plates 1, 2, 3&4). Sixty four species (27 genera and 4 families) of butterflies were identified in the nondisturbed forest. In the moderately disturbed forest, 59 species (27 generaand 4 families) were identified, while the highly disturbed forest recorded 48 species (22 genera and 4 families).

Table 2. Species richness, composition and abundance of butterflies in non-disturbed (NDF), moderately disturbed (MDF) and highly disturbed (HDF) forests in the Atewa Range Forest Reserve

	Abundance			
Family/Species	NDF	MDF	HDF	Total
LYCAENIDAE				
Aslauga marginalis(Kirby, 1890)	11	5	0	16
Aslauga sp.	2	0	0	2
Neaveialamborni(Druce, 1910)	15	17	10	42
Tetrarhanis baralingam(Larsen, 1998)	14	5	5	24
TOTAL	42	27	15	84
NYMPHALIDAE				
*Acraeaalcino*e (Felder&Felder, 1865)	20	4	7	31
Acraea epaea(Cramer, 1779)	16	13	22	51
Acraeavestalis (Felder&Felder, 1865)	25	1	9	35
Aterica galene (Brown, 1776)	0	10	0	10
Bebeariaaurota (Hewitson, 1869)	0	2	0	2
Bebeariaphatasina (Staudinger, 1891)	9	1	1	11
Bebearia paludicola(Holmes, 1880)	0	2	0	2
Bebeariasophus (Fabricius, 1793)	26	8	12	46
Bebeariatentyris (Hewitson, 1866)	0	2	0	2
Bebeariazonara (Butler, 1871)	4	12	2	18
Bicyclus auricruda (Butler, 1868)	24	11	13	48
Bicyclusdorothea (Cramer, 1779)	8	5	4	17
Bicyclusephorus (Weymer, 1892)	1	5	0	6
Bicyclusistaris (Plotz, 1880)	2	0	0	2

Bicyclusnobilis (Aurivillius, 1893)	0	2	1	3
Bicyclusmadetes (Condanim, 1986)	16	6	9	31
Bicyclussafitza (Westwood, 1850)	6	16	9	31
Bicyclussangmelinae (Condanim, 1963)	2	14	8	24
Bicyclustaenias(Hewitson, 1877)	4	14	1	19
Charaxesbrutus (Butler, 1869)	27	15	14	56
Charaxescedreatis (Hewitson, 1874)	14	0	2	16
Charaxes Cynthia (Butler, 1869)	11	4	6	21
Charaxes eupale (Drury, 1782)	0	3	0	3

Table 2 cont'd.

Family/Species	Abundance NDF	MDF	HDF	Total
NYMPHALIDAE				
Charaxes sp. 1	0	2	0	2
Charaxes sp. 2	0	2	0	2
Charaxeszelica (Butler, 1869)	6	0	4	10
Cymathoeegesta (Cramer, 1775)	4	3	0	7
CyrestisCamillus (Fabricius, 1781)	1	11	0	12
Danauschrysippus (Linnaaeus, 1758)	23	22	5	50
*Euphaedraedwardsi (*Van der Hoven, 1845)	2	13	2	17
Euphaedraeupalus (Fabricius, 1781)	11	0	0	11
Euphaedrahebes (Hecq, 1980)	0	0	8	8
Euphaedrajanetta (Butler, 1866)	4	11	2	17
Euphaedraperseis(Drury, 1773)	8	1	0	9
Euphaedraphaethusa (Butler, 1866)	0	4	8	12
Euripheneamicia (Aurivillius, 1892)	2	3	0	5
Euripheneampedusa .(Hewitson, 1866)	8	0	1	9
Euriphene aridatha.(Hewitson, 1866)	2	0	0	2
Euriphenebarombina (Aurivillius, 1894)	1	3	0	4
Euripheneatossa.(Hewitson, 1868)	2	0	0	2
Euriphene sp.	4	0	1	5
Hypolimnasbolina (Larsen, 1998)	5	2	7	14

Hypolimnas salmacis (Drury, 1773)	46	18	14	78
Junonia orithya (Linnaeus, 1758)	16	4	2	22
Junoniaterea (Druce, 1773)	49	37	32	118
Kallimoidesrumia (Fox, 1849)	15	10	18	43
Melanitis leda (Linnaeus, 1758)	0	0	6	6
Palla decius (Cramer, 1777)	0	4	1	5
Palla publius (van Someren, 1975)	0	0	5	5
Pallaussheri(Hall, 1919)	3	0	4	7
Protogoniomorphaparhassus (Drury, 1782)	7	5	0	12
Pseudacraeaeurytus(Linnaeus, 1758)	24	12	15	51
TOTAL	458	317	255	1030
PAPILIONIDAE				
Graphiumlatreillianus(Godart,1819)	13	4	9	26
Graphium leonidas (Fabricius, 1793)	0	10	0	10
Papilioantimachus (Drury, 1782)	9	0	0	9
Papiliochrapkowskoides (Forace, 1952)	7	0	0	7
Papiliocynorta (Fibricius, 1793)	15	8	11	34
Papilio cyproeofila (Butler, 1868)	35	30	26	91
Papiliodardanus (Poulton, 1924)	12	15	14	41
Papiliomenestheus (Drury, 1773)	8	1	0	9

Table 2 cont'd.

Family/Species	Abundance NDF	MDF	HDF	Total
PAPILIONIDAE				
Papilionireus (Linnaeus, 1758)	10	7	0	17
Papilionobicea (Suffert, 1904)	3	2	1	6
Papiliozenobia (Fibricius, 1775)	1	0	0	1
TOTAL	113	77	61	251
PIERIDAE				
Appiasphaola (Doubleday, 1847)	15	18	0	33
Belenoisalcino (Grose-Smith,1889)	2	1	1	4
Belenoisaurota (Fibricius, 1793)	15	5	4	24
Belenois creona (Cramer, 1776)	1	0	0	1
Belenoishedyle (Cramer, 1777)	6	9	7	22
Eurema brigitta(Cramer, 1780)	13	4	3	20

Eurema sp.	0	4	0	4
Mylothrisatewa (Berber, 1980)	38	29	23	90
Mylothrisschumanni (Suffert, 1904)	4	0	0	4
Nepheroniapharis (Boisduval, 1836)	7	0	5	12
Nepheroniathalassina(Boisduval, 1836)	43	26	23	92
Pseudopontia paradoxa (R. Felder, 1869)	1	0	0	1
TOTAL	145	96	66	307

SUM OF ALL species = 1672

Mean species richness, diversity and abundance of butterflies are shown in Table 3.Mean species richness, diversity and abundance of butterflies was high in non- disturbed forest, followed by moderately disturbed forest and least in highly disturbed forest. In all, mean species richness and diversity of butterflies per plot decreased significantly among the forest types ($P < 0.001$; Table 3).

Table 3.Butterfly diversity and abundance in the non-disturbed (NDF), moderately disturbed (MDF) and highly disturbed (HDF) forests in the Atewa Range Forest Reserve (± Standard error of mean)

Attribute	Mean		
	NDF	MDF	HDF
Species richness	$36.60^{a}\pm2.09$	$29.50^{b}\pm1.06$	$23.50^{c}\pm0.73$
Diversity	$3.36^{a}\pm0.05$	$3.27^{a}\pm0.04$	$2.93^{b}\pm0.03$
Abundance	$75.80\,^{a}\pm4.66$	$51.70^{a}\pm1.08$	$39.70\,^{b}\pm1.93$

Means in the same row that have different superscripts are significantly different at α = 5 %.

Butterfly species composition

Butterfly species composition was highest between the non-disturbed and moderately disturbed forests (S = 0.75), and least between the moderately disturbed and heavily disturbed forests (S = 0.67) (Table 4).

Table 4. Similarity coefficient of Butterfly species between non-disturbed (NDF), moderately disturbed (MDF) and highly disturbed (HDF) forests in the Atewa Range Forest Reserve

Forest type	NDF	MDF	HDF
NDF	-	0.75	0.74
MDF	-	-	0.67

There were some butterfly species that occurred in only one forest type but not the others. For instance, species such as *Aslauga* sp., *Belenois creona*, *Papilio zenobia*, *Euriphene aridatha*, *Papilio chrapkowskoides, and Pseudopontia paradoxa* were recorded only in the non-disturbed forest. *Graphium leonidas*, *Euremia sp.*, *Charaxes eupale, Charaxes*sp. 1,*Charaxes*sp. 2, *Aterica galena* and *Bebearia paludicola* occurred only in moderately disturbed forest whereas *Melanitis leda* and *Palla publius* were distributed only in the highly disturbed forest (Table 2).

Butterfly abundance

A total of 1672 individual butterflies were sampled in the study (Table 2). There were more individual butterflies sampled in the non-disturbed forest (758 individuals) compared to the moderately disturbed forest (517 individuals) and highly disturbed forest (397 individuals). Mean butterfly abundance per plot was the same for the non-disturbed and moderately disturbed forests, although each was significantly higher than that of highly disturbed forest ($P < 0.001$;

Table 3).

Regardless of forest type, *Junoniaterea*, *Papilio cyproeofila and Nepheronia thalassina*, were the most dominant butterfly species in the forest reserve (Table 2). *J. terea, Hypolimnas salmacis, Mylothris atewa and Nepheronia thalassina* were the most abundant species in the non-disturbed forest. In the moderately disturbed forest, *J. terea, M. atewa and P. cyproeofil*a were the most abundant species. Two species namely, *J. terea, and P. cyproeofil*a were the most abundant species in the highly-disturbed forest. The least common butterfly species were *Melanitis leda*, *Belenois creona*, *P. zenobia*and *Pseudopontia paradoxa*. All these species appeared only once during the sampling.

Influence of vegetation characteristics on butterfly diversity and abundance

Butterfly species richness and Shannon diversity depended significantly on plant abundance (p = 0.009 and 0.014 respectively) and canopy cover (p = 0.015 and 0.045 respectively) in the forest reserve (Table 5). Plant species richness and canopy cover were significant predictors of butterfly abundance in the study (p = 0.000 and 0.006 respectively). The total variation explained by butterfly abundance-vegetation characteristics regressions was highest in the study (r^2 = 73.12 %).

Table 5. Multiple regression (stepwise) analysis of the effects of vegetation characteristics on butterfly diversity and abundance in the Atewa Range Forest Reserve. The final model included only those variables which made significant influence on the dependent variables.

Dependent variable	r^2 (adjusted)	Independent variable	p-value
Butterfly species richness	56.78	Plant abundance	0.009
		Canopy cover	0.015

Shannon diversity	52.17	Plant abundance	0.014
		Canopy cover	0.045
Butterfly abundance	73.12	Plant species richness	0.000
		Canopy cover	0.006

CHAPTER FIVE

DISCUSSION

Butterfly species richness and diversity differed considerably among the three forest types, and depended significantly on plant abundance and canopy cover in the study. The results of this study showed strong effects of human-induced disturbances on several important aspects of forest community diversity and structure which created significant heterogeneity in the forest ecosystem. The creation of the heterogeneity in the forest types by human disturbance could account for the patterns of butterfly diversity observed in this study (Table 2). These findings are consistent with some previous works of Brown (1997), Hill(1999) and Wettstein and Schmid(1999). The pattern of butterfly diversity observed in this study brings to the fore the important roles vegetation and disturbance play in structuring butterfly species richness and diversity in forest ecosystems as was indicated by Rajagopal *et al*. (2011). Out of the 11 butterfly species that were previously reported as endemic to the Atewa Range Forest Reserve (Larsen, 2005), only one of them, *Mylothris atewa*, was recorded in the present study (Table 2). While some of the endemic species in the forest reserve may have been missed due to the relatively small area sampled compared to the above mentioned study, there is a high possibility that some of the species might have been affected by human activities in the forest, resulting in their possible extinction. Further studies on a larger spatial scale may be useful for more accurate determination of the composition of butterfly species in the ARFR.

Butterfly species composition also differed among the forest types in the study (Table 4). Similarity in butterfly composition between the highly disturbed and non-disturbed forests may be attributed to the presence of similar plant resources in the two forest types. The composition and distribution of butterfly species in the forests revealed three groups of butterflies namely, disturbance-avoiding, moderately disturbance-adapted and highly disturbance-adapted species, which were restricted to only the non-disturbed, moderately disturbed and highly disturbed forests respectively. These species could serve as useful indicators of different levels of disturbance intensities in forests. The non-disturbed and moderately disturbed forests harboured equal number of unique species (disturbance-avoiding and moderately disturbance-adapted species respectively), which was more than that of the highly disturbed forest (highly disturbance-adapted species). This suggests that intermediate form of disturbance was capable of maintaining unique butterfly species diversity just as the non-disturbed forest. Majority of the butterfly species occurred in at least two forest types. These species may be considered as generalists that are able to utilize a wide range of habitats for resourcesas indicated by Kasangaki*et al*. (2012).

Butterfly abundance depended significantly on vegetation characteristics, indicating that areas with high plant resources supported more butterflies. Thus, the relatively low abundance of butterflies in the highly disturbed forest compared to the other forest types may be due to fewer resources provided by this forest type. These results which indicate the importance of plant resources in influencing butterfly abundance in the forest are supported by the works of (Brown, 1991; Wettstein and Schmid, 1999). Most of the butterfly species either showed low abundance in some of the forest types or were absent in them, indicating that they were sensitive to changes in plant community diversity and structure in the forest types (Table). Despite the low abundance of some species in certain forest types, other species such as *Junonia terea, Papilio cyproeofila* and *Nepheronia thalassina* were highly abundant in all the forest types. These species were identified as the dominant butterfly species in the ARFR in a previous study by McCullough *et al*. (2007). Thus, the dominance of these species in the ARFR has been maintained for some years now. These dominant species appear not to have been affected much by human disturbance, probably due to their broad ecological amplitude or ecological plasticity.

In spite of human disturbance in the forest reserve, *Mylothris atewa, Neaveia lamboni, Tetrarhanis baralingam* and *Bicyclus auricruda* which were reported as endemic to ARFR (Larsen, 2005;McCullough*et al*., 2007) were relatively abundant in all plots within the study area.

The continuous presence of these species in high numbers in the area suggests that the forest still provides favourable conditions and resources for them. In terms of both species richness and abundance of butterflies, the family *Nymphalidae* was the most dominant in all the forest types. This confirms its dominance in tropical forests(Humpden and Nathan, 2010;McCullough*et al*., 2007; Sundufu and Dumbuya, 2008).

Implications of the study for conservation

Due to the importance of tropical forests to butterflies by means of provision of habitats and resources, it is essential for forests to be conserved so as to maintain butterfly diversity and abundance. The findings of the current study indicated that butterfly diversity and abundance were similar in the non-disturbed and moderately disturbed forests, although they were significantly lower in the highly disturbed forest. Besides, butterfly diversity and abundance were significantly related with plant species richness, diversity, abundance and canopy cover, suggesting the important role of vegetation in determining butterfly assemblages in the forest.

These suggest that for butterfly species diversity and abundance to be maintained in tropical forests, they should be protected from human activities or only minimal form of disturbance be allowed in them. To this end, selective logging should be encouraged (Brown, 1997) in areas earmarked for exploitation in order to enhance and maintain butterfly species diversity and abundance in the forest. In areas with high level of human disturbance, tree species enrichment could be practiced so as to improve upon plant diversity and forest structure, thereby increasing and maintaining butterfly diversity and abundance.

CHAPTER SIX CONCLUSION AND RECOMMENDATIONS

Conclusion

Human-induced disturbance in the ARFR created heterogeneity in plant community diversity and structure in the forest. Consequently, butterfly diversity and abundance differed significantly among the forest types, and depended significantly on plant community diversity and structure of the forest.Human disturbance influenced butterfly species composition, as it varied among the forest types. On the basis of species composition, butterflies were grouped into disturbance-avoiding, moderately disturbance-adapted and highly disturbance-adapted species.

Recommendations

1. A study should be conducted in the rainy and dry seasons to examine the influence of seasonalityon butterfly assemblages in the ARFR.

2. Based on the significant effects of human disturbance on butterfly assemblages in this study, the following are recommended:

- There is the need for public education for the people in the community on the need to protect the Atewa Range Forest Reserve from destruction. This can be done through the establishment of educational groups such as Nongovernmental organizations that will be concerned with forest conservation. Also training of people to form part of the Atewa forest guards to be sent into various homes in the Atewa community to educate member in the community. The National Commission of Civic Education (NCCE) set up by the government of Ghana should organize regular forum for people within the Atewa and it's environs and also encourage them of participation in the NCCE programmes.

- The Atewa Range forest is rich in valuable resources such as plant and animal species as well as minerals such as bauxite and gold. These resources put people into temptation to engage in several activities that destroys the Atewa Range Forest reserve. In order to ensure the sustainable protection of the Atewa forest, there must be implementation of management plans of protecting the Atewa forestthat will be collaborative approach between the forests commission themselves, the public and private institutions, in order not toallowthe forests commission only to protect the forest. This measures will enhance tight security in and around Atewa Range Forest Reserve

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