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DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

IMPACT OF FOREST MANAGEMENT SYSTEMS ON DIVERSITY AND ABUNDANCE OF BUTTERFLIES IN THE ASENANYO FOREST RESERVE, GHANA

A THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN ENVIRONMENTAL SCIENCE.

BY

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DECLARATION

I hereby declare that the results of these studies, except otherwise cited are my own work and have not been submitted for any degree other than that of my Master of Science in the Kwame Nkrumah University of Science and Technology.

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DEDICATION

I dedicate this work to God Almighty, who gave me life and strength throughout my study and to my father, Mr. Samuel Kwabena Owusu Abu of blessed memory for his financial and moral support.

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ABSTRACT

Every forest management practice has the potential to affect the structural elements of the forest and the habitat conditions of the biodiversity living in it. Forest management practices such as selective logging and plantation establishment have been widely practice, however, there is limited information on the potential effect of these systems butterfly diversity and abundance. This study was conducted in the Asenanyo River Forest Reserve to determine the impact of forest management systems on the diversity and abundance of butterflies in the forest reserve. Transect method using standard fruit baited traps were employed to capture butterflies in an unlogged, selectively logged and plantation forest management zones. In each study site, six transects were located at least 500 m apart and on each transect, eight trap net stations spaced at 100 m were installed for a more quantitative butterfly diversity sampling. Shannon-Wiener and Simpson‗s diversity indexes were used to analyze for species richness and diversity of butterflies. A total of 2,314 butterfly specimens belonging to 87 species, 41genera and 5 families were trapped in the understory of the three management zones in the forest reserve. The selective logged zone recorded the largest number of butterflies (968) followed by unlogged (880) whiles the plantation recorded the least butterflies of (466). Shannon-Wiener and Simpson‗s indices for the selectively logged forest and unlogged forest were similar. Shannon-Wiener and Simpson‗s indices were however significantly higher in the unlogged than in the plantation forest ($P< 0.05$). The findings of the study indicated that butterfly diversity and abundance were directly related to plant diversity, abundance and canopy cover, thus highlighting the important role vegetation play in determining butterfly assemblages in the forest. The study further showed that although plantations are generally

poor substitutes for the butterfly habitat compared to intact forest, they did provide habitat of some form for forest butterflies. It is recommended that further studies should consider vertical stratification in the forest reserve and the impact of seasonal variations on the butterfly species.

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CHAPTER ONE

INTRODUCTION

1.1 Background

The Tropical rainforest is a complex community and is probably the most diverse terrestrial ecosystems earth, with the highest numbers of plant and animal species coexisting (Whitemore, 1984; Marshall, 1992). According to Marshall (1992), Tropical rainforest is probably the richest terrestrial ecosystem. Although it covers 6% of the total land area of the earth, it contains approximately half of the world's animal and plant species, including 70-75% of all known arthropods (Mabberley, 1983). Tropical rainforests are well known as centres of biological diversity and much attention has been focused on the ecological process responsible for generating and maintaining this diversity. Recently, some authors have emphasized the importance of natural disturbances and non-equilibrium dynamics, coupled with the variations across environmental gradients generated by topographic and edaphic landscape features within the forest (Hill *et al*., 2001; Marshall, 1992). Although tropical rainforests are diverse in species richness, they are among the most threatened of all habitats because of exploitation of forests for timber and economic development (Whitmore, 1984; Wilson, 1988). Forests in West Africa are under serious threats from logging and agricultural activities.

Forest management practices in Ghana aim at achieving sustainable forest management by the year 2020 (Kufuor, 2000). These management practices which serve as control systems have been inadequate resulting in unsustainable exploitation (Foli, *et al.,* 2004).

Management of natural forests is believed to be adequate measure for the long term maintenance of forest habitat and biological diversity living in it (parren and de Graaf, 1995) Among terrestrial ecosystems, forests support the greatest global biodiversity (Battles *et al*., 2001; Lindenmayer *et al.*, 2006), and thus the conservation of forest biodiversity is an important goal for forest management (Lindenmayer *et al.,* 2000; Kremen, 2005; Junninen *et al.*, 2007). Thinning operations which are essential part of management plans promotes the growth of timber species and plantations. They improve the value of the forest economically and provide vital arguments against complete land conversions (Wöll, 1992). Traditionally, almost all logging in the tropical forest has been selective where only the valuable trees are removed (Fimbel *et al*., 2001). Forest managers recently, have dedicated their attention to the development of sustainable forest management regimes, with the objectives of providing a renewable forest resources through selective logging whiles reducing the negative impact on forest biological diversity (Bruenig, 1996; Dickinson *et al.*, 1996; Hunter, 1999). Forest management practices which may come with various disturbance regimes has the potential to influence butterfly species richness, abundance and relationship with their host. For selective logging to be a sustainable method of forest management, it needs to be viable economically to provide a sustained yield of timber and also conserve biodiversity (Bawa and Seidler, 1998).

Selective logging can affect the structure of the forest and the amount of light reaching the forest floor as a result of changes in the canopy cover (Hamer *et al*., 2003), meaning that selective logging has the potential to interrupt vertical stratification of species (Willot, 1999).

Amongst insects, butterflies can be considered as one of the best group that can be used to study human disturbance and other forest management practices, because they are sensitive to changes in environmental conditions (Brown, 1991; DeVries *et al.*, 1999). Butterflies are larges group, twice as many species as birds and thrice the number of mammals, reptiles, mosquitos, termites or beetles (Robbins and Opler, 1997). Butterflies belongs to order Lepidoptera with over 150,000 species (Burnie and Tschinkel, 2005), which are part of the Class Insecta with more than a million species have been described representing about half the global diversity (Larson, 2005). There are approximately 1,100 West African butterfly species of which ~940 are present in Ghana

(Larsen, 2005b). Butterflies are the best known group and the most popular of all insects (DeVries, 2001; Larson, 2005), they are taxonomically well-known and ecologically diverse (Bouyer *et al*., 2007), ease of identifying and recording (DeVries *et al*., 1997; Larson, 2005; Lewis, 2001). Butterflies have been used as indicator species in many studies to predict changes in the environment (Thomson *et al*., 2007). Butterflies species richness may change as a results of changes in plant composition and density, intensity of light and humidity, these make them good indicators to predict changes in the environment (Barlow *et al*., 2007; Bossart *et al*., 2006; Bouyer *et al*., 2007).

Since selective logging is being employed in many parts of humid tropics, it is important to understand their effects on rainforests biodiversity (Boyle and Sayer, 1995). Insects play important role in biodiversity assessments because of their dominance in terrestrial ecosystems (Wilson, 1987) and their rapid population responses to disturbances make them sensitive to changes in the biotic and abiotic environments (Kremen *et al*., 1993). Monitoring butterfly abundance can indicate the presence of semi natural conditions;

specifically, flower abundance, understorey cover, and vegetation diversity have been found to promote butterfly diversity in an ecosystem (Inoue, 2003, Kitahara, 2004; Barlow *et al.,* 2008; Bergman *et al.,* 2008; Halder *et al.,* 2008)

1.2 Problem Statement and Justification

Forest ecosystems provide habitats for disproportionally large numbers of the world biodiversity. The ethical and ecological significance of this biodiversity has motivated professional forestry to work towards maintaining this intrinsic diversity while meeting the demands of wood and other forest products (Hunter, 1999). Forest management practice characteristically can affect the structural elements of forests which eventually influence the habitat conditions of biodiversity living in it. There is widespread concerns about the effect of tropical forest disturbances on biodiversity (Whitmore and Sayer, 1992). Forests in West Africa are under serious threat from logging and agricultural conversion. Forest destruction in Africa remains among the highest in the world. According to IUCN (2006), deforestation rates in Ghana is estimated at around 3% per annum, however, information on the potential effects of different type of management practices on diversity patterns of many forest communities are insufficient (Wood and Gilliam, 1998).

The magnitude of selective logging for ecosystem and species are therefore of great concern. Conventional logging and conversion of forest to plantations and other forms of land use generally results in decrease in insect diversity (Holloway and Chey, 1992).

Several studies have revealed that logging and its related activities has the potential to affect to affect richness, diversity and composition of fruit feeding butterflies (Koh, 2007;

Dumbrell and Hill, 2005). Selective logging is known to affect forest structure and the amount of light reaching the ground level through changes in canopy cover (Hamer *et al*., 2003). Plantation forests account for about 3.5% of the world‵s forested area (FAO, 2007). According to Evans and Turnbull (2004), forest plantations are increasing in the tropics, therefore the role of plantation forests in maintaining biodiversity cannot be ignored. Gardner *et al.* (2007), also reported that, despite their increased in coverage and potential importance, the biodiversity conservation value of extensive monocultures and areas of native regeneration are poorly understood. Therefore understanding the ecological consequences of forest conversion to mono-specific plantation forests and other types of land use is critical. Habitat specificity and arthropod assemblages can indicate the ecological consequences of forest conversion. Due to increasing global habitat destruction modern studies of species diversity are of vital importance for understanding biological communities and their conservation (Purvis and Hector, 2000)

Therefore, the study of butterfly assemblages in unlogged, selectively logged and plantation forests may be useful to investigate the impacts of forest disturbance. The Asenanyo river forest reserve is a popular forest reserve in Ghana which has been used for many research works, however, there is limited literature on butterfly species in the forest. The impacts of management practices on butterfly species richness, abundance and diversity are also not known. Therefore it is against these backgrounds that this study sought to determine the effect of selective logging and *Cedrela odorata* plantation establishment on butterflies‵ diversity and abundance.

1.3 Objectives of the Research

The main objective of the study was to investigate the impact of forest management systems mainly selective logging and plantations on the diversity and abundance of butterfly species in the Asenanyo Forest Reserve.

1.3.1 Specific Objective:

The specific objectives were to determine the:

- species richness and diversity of butterflies in the three identified management regimes in the reserve.
- relative abundance of butterflies in the management regimes.

CHAPTER TWO

LITERATURE REVIEW

2.1 Tropical Rainforest

The concept of forest as defined by FAO (2010) is a land covering more than 0.5 hectares with trees taller than five metres and a canopy cover of more than 10%or trees able to reach this threshold in site. This does not include land under agriculture cultivation or urban land use. Tropical rainforests are the richest terrestrial ecosystems on Earth, and explaining the mystery behind the co-existence of the diverse assemblages of species remains one of the fundamental challenges of tropical ecology (Harrison, 2005). The tropical forest ecosystem is home to many animal species, including a lot of threatened and endangered species in the world. There are two major kinds of tropical humid forest, tropical rainforest and monsoon forest (Collins *et al.,* 1991). Rainforests occur in humid climates where rainfall occurs throughout the year, although it may not be uniformly distributed. Rainfall in these areas averages 100mm or more per month, although there may be drier periods in certain months (Whitmore, 1984). Tropical monsoon forest occurs where there are long dry seasons, usually with more than three months with less than 60mm rainfall (Collins *et al.,* 1991).Tropical rainforest exist in tree major regions; South American rainforest which covers the largest area, followed by Southeast Asian rainforest, and African rainforest.

Temperature in these regions is above 18°C, even during the coldest months, with the exception of some tropical montane forest (Whitmore, 1990). Average temperatures are usually between 25°C and 28°C. There is a strong influence of the surrounding season total rainfall received in these rainforests (Whitmore, 1984). South East Asia is more influenced by the surrounding oceans compared with the two rainforest blocks of Western Africa and South America. There are various forest formations within tropical rainforest and monsoon forest depending on local conditions of soil, topography, climate and groundwater (Collins *et al.,* 1991). Forest formations differ from one another in physiognomy (forest structure), and floristic composition (Whitmore, 1990). The existing tropical rainforest formations in South East Asia are lowland mixed-dipterocarp forest, peat swamp and freshwater swamp forest, heath forest, ultramafic forest, limestone forest, montane forest, mangrove forest, and beach forest (Whitmore, 1984).

2.2 Biological Diversity and Biodiversity Monitoring

Biological diversity is the range of biological differences within the living world. De Laat (2010), defined Biodiversity as the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems. Groombridge (1992), defined biodiversity in terms of species, genes and ecosystems corresponding to three fundamental and hierarchicallyrelated levels of biological organization. Biological diversity comprises species richness and species evenness (Begon *et al.,* 1997). The use of monitoring in biodiversity conservation and research has often been in a very broad context, resulting in varying explanations and interpretations of the term.

McGeoch *et al.* (2002) defined biodiversity monitoring as "the repeated application of bio indicator taxa to provide information on the conditions of the environment. , or effects thereof, to which they were initially identified as suitably sensitive and for which baseline standards, thresholds or relationships have already been determined." The objectives of biological monitoring programmes are to predict or evaluate changes in habitat structure, functions and compositions in response to natural and anthropogenic factors (McGeoch *et al.,* 2002). Plant and animal species interactions depend on factors such as habitat availability, food resources and environmental factors such as soil nutrients and oxygen. Maintenance of diversities of plant and animals in ecosystems is necessary to preserve a web of life that sustains all living organisms (Manu, 2011). The more species there are and the more nearly even their abundance the greater the diversity (Pielou, 1975). Although it is difficult to quantify the economic value of biodiversity, the genetic variations within species, the varieties of species, and the existence of diverse and productive ecosystems are undoubtedly of economic importance (IUCN/UNEP/WWF, 1991). One important aspect of biological diversity may be the conservation and preservation of biological ecosystems to meet needs which are as yet unforeseen. However, higher species diversity does not necessarily entail more endemic species compared with lower species diversity (Spellerberg, 1991).

2.3 Forest Biodiversity in Ghana

Ghana‘s forest forms part of the Upper Guinean forest ecosystem region of West Africa. It contains unique diverse ecological communities of forest habitat providing refuge to numerous endemic species (Allotey, 2007). The Upper Guinea Forest, ranks among the 34 most significant biodiversity Hotspots worldwide (Baker *et al*., 2004). There is insufficient informations on the full coverages of biological resources in Ghana, however, according to Allotey (2007) there are about 2, 974 native plant species, 504 fishes, 728 birds, 225 mammals, 221 amphibians and reptile species that have been recorded. Endemic species include three species of frogs and 23 species of butterflies. Hall and Swaine (1981) reported that there are over 2,100 plant species in the high forest zone, 23 of them endemic.

A total of 730 tree species have been recorded in the closed forests (Hawthorne, 1989). Floristically, the wet evergreen forest is the richest whiles Southern Marginal Forest is the poorest. In terms of commercial timber production, the Moist Evergreen and the Moist Semi deciduous forest types are the most important. The Fauna of the high forest zone includes 200 species of mammals, many of which are rare or endangered (Mensah, 1989). According to IUCN (1992), 200 species of birds, 74 species of bats, 37 species of rodents and a variety of reptiles. According to National Biodiversity Strategy for Ghana (2002 as cited in MLNR, 2011), the high forest zone accounts for most of the biodiversity in the country.

2.4 Treats Facing Biodiversity in Ghana

The biological diversity in Ghana‘s forest is increasingly under serious threat from socio-economic activities such urban expansions, industrial and tourism developments (Allotey, 2007). There are many factors that affect biodiversity in Ghana, principal among these are land use changes, overexploitation, invasive species and habitat fragmentation and loss. Habitat fragmentation have important repercussion on the species of the flora and fauna (Gehring and Swihart, 2003). Fragmentation results in the breaking of large continuous area into smaller patches leading to a net habitat loss.

Consequently, this will decrease the amount of habitats and environmental resources available. This may further result in a general decline in the populations that can be hosted. Fragmentation results in a substantial increases in edges (Sih *et al*., 2000). Edges come along with distinct micro-climatic conditions from the core areas that might become less appropriate for species. Furthermore, the edges results in increase rates of predation by favouring generalist predator immigration (Schmiegelow and Monkkonen, 2002) which in turn greatly affects the number of individual resident species.

Over-exploitation of resources may lead to the depletion of resources, resources, lowering population, affects genetic diversity and increases the risk of extinction. (Winterbottom and Eilu, 2006). The main driver of over exploitation of forest is the ever increasing rate of population growth. As the human population grows, there is increased demand of forest resources to meet developmental and livelihood needs of the population. Fahrig (2003) indicated that land use change also leads to the modification of an existing natural environment by anthropogenic activities which is a key driver for biodiversity loss. Converting natural habitats into land use areas may totally destroy the living conditions of a particular species, alter species composition, and initiate species extinctions. The root cause of land-use change leading to forest degradation and subsequently biodiversity loss may be categorized as demographic, economic, policies, institutional, politics, infrastructure, and socio-cultural factors (William, 2003).

Another major treat to biodiversity is logging operations. Excessive logging operations effects the structure of the forest and the biodiversity living in it (Foaham and Jonkars, 1992). Invasive species are able to exert strong competitive effects on the growth, reproduction and resources allocation on native species, and finally take their place, thus reducing their diversity (Winterbottom and Eilu, 2006). Mining leads to rapid environmental degradation and more particularly reduces the amount of vegetation thereby affecting the biodiversity of the area (Akabzaa and Darimani). Mining activities require large concessionary areas for the tailings dam, plant site and feed stockpile, siting of mines, heap leach facilities, open pits and mine camps which could have both direct and indirect impact on the natural forest habitat. Over the years, mining activities have resulted in substantial disturbance of surface soils in the mining areas, destruction of vegetation and the pollution of water and air (Ayensu *et al.*, 1996). Furthermore, mining projects are usually sited in remote areas and are as such associated with the construction of substantial physical and social infrastructure including roads, schools, hospitals, electricity and water supplies (Akabzaa and Darimani, 2001). The development of these infrastructure impacts negatively on biodiversity as clearing of forest for space normally leads to the removal and destruction of suitable natural habits.

2.5 The State of Forest in Ghana

Ghana has been endowed with forest resources which are vital for her economic developments and future prosperity (Boon *et al.,* 2009). The sector provides livelihoods for many forest-fringe communities and employments both direct and indirect to people (ITTO, 2006). The forestry sector contributed 1.4% to Ghana's Gross Domestic Product in 2011. Ghana forest area occupies a total land area of 23.85 million hectares with forest area confine to two vegetation zones, the high forest zone which constitutes about 34% and the savanna zone forming the remaining 66% (Marfo, 2010). For the reserved forests, 11,590 km^2 have been designated as production forest, of production forests;

4,323 km^2 for protection and about 1,980 km^2 for game productions (Siaw, 2001).

Reserve forests were reserves were formally established by the state to encourage ecological stability whiles seeking to guarantee the flow of goods and services for socioeconomic developments (Bird *et al.*, 2006).

In recent years, the state of Ghana's forest have come under continuous and increasing threat from over exploitation and degradation driven by various social, political and economic factors. Various studies have reported on how Ghana's forest has decreased over the years. Asibey and Owusu (1982), reported that since the 1940s, more than 90% of Ghana‘s high forest have been exploited. Green (1996) also revealed that at the beginning of the 20th century, Ghana had about 8.2 million hectares of high forest zone. However, this zone has for the past years been reducing at the rate of 75,000 hectares per annum or 2% to about if not less than 1.3 million hectares. FAO (2011) also projected Ghana‘s forests to be about 4.68 million hectares in 2010, which is about 20% of the land area.

Ghana‘s deforestation rate has now been estimated at 135,395 ha per year (FAO, 2010). Forest degradation is the changes within the forest which affects the structures and functions of the stands thereby lowering its capacities to supply product and services (FAO, 2006). Many reserves and off- reserve forests are been encroached and these have resulted in rapid depletion. The main factors fueling these are, weak policies and market failure in the timber sector, excessive demands for wood products both in the international and the local markets, less technological developments in farming systems and dependencies on wood fuel and charcoal (Forestry Commission, 2010). These destructive forces are influenced by population pressures and poverty as well as by infrastructure and economic development programmes (Blajer *et al*., 2011).

2.6 Sustainable Forest Management.

Sustainable forest management is the practice of managing permanent forests lands to achieve a defined objectives with regards to the productions of continuous flow of desired forest products and services without undermining its intrinsic values and the environment. Sustainable forest management (SFM) indicates several deliberate human interventions, ranging from actions aimed at safeguarding and maintaining the forest ecosystems and its functions for the improved production of goods and services (FAO, 1999). According to Prabhu (1996), sustainable forest management can be defined as a set of objectives, activities and outcomes consistent with maintaining or improving the forest‘s ecological integrity and contributing to the people‘s well-being both now and in future.

Sustainable forest management ensures that the benefits obtained from the forest meets the needs of the current and the future generations (FAO, 2008). It has a great potentials to serve as a tool for fighting against climate change, protecting people and livelihoods, and creating a foundations for sustainable economic and social developments. Peters (1994) indicated that there is growing awareness that sustainable forest management should include process for effective conservation and management of forest resources to meet the present and future demands of the people. Sustainable forest management also promotes public participation as one of its core principles. Creating public awareness plays an important role in educating and informing the public thereby allowing them to participate in the decision making processes of sustainable forest management (IUCN, 2010). The concept is also applied in timber harvesting as it constitutes an important part of silvicultural and forest managements.

2.7 Selective Logging

Selective logging or Reduce impact logging are now well known (Dykstra, 2002), and one of the main forest management systems in the tropical African forests. It occurs at different intensities and felling regimes in accordance with aims and objectives of the forest manager (Johns, 1985). Selective logging can be defined as carefully planned and controlled harvesting practice that minimizes impacts on forest stands and soils (Schwab *et al*., 2001). Putz and Pinard (1993) also defined selective logging as an intensively planned and carefully controlled timber harvesting conducted by trained workers in ways that minimize the harmful impacts of logging. Dudley *et al*. (1995) reported that selective logging embraces various different methods including:

- The removal of a certain number of trees from a given area,
- Retaining a relatively unbroken canopy,
- Removal of one or more commercially important species,
- The removal of certain age classes of all trees and removal of parts of trees without killing them, thus allowing regrowth through coppicing or pollarding.

Selective logging is an improvement over conventional logging because it retains some amount of forest structure and enhances the economic values and also provides important arguments against complete land conversions.

Selective cuttings removes proportions of trees in a stand to allow for natural regenerations, improve habitats of wildlife and increases species diversity. Selective logging is done with the intentions of re-harvesting the areas at 20-40 years interval (Fimbel *et al*., 2001). It may also include opening gaps allow trees that requires greater light intensity to grow (Nyland, 1998). Sist and Ferreira (2007) found that selective logging reduces the overall damage by 50% compared to conventional logging at a harvest intensity of 8 stems/ha, but at higher logging intensities improvement were less marked.

2.8 Impact of Selective Logging on Biodiversity

The main threat to biological diversity in the tropics include wild fires, conversion of forest to agriculture and other land uses and overexploitation (Hawthorne, 1996). Logging procedures may results in the disappearance of species thus reducing diversity and the potentials of the forests.

Selective logging of mature or superior trees generally causes genetic depletion, consequent loss of potential food sources and disease control, reduction in the stability of ecosystems and loss of resilience against catastrophes (Hawthorne *et al*., 2011). The removal of seeds also decreases the potentials of the forests to regenerate after logging. The effects of logging on forest flora is similar to that on fauna and depend on the ecology of particular group of species. Logging also alters the habitats of wildlife by changing or destroying nesting, feeding and breeding sites. Selective logging also causes the removal of topsoil at timber collection areas (log landings where logs are debarked, stored and loaded on to trucks for removal) and skid trails (trails used by bulldozers and other heavy machinery to extract logs) (Tangah, 2000). This continuous disturbance of topsoil results in soil compaction and causes removal of soil nutrients which retards the recovery of vegetation (Pinard and Putz, 1993).

Traditionally, selective loggings have had effects on different groups of organisms (Dumbrell and Hill, 2005) and causes severe changes to the structure of the existing forests (Gerwing, 2002). These also causes soil compactions and affects light penetration in the understory (Whitman *et al*., 1997). Selective logging can have a number of different impacts on the forest depending partly on timber volume extracted, the harvesting system used (in this case conventional selective logging), the extent of damage to residual trees (such as small trees, saplings and seedlings), and damage to the soil (Gerwing, 2002).

2.9 Plantation Forest and Biodiversity Conservation

There is a growing interest in the value of plantation forest in conserving biological diversity. Longer-lived plantation establishments are important for biodiversity because it mimics the natural mature forests (Allen *et al*., 1995; Ogden *et al*., 1997). Older plantations are likely to benefit biodiversity because of increases in spatial and vertical heterogeneity, well developed soil organic layers and associated fungal flora (Molloy, 1992).

Plantation forest contributes to the conservation of local biodiversity by providing habitats, buffering indigenous forest remnants and improving connectivity between remnants (Norton, 1998). Some plant and animal species remains in the plantation forests without relying on adjacent natural forest. In some instances, plantations provides right combinations of conditions comparable to the natural forest. Tree plantations have the abilities to provide conservation services because they are rapidly increasing in extent, and presents less of a structural contrast with native vegetation than many alternatives. These species are valuable for biodiversity conservation because they provide resources such as mast, fruit and nectar (Hartley, 2002). Plantations establishments are therefore capable of providing habitat with structural and understory conditions even similar to that which pertain in natural forests.

2.10 Butterfly Diversity

Butterflies are a large group, with twice as many species as terrestrial birds and about thrice numbers of mammals, reptiles, mosquitoes, termites and tiger beetles (Robbins and Opler, 1997). Butterflies belong to the order Lepidoptera with over 150,000 species (Burnie and Tschinkel, 2005) which is part of the Class Insecta of which more than a million species have been described, representing about half the global diversity (Larson, 2005). According to Emmel and Larsen (1996), 18,000 butterfly species approximately exist on earth. 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 widespread from one region to another (Emmel and Larsen, 1997). Ghana is amongst the most extensively researched countries concerning butterflies in West Africa with many recent publications (Bossart *et al.*, 2006, Larsen *et al.*, 2007). Larsen (2006) reported that, about 925 species of butterfly are found in Ghana. These species are spread in families of Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae and Pieridae (Larsen, 2006; McCullough *et al.*, 2007). The study further indicated that butterfly species in Ghana are distributed in the dry coastal regions, drier tropical deciduous forest, evergreen rainforest and tropical semi deciduous forest. 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 refused to migrate into non forest areas after their adaptation to the forest. The butterflies dwell at such places due to availability of food resource from flower nectar. In many parts of the world, butterflies have been used in biodiversity monitoring programmes with considerable success (Aduse-Poku, 2008). In the invertebrate taxa, butterflies are the best known group. Many species of butterflies are seasonal and prefers particular type of habitats (Kunte, 1997). Butterflies species richness may change as a results of changes in plant composition and density, intensity of light and humidity and these make them good indicators to predict ecosystem changes (Barlow *et al*., 2007; Bossart *et al*., 2006; Bouyer *et al*., 2007; Thomson *et al*., 2007).

Butterfly assemblages and the factors which influence it, have long been a topic of interest to ecologists and conservationists. Human dominated landscape forms a substantial and ever increasing amount of the earth‘s land surface. These habitats often negatively influence butterfly species and their dynamics (Ricketts *et al*., 2001). Butterflies are threatened especially in the early stages by 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) In general, butterfly species are more widespread at moist places.

2.11 Ecological Importance of Butterflies

Butterflies plays an important role in ecosystems as they act as pollinators, source of food and indicators of the ecosystem's well-being (Brown *et al.*, 1991). According to

Lomov *et al.* (2006) butterflies have a strong association with vegetation structures and compositions and these makes them suitable indicators for various ecological studies.

Some of the ecological importance of butterflies is as follow:

2.11.1 Biological Indicator for Forest Disturbance

Tscharntke *et al.* (1998) proposed a number of reasons that makes butterflies good indicators. These are;

1. Butterflies have a well-known taxonomy.
2. Their life cycle is well understood, readily manipulated and surveyed.
3. They have broad geographical ranges.
4. They are sensitive to changes in habitat stresses and conditions.
5. Their responsiveness to biodiversity patterns of other taxa.
6. They are of potential economic importance.

Butterflies fulfilling these criteria make them good bio-indicators for anthropogenic disturbances and quality of habitats (Brown and Hutching, 1997; Ghazoul, 2002). Cleary (2002), stated that butterfly sensitivity to environmental changes, their responsiveness to biodiversity patterns of other taxa, their comparatively well-known life history and the fact that they are relatively easy to observe, catch and identify, make this order convenient for using in monitoring forest disturbances. Butterflies are very sensitive to disturbances, which make habitat fragmentation, degradation and destruction of natural landscapes some of the most important causes for declines in butterfly assemblages (Uehara-Prado *et al.,* 2007).

2.11.2 Ecosystem Restoration

Butterflies react both to short-term and long-term habitat changes caused by restoration Treatments. According to Minard (2003) treatments involving ecosystem restorations affect many animals, but butterflies are particularly useful indicators of ecological changes for several reasons:

- They are easy to watch as they tend to be visible, and most are easily identified in the field,

- They are sensitive to habitat changes brought on by restoration. Butterflies are sensitive to changes in microclimatic conditions such as light intensity and fluctuations in temperature. In addition, increased understory growth can result in more flowering and nectar production, thereby increasing food supplies for adult butterflies and other pollinators (Short and Negrón, 2003).
- They can indicate what‘s happening with plants and other animals. Changes in butterfly populations can indicate important, yet less easily detected changes in populations of other organisms. Butterfly larvae—caterpillars—live exclusively on particular species of grasses, herbs, shrubs, or trees. Therefore, the presence of certain species of butterflies and moths indicate the presence of specific larval host plants in the area. Adult butterflies, on the other hand, generally utilize a variety of nectar-producing plants. For that reason, the number of adult butterflies can reflect the abundance and diversity of nectar-producing plants.

Increased butterfly populations may indicates an increase in plant diversity and other pollinator groups within restored areas (Thomas, 2005). Maleque *et al*. (2008) indicated that, in a certain period after harvesting and forest fire disturbance, understory vegetation and arthropod species may recover. Monitoring arthropods can infer the restoration stages of understory vegetation, other arthropod species, and ecosystem functioning. Recolonization by arthropod species indicates the restoration of ecosystem functioning after forest disturbances. Moths have also been used as bioindicators during vegetation recovery after environmental disturbance (New, 2004). Some moth families/subfamilies (e.g., Arctiinae, Catocalinae, Heliothinae, Noctuinae, Hermeniidae, and Phycitinae) respond positively to disturbances, while others (e.g., Ennominae, Geometrinae, Epipaschiinae, Lymantriidae, and Anthelidae) respond negatively to disturbance (Kitching et al., 2000). These different responses to environmental changes make them suitable bioindicators.

2.11.3 Conservation Indicators

Butterflies can act as conservation indicators (Larsen, 2006). Monitoring butterfly abundance and diversity may be useful to understand ecosystem structure and function on a landscape scale. Seminatural habitat patches within plantation forests support high butterfly diversity (Bergman *et al*., 2008; Halder *et al*., 2008). Since butterflies are often associated with old-growth woodlands, forest edges, and seminatural grassland habitats, they indicate the importance of habitat preservation for conserving regional biodiversity (Kitahara, 2004; Halder *et al*., 2008; Smith *et al*., 1994).

Butterflies have been used as indicators of healthy ecosystems because they have strong associations with habitat variables such as sunny conditions, flower-filled fields, meadows, hilly regions, edges of woodlands, and an abundance of herbaceous plants (Niemelä and Baur, 1998; Makino *et al*., 2006; Nelson, 2007; Halder *et al.*, 2008). Monitoring butterfly abundance can indicate the presence of semi- natural conditions; specifically, flower abundance, understory herb cover, and vegetation diversity have been found to promote butterfly diversity in an ecosystem (Barlow *et al*., 2008; Bergman *et al*., 2008; Halder *et al*., 2008; Kitahara *et al*., 2008). This is presumably because butterfly species richness is associated with vascular plants, nectar plants, and herbaceous plants abundance and richness (Niemelä and Baur, 1998; Kitahara *et al*., 2008); therefore, maintenance of native understory vegetation and grassland conditions through forestry practices should ensure butterfly conservation, even in conifer plantations (Kitahara 2004; Barlow *et al*., 2008; Bergman *et al.*, 2008; Halder *et al*., 2008; Kitahara *et al*., 2008). Addae –Wireko (2008) further stated that, an abundance of butterflies usually indicates a healthier ecosystem.

2.11.3 Pollination

Taron (1996) stated that butterflies are not efficient as bees when it comes to pollination but they still plays a significant role in pollination. Butterflies tend to prefer big, colorful flowers that have a landing platforms (labella) and gather pollen on their long, thin legs as they sip nectars from flowers (Emmel and Larson, 1997).They serve as importance plant pollinators in the local environment and help pollinates many economically important species (Manu, 2011). Among the significant roles of the butterfly in the ecosystem is pollination associated with regeneration of forest (Bailowitz and Sitter, 2005).

2.12 Economic Importance of Butterflies

During larval stages of their life cycle, caterpillars (cocoon) spins on plants which results in silk production which can be used for making clothing (Mader, 2003). The cultivation of silk moths domestically for fibers in their cocoons has been a major industry in many Asian countries. When unraveled, each silk moth cocoon yields hundreds of meters of strong, durable silk fibre that absorbs colours beautifully and weaves into a soft, glossy fabric (Kunte, 1997). According to Larsen (2006) butterflies of Ghana can potentially provide the basis for income and employment in a number of ways; Ecological tourism and Research activities in butterflies are an important component in biology, entomology, population biology, evolution, and other studies.

Due to such behavior and their aesthetic appearance, they attract tourists (Griffis *et al*., 2001). There are a number of attributes of butterflies that makes them suitable for ecotourism. Butterfly are generally view as highly aesthetic by the general public. Some Lepidopterans are considered destructive. The moth causes damage to cabbage, broccoli, and other crops (Pyle, 1992). Many more moths than butterflies are regarded as pests (Tiple *et al.,* 2011). The caterpillars feed ferociously on leaves and cause serious damage to plants especially the citrus trees (Bailowitz and Sitter, 2005).

2.13 Factors Influencing Abundance and Diversity of Butterflies.

2.13.1 Climatic Factors

Climatic conditions such as sunshine and temperature influence butterfly diversity and abundance (Kremen, 1992). Stefanescu *et al*. (2003) reported that low temperature affects butterfly diversity and distribution. Therefore warmer temperatures benefits butterflies directly because it enables individuals may spend more time acquiring resources (Boggs and Murphy, 1997). According to Chen *et al*. (2009), changes in climatic conditions may soon be more persistence on tropical insects than habitat destruction. Changes in rainfall could affect the diversity and abundance of butterflies (Kremen, 1992). Thus, 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) Rainfall affects butterflies due to their positive effects on the vegetation growth which serves as resource for butterflies (Hill, 1999). 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 less variations or changes in temperatures and rainfall which are most important factors affecting wet and dry season (Spitzer *et al*., 1993). Several environmental factors including temperature and rainfall affect butterflies‘ resource availability and habitat diversity (Currie, 1991). Climatic factors may influence butterfly populations through effects on host quality.

The metabolism of butterfly depends strongly on climatic conditions (Dennis and Sparks, 2006). Butterfly diversity is said to be strongly influenced by the amount of energy available during favourable 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). On the other hand, the release and accumulation of excessive temperature through global warming affect the diversity, abundance and distribution of butterflies.

2.13.2 Habitat Destruction

Butterflies patterns of movements are known to depend on host plants distributions and resources availability (Baker, 1984). Butterflies feed on nectar from flowers and other plants sources such as pollen, trees sap and rotten fruits (Brakefield *et al*., 1984). DeVries *et al*. (1997) showed that, conditions for survival of butterflies are existed in non-disturbed

habitat structure; even though, changes in compositions and structures effects butterflies (Dennis and Sparks, 2006). Butterfly abundance depended
significantly on vegetation characteristics, indicating that areas with high plant resources supported more butterflies (Addo-Fordjour *et al*., 2015). Thus, the relatively lower abundances of butterflies in the highly disturbed forests compared to the other forest types may be due to fewer resources provided by this forest type. He went on to say 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.

Human disturbance on the forest cause destruction and deterioration of natural habitat of butterflies which even leads to natural habitat being lost (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 certain plants that provides trophic resources for caterpillars of butterflies as well as nectar which also supply the adults with food to survive (Brown, 1997). Forest fragmentation often has a more negative effect on forest-dwelling organisms than forest cutting or logging (Maleque *et al*., 2008). Chen *et al*., (2009) remarked that habitat destruction is the greatest threat to tropical insects currently. Loss biodiversity as a result of destruction of habitat also affects conditions that affect species (Maleque *et al*., 2008). Fahrig, (2003) indicated that the effect of human disturbance on the forest ecosystem results in large scale modification and destruction of the forest which in turn affect butterfly diversity and abundance. These disturbances lead to colossal losses of forest biodiversity which may affect butterfly diversity (Kremen, 1992; Griffis *et al*., 2001). Many research works have reported that forest disturbances can have adverse effects on vertical stratifications of butterfly community. Vegetation offers favourable microclimatic conditions for production, sun-basking and mating which are critical for the survival of butterflies (Dover *et al*., 1997). Vegetation structure is likely to be an important factor to butterflies because it is likely to affect the availability of adult and larval resources therefore changes or disturbance in vegetation structure may directly influence species composition of butterflies.

Logging had less impact, while forest conversion to agriculture or pasture exerted a greater impact on overall species richness of ants, birds, and Lepidoptera (Dunn, 2004). Clear felling and conversion of forested land areas to agriculture normally leads to reductions in insect diversities (Holloway et al., 1992). Selective commercial logging has been shown to affect insect diversity, especially species with narrow geographical ranges (Hill *et al.*, 1995; Hill, 1999). Insects are the most diverse fauna on earth, and respond to disturbance more rapidly than other fauna. Butterflies in particular are extremely sensitive to environmental changes resulting from disturbance (Kremen *et al.* 1993). Tangah (2000) also found that selective logging has negative impact on diversity of butterflies.

2.13.4 Occurrence of Competition in the Ecosystem

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 larvae are fed on by birds and other animals (Thomas, 2005). Eggs and young larvae of many butterflies‘ species may suffer heavy predation from invertebrates or birds depending on the type of habitat. There have been many explanations through theories by many authors in terms of competition and its influence on species diversity (Paine, 1971). 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; example is predation (Fahrig, 2003). Predation may affect the breeding of the adults because parts of the mates are reduced during the predation. The larvae that continue the generations are fed on by consumers to create a gap in the growth cycle which affects the diversity (Mader, 2003).

2.5 Diversity and Rarity in the Asenanyo Forest Reserve

The Asenanyo River Forest reserve harbours a wide range of biological resources. Some fauna components of the reserve of global and national conservation and protection requirements using Collar (1994), Satterfield *et al.* (*1998*), the IUCN Red List of Threatened Birds and the Ghana Wildlife Division Conservation Regulation 1971(LI 685) can be found in Table 2.

Table 1: Some Key Faunal Types in the Asenanyo River Forest Reserve

Key Fauna Type	Scientific Name	Common Name	Conservation Status
Birds	*Tropicranus albocristatus*	White-crested Horn bill	BR
	Melanerpes formicivorus	―Abobodua‖	LR
	Cyanomitra obscura	Western Olive Sunbird	CSP

Reptiles	*Dendroaspis viridis*	―Kyerebine‖	LR
Large Mammals			
Primates	*Cercopithecus mona*	Mona Monkey	PP
	Cercopithecus petaurista	Spotted-Nose Monkey	LR
Rodents	*Atherurus africanus*	Bush-tailed Porcupine	PP
	Euxerus erythropus	Striped Ground Squirrel	CSP
Carnivores	*Genetta genetta*	Common genet	PP
	Civettictis civetta	African Civet	PP
	Atilax paludinosus	Marsh Mongoose	LR
Pholidota	*Phataginus tricuspis*	Tree Pangolin	LR
	Potamochoerus porcus	Red River Hog	PP
Artiohactyls	*Tragelaphus scriptus*	Bushbusk (―Owansane‖)	PP
	Cephalophus maxwelli	Maxwell‗s Duiker	PP
	Neotragus pygmaeus	Royal Antelope	PP
	Cephalophus niger	Black Duiker	PP

Source: FC (2010)

A total of 192 species were recorded in the reserve of which 66 are timber species (Hall and Swain, 1981). This figure falls far below the MSNW vegetation zone estimate which stands at 335 trees species. Timber species such as *Celtis mildbreadii*, *Triplochiton scleroxylon*, *Corynanthe pacheyceas*, *Pterygota macrocarpa*, *Antiaris toxicaria*, *Nesogordonia papaverifera*, *Sterculia oblongata*, *Turraeanthus africanus* and *Piptadeniastrum africanum* are well represented above 70 cm dbh (more than 20 stems per 100 ha) in the reserve (FC, 2010). The stockin levels for *Celtis zenkeri*, *Cola giguntae*, *Petersianthus macrocarpus*, *Sterculia rhinopetala*, *Entandrophragma angolense*, *Mansonia altissim* and *Terminalia superba* are moderately low while that of *Cylicodiscus* *gabunensis, guarea cedrata Albezia adianthifolia and Tieghemella heckelii* are low compared to the ecological zone (FC, 2010)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

3.1.2 Location and Extent

The study was carried out in the Asenanyo River Forest Reserve in the Nkawie Forest District of the Ashanti Region. The Asenanyo River Forest Reserve lies between latitudes 6° 17' and 6° 36' North and longitudes 1° 50' and 2° 16' west. This location can be traced on Ghana Survey Department Topographical sheet numbers 121, 122, 125 and 84 on a

scale of 1:62,500. It is currently under Forest Management Unit (FMU) 37. The reserve is a continuous block which is only divided into two unequal halves by the Kumasi – Bibiani road and is situated about 70km from Kumasi (Fig 1). The forest reserve is covered by three District Assemblies, namely: Atwima Nwabiagya (Nkawie), Atwima Mponua (Nyinahin) and Amasie West (Manso-Nkwanta) and covers a gross area of about 22,792 hectares (Table 2). The external boundary of the reserve has a total length of 99.70 km and shares a common boundary with Tano-Offin Forest Reserve on the northern boundary along a stretch of about 5.58 km. The boundary of Asenanyo
River Forest Reserve between boundary points 30 and 35 and between boundary points (BP‘S) 45 and 46 follows the course of the Offin River.

Table 2: Gross Area Distribution of Asenanyo River Forest Reserve

Gross Area (ha)	Productive Area (ha)	Unproductive Area (ha)	Admitted Farms And Village Land (ha)
22,792.00	15,991.97	5,751.03	1,049.00

Source: FC (2010)

Unproductive area include areas under research, protection, convalescence, conversion, plantation and area under Teak (*Tectona grandis*) seed orchard.

3.2.2 Status and Property/Communal Rights

Ownership of the reserve is vested in the Golden Stool for which the stools of Nkawie Kuma, Nkawie Panin, Nyinahin, Domi Keniago, Manso-Nkwanta and Akwamu all act as caretakers. Under the Ashanti Rule No. 6 of 1940 made by the Asantehene and his councilors the forest reserve was selected and maintained as such and published in Gazette No. 35 of 18/5/40 (Reserve Settlement Commissioners Report, 1940). The reserve was constituted under the Kumasi Native Authority Rules of 15th December, 1949 and approved by the then Governor-in-Council. Individual and communal rights in the form of admitted farms and natural benefits respectively are permitted in the reserve. In this regard, the fringe communities have domestic user right over a variety of Non- timber forest products such as:

i. Food: snails, bush meat, mushrooms, fruits, nuts

ii. Medicine: tree bark, herbs, leaves iii. Building materials: poles, bamboo, leaves iv. Household goods: pestles, brooms, mats

v. Soil fertility: litter, humus

Hunting of game is regulated by the Wildlife Division (WD) of the Forestry Commission through the issuance of permits. Currently, Messrs Kumi and Company (with the property mark _KC‘) has the right of Timber harverting in the whole reserve with the exceptions of the Akota village.

3.2.3 Climate and Biodiversity

The Asenanyo Forest reserve lies in the two-peak rainfall belt, with the maximum during May-June and the minimum in September-October. The Reserve lies in the 12501500 mm isohyets zone (Hall and Swaine, 1981). The average temperatures of the area is about 27.9^{0C} and relative humidity is around 85%. The south-westerly wind which is the prevailing wind experienced during the rainy season is replaced by the northeasterly trade winds (Hamarttan) during the dry season. The reserve forms part of Tano-Offin watershed.

Taylor (1960) classified the Asenanyo Forest Reserve as belonging to the *Celtis triplochiton* association, whilst Hall and Swain (1981) put the reserve within Moist Semi-Deciduous North-West subtype (MSNW). Forest tree families that are common in the reserve includes, Moraceae, Sterculiaceae, Ulmaceae, Rubiaceae, Bombaceae and Combraceae. Very limited information on faunal components of the reserve has been published in past management plan of the reserve and other documents. Careful analysis of animal footprints within sample plots during a recent (September, 2009) fauna survey conducted by staff of Resource Management Support Centre (RMSC, Kumasi) and Nkawie Forest District revealed the presence of twenty nine (29) species covering mammals (such as *Cercopithecus mona*, *Civettictis civetta*, *Potamochoerus porcus* and *Tragelaphus scriptus*), birds (such as *Melanerpes formicivorus*, *Cyanomitra obscura* and *Tropicranus albocristatus*), and reptiles (such as *Dendroaspis viridis*)

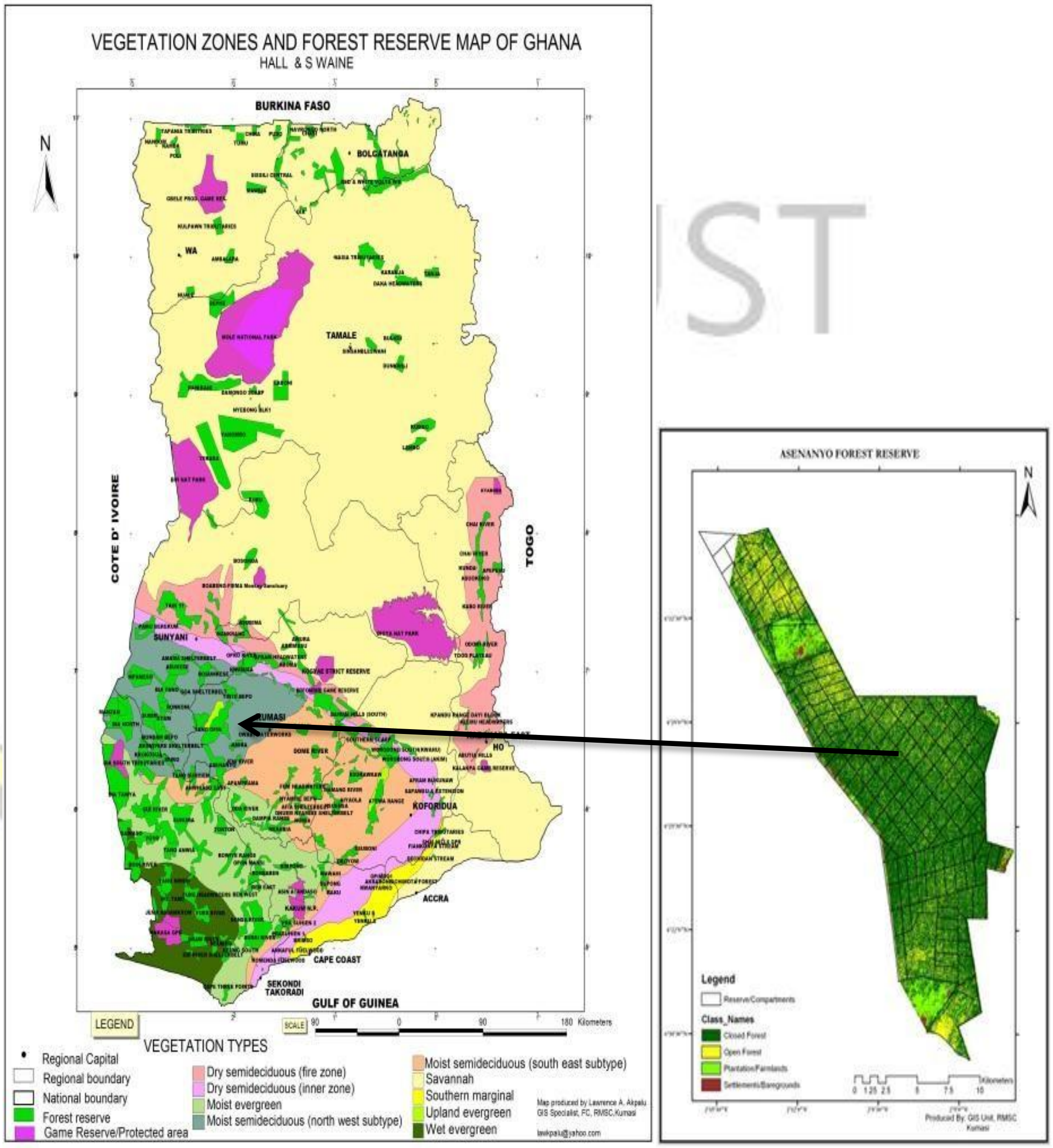

Figure 1: Map of Asenanyo River Forest Reserve (right) with arrow pointing to location on Ghana map (left)

3.3 Butterfly Sampling

The study was conducted within a period of six months (January to June 2014). Sampling was done in the unlogged, selectively logged (more than fifteen years after logging) and plantation forest (fifteen years old) in the forest reserve. The sampling protocol involved the use of line transects and fruit-baiting techniques. At each study site, butterflies were sampled using six transects. A transect of 1 kilometre was used for the sampling in all the study areas. On each transect, eight standard butterfly trap net stations spaced at 100m were installed for a more quantitative butterfly diversity sampling (Plate 1). This was replicated each other month in all the study areas for a period of six months with transect located about 500 m from each other for sampling.

Butterfly trap nets were hung at about 50 cm above the forest floor and baited with different attractants such as overripe pineapples fruits and banana fruits mixed with palm wine for maximum attraction (Plate 2). Baits were replaced with fresh ones after each specimen collection. In addition, walk and catch method using butterfly nets was employed within one kilometre line transect in each of the study areas to capture butterflies that are not easily attracted by the baited traps. Traps were inspected at the same time in all the study sites during the sampling periods between 10.00 and 15.00 hours GMT.

After collection, trapped specimens were transported in glassine envelopes for identification. To avoid a butterfly being identified more than once, permanent markers were used to mark under the wings of the butterfly. Identification was done using Butterflies of West Africa (Larson, 2005), as an identification guide. Butterflies were identified to species-level and grouped into respective taxonomic units (species, genus, and family) using features such as body size, wing shape, wing colour and pattern, flight pattern and behaviors.

Plate 1: Hanging of Traps net in the sampling sites

Plate 2: Baited trapped net

3.4 Data Analysis

Butterfly diversity was analysed using Shannon-Wiener (H') and Simpson's indices of diversity (Magurran, 2004). The Shannon-Wiener index (H') is an estimate of species diversity which incorporates richness and evenness into a single measure whilst Simpson's index is a measure of species evenness.

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \qquad D = \sum_{i=1}^{s} p_i^2$$

Where

H′ = Shannon index;

D = Simpson index and S = Number of observed species the

quantity pi = the proportion of individuals in the ith species

Relative abundance and dominance were calculated for each of the management sites surveyed.

These were calculated using the formulae;

$$\text{Relative Abundance} = \frac{\text{The number of individuals of a species}}{\text{Total number of butterflies captured at each site}} \times 100$$

(Addai and Baidoo, 2013).

Further analysis were done using student edition Statistix 9 statistical package. LSD pair wise comparison test was used to determine differences of means at significance level of 5 % among the management types.

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CHAPTER FOUR

RESULTS

4.1 Species diversity of butterflies in the management zones

Results of Shannon diversity, Species richness, Simpson diversity, Evenness and Abundance of butterflies calculated for each of the management zones in the forest reserve is presented in table 3. Although Shannon and Simpson‘s diversity were high in the selectively logged zone than the unlogged, there was no significant difference ($p>0.05$) between the two, however, there was a significant difference ($p<0.05$) between the unlogged and the plantation management zones. Significant difference ($p<0.05$) existed between the unlogged and the plantation in terms of species richness and abundance, but between the unlogged and the selectively logged zones there was no significant difference ($p>0.05$). Species evenness did not show significant differences ($p>0.05$) among all the management zones in the reserve (Table 3).

Table 3. Butterfly diversity, species richness, evenness and abundance in the different management zones in the Asenanyo Forest Reserve (± Standard error of mean)

	Mean

Parameters	Unlogged Forest	Selectively logged	Plantation
Shannon Diversity index(H')	$3.29^{a} \pm 0.07$	$3.49^{a} \pm 0.09$	$2.93^{b} \pm 0.09$
Shannon Evenness	$0.93^{a} \pm 0.003$	$0.93^{a} \pm 0.005$	$0.92^{a} \pm 0.006$
Species Richness	$34.17^{a} \pm 2.21$	$44.17^{ab} \pm 4.31$	$25.67^{b} \pm 3.22$
Simpson Diversity(1-D)	$0.95^{a} \pm 0.004$	$0.96^{a} \pm 0.004$	$0.92^{b} \pm 0.004$
Species Abundance	$141.83^{a} \pm 13.39$	$162.83^{a} \pm 24.70$	$81.16^{b} \pm 11.37$

Within rows, means with different letters are significantly different ($P < 0.05$)

4.2 Community characteristics of butterflies at Asenanyo Forest Reserve

A total of 2,314 individual butterflies belonging to 87 species, 41genera and 5 families were trapped in the three management zones in the forest reserve. The Selectively logged zone recorded the highest number of individual butterflies (968 individuals) and (82 species). Plantation forest management zone had the least individual butterflies (466) and (39 species). All the butterflies recorded in the three management zones belongs to five families as shown in (Table 4)

Table 4. Community characteristics of butterflies at the Asenanyo Forest Reserve

Attributes	Management Systems		
	Unlogged Forest(UF)	Selectively Logged(SL)	Plantation Forest(PF)
Individuals	880	968	466

Species	78	82	59
Genera	37	39	36
Families	5	5	5

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4.2.1 Families of Butterflies Captured in the forest reserve

A total of five families were recorded in the forest reserve. These were Papilionidae, Nymphalidae, Pieridae, Hesperidae and Lycaenidae. Nymphalidae recorded the largest number of individual butterflies accounting for 77.27% of total number of butterflies whilst Hesperidae recorded the least number of butterflies (Fig. 2).

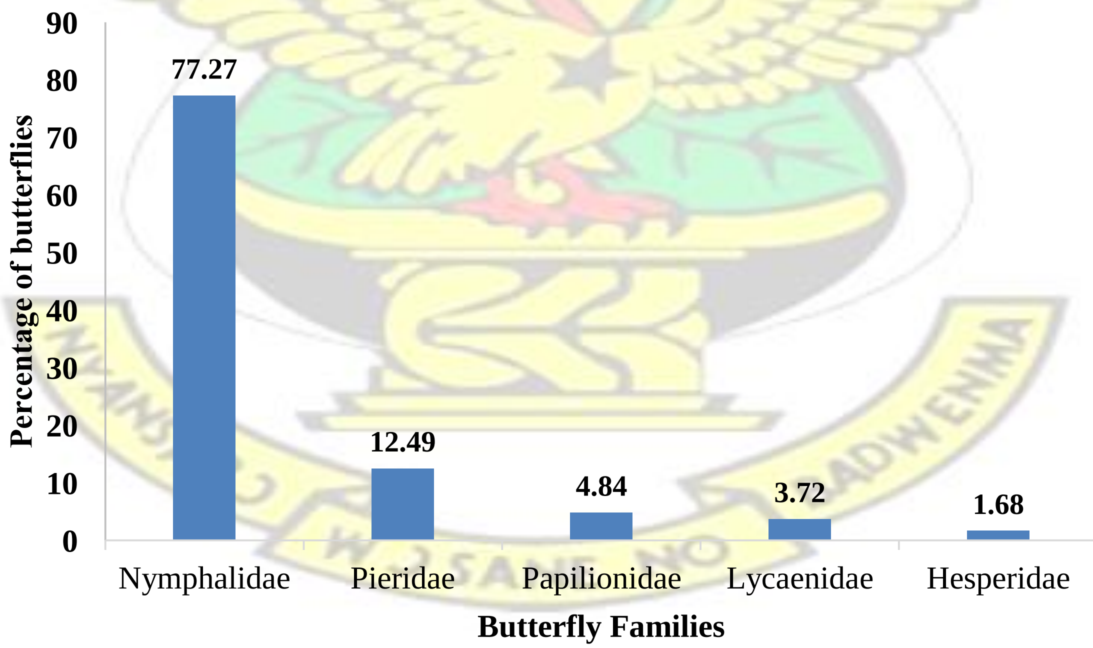

Fig. 2 Families of butterflies recorded in the Asenanyo Forest Reserve

4.3 Distribution and Abundance of captured butterflies among the three management zones

The abundance of butterfly species captured in the forest reserve and their distribution across the management types are shown in Table 2. Genus *Euphaedra,* recorded the highest abundance (503 individuals) made up of 12 species. In terms of species, *Junonia terea* was the most abundant species trapped in the forest reserve, recording 131 individuals followed by *Euphaedra phaethusa* (120 individuals) and *Euphaedra harpalyce* (101 individuals). The Species with least numbers were *Pseadacrea eurytus* (1 individual) and *Abantis tanobia* (2 individuals). In the selectively logged management zone, *E. phaethusa* was the most abundant species (91individuals) species. *Charaxes cynthia* (55 individuals) and *J. terea* (85 individuals) were the most abundant species in the plantations and the unlogged zones, respectively. Thirteen species were found to be unique because they were found in only one forest management zone. *Acrea umbra, A. tanobia, Bicyclus nobiliss, Charaxes petersi,* and *Neptis angusta* were found only in the unlogged forest. The following species were also found only in the selectively logged zone; *Bicyclus medetes, Charaxes castor, Euphaedra ceres, Euphaedra thermis, Euphaedra zampa, Eurytela dryope, P. eurytus* and *Salamis cacta*. Regardless of the management system, *J. tera, E. phaethusa, E. harpalyce, Euphaedra medon and Euphaedra janett*a were the most dominant butterfly species in the forest reserve.

In the unlogged zone, the five most relatively abundant species included *J. terea*

(9.66%), *E. harpalyce* (7.39%), *Bicyclus dorothea* (5.45%), *Catuna crithea* (5.00%) and *Nepheronia thalasina* (4.20%) constituted (31.70%) of 880 individual butterflies species trapped. However, *Papillio nireus*, *Pseudopontia paradoxa*, *Ariadne enotrea*, *Junonia sophus*, *A. tanobia and pentila pecina* were the least relatively abundant.

E. phaethusa (9.83%) E. *medon* (7.24%), E. j*anetta* (6.59%), *Papillio dardanus* (5.51%) and *Junonia terea* (3.78%) which accounted for 32.95% of the 968 butterflies, were the five most relatively abundant species recorded in the selectively logged management zone. The least relatively abundant species included *Leptosia hybrid*, *Leptosia medusa*, *Eurytela dryope*, *Melphenia malthina*, *Egris decastigma* and *Pentila pauli* constituted 1.18%.

Plantation forest also recorded *Charaxes cynthia (*11.80%), *Bicyclus funebris* (10.73*%) A. enotrea (*6.01%), *Bicyclus vulgaris (*5.79*%) and E. harpalyce (*2.97*%)* with a total relative abundance of (37.30%) out 466 individuals butterflies. *Anthene wilsoni*, *pentilla hewitsonii*, *anthene radiate*, *Liptena catalina* and *Euphaedra xypete* recording the least abundant of 2.17%.

Table 5. Distribution and Abundance of butterflies in the different forest management types in the Asenanyo Forest Reserve

Family/Species	Forest Management Systems		
	Unlogged	Selectively Logged	Plantation
PAPILIONIDAE			
Papillio dardanus (Poulton 1924)	15	51	5
Papilio nireus (Linnaeus, 1758)	2	5	-
Graphium Policence (Cramer, 1775)	12	13	9
PIERIDAE			
Pseudopontia paradoxa (Field, 1869)	2	5	3
Eurema hapale (Mabile, 1887)	6	7	-
Eurema hecabe (Buttler, 1875)	12	15	6
Captopsilia florrela (Fabricius, 1793)	13	10	5
Colotis equippe (Linnacus, 1758)	9	11	6
Nepheronia thalasina (Boisduval, 1836)	37	18	12
Leptosia hybrida (Bernardi, 1952)	12	2	6
Leptosia medusa (Cramer, 1777)	9	2	-

Mylothris atewa (Berber, 1980)	11	9	3
Belenois calypso (Drury, 1776)	10	9	5
Appias sabina (Field, 1865)	11	8	3
Leptosia alcesta (Cramer, 1777)	3	5	4
NYMPHALIDAE			
Acraea Pharsalus (Ward, 1871)	5	6	6
Acraea umbra (Drury, 1782)	3	-	-
Ariadne enotrea (Cramer, 1779)	2	5	28
Atrica galena (Brown, 1776)	11	14	6
Bebearia madinga (Felder, 1860)	9	6	3
Bebearia safitza (Westwood, 1850)	3	6	3
Bebearia sophus (Fabriscus, 1793)	6	4	-
Bebearia tentyris (Hewitson, 1869)	9	11	13

Table 5 Cont'd

Family/ Species	**Forest Management Systems**		
	Unlogged	**Selectively Logged**	**Plantation**
NYMPHALIDAE			
Bebearia zonoria (Butler, 1868)	6	16	3
Bicyclus dorothea (Cramer, 1779)	48	12	5
Bicyclus funebris (Meneville, 1884)	13	21	50
Bicyclus Italus (Butler, 1869)	10	8	3
Bicyclus madetes (Condanim, 1986)	-	4	-
Bicyclus nobilis (Aurivillius, 1893)	5	-	-
Bicyclus sandace (Hewitson, 1877)	12	17	9
Bicyclus sangmelinae (Condamin, 1963)	9	10	8
Bicyclus uniformis (Bethune-Baker, 1908)	6	7	4
Bicyclus vulgaris (Butler, 1868)	16	15	27

Catuna crithea (Drury, 1773)	44	18	4
Charaxes boueti (Feisthamel, 1850)	13	14	12
Charaxes brutus (Butler,1869)	12	13	11
Charaxes castor (Cramer,1775)	-	3	-
Charaxes cynthia (Butler, 1869)	14	15	55
Charaxes eupale (Drury, 1782)	12	13	8
Charaxes Petersi (van Someren, 1969)	3	-	-
Charaxes protoclea (Feist, 1850)	9	12	4
Charaxes viola (Butler, 1865)	3	9	-
Cymothea caenis (Drury, 1773)	10	8	-
Cymothoe egesta (Cramer, 1775)	12	11	3
Cymothoe mabilei (Overlect, 1944)	11	6	4
Danus chrysippus (Linnaeus, 1958)	10	14	6
Euphaedra ceres (Fabricius, 1775)	-	3	-
Euphaedra diffusa (Butler, 1866)	4	9	5

Table 5 Cont'd

Forest Management Systems	Family/Species		
	Unlogged	**Selectively Logged**	**Plantation**
NYMPHALIDAE			
Euphaedra harpalyce (Cramer, 1777)	65	23	13
Euphaedra janetta (Butler,1866)	18	61	12
Euphaedra mendon (Linnaeus, 1758)	14	67	11
Euphaedra perseis (Drury, 1773)	4	12	-
Euphaedra edwarsii (Van der Hoven, 1854	8	9	-
Euphaedra phaethusa (Buttler, 1866)	18	91	11
Euphaedra thermis (Hubner, 1806)	-	9	-
Euphaedra velutina	7	9	4
Euphaedra xypete (Hewitson, 1865)	4	7	1
Euphaedra zampa (Westwood, 1850)	-	3	-
Euriphene incerta (Aurivillius, 1912)	4	7	-

Euriphene aridatha (Hewitson, 1868)	8	4	-
Euriphene barombina (Aurivillius, 1894)	17	21	8
Euriphene gambiae (Feisthamel, 1850)	13	15	6
Euryphura chalcis (Felder, 1860)	12	11	3
Eurytela dryope (Cramer, 1775)	-	2	-
Gnophodes betsimena (Dbiday, 1849)	3	9	-
Hallelesis halyma (Fabricus, 1793)	6	3	-
Hypolimnas salmacis (Drury, 1773)	4	8	3
Junonia sophia (Fabricius, 1793)	2	6	-
Junonia terea (Druce, 1773)	85	35	11
Neptis nebrodes (Hewitson, 1874)	3	-	-
Palla ussheri (Hall, 1919)	9	4	3
Pseudacreae lucretia (Cramer,1775)	9	7	5
Salamis cacta (Fabricius, 1793)	-	4	-

Table 5 Cont'd

Family/Species	Forest Management Systems		
	Unlogged	Selectively Logged	Plantation
NYMPHALIDAE			
Pseudacraea eurytus (Linnacus, 1758)	-	1	-
Amaurina hecate (Butler, 1866)	9	4	3
HESPERIIDAE		-	-
Abantis tanobia (Larson, 2005)	2		
Eagris decastigma (Mabille, 1891)	3	1	-
Meza meza (Hewitson,1877)	6	12	8
Melphina malthina (Hewitson, 1876)	4	2	1
LYCAENIDAE			
Pentila hewitsonii (Hewitson, 1876)	9	3	2
Pentila pauli (Staudinger, 1888)	-	1	3

Pentila picena (Hewitson, 1866)	1	5	-
Mimeresia libentina (Hewitson, 1874)	8	7	6
Anthene radiate (Baker, 1910)	8	7	2
Anthene wilson (Taibot, 1935)	6	4	3
Liptena catalina (Smith, and Kirby,1890)	6	3	2

CHAPTER FIVE

DISCUSSION

5.1 Impact of selective logging on butterfly species richness and diversity

The result showed that species richness and diversity of butterflies were similar between the unlogged and selectively logged management zones. Shannon Wiener and Simpson diversity indices the in unlogged forest was similar to that in the selectively logged forest. This implies that the selectively logged forest still harbours resources that favour butterfly success. Ribeiro and Freitas (2012) reported increase in butterfly diversity which is related to the increase in its host-plant availability caused by reduced impact logging. Addo-Fordjour *et al*. (2015) also found that butterflies diversity depended significantly on vegetation characteristics, indicating that areas with high plant resources supported more butterflies. Thus, selective logging which usually promote natural regeneration, could have resulted in an increase in plant diversity and impacted on butterfly diversity positively. Adult butterflies and their larvae depends on monocotyledonous plants for food resources (Harder *et al*., 2008). The selective logging had also increased the intensity of sunlight which leads to relatively warmer microclimatic conditions which also favours butterfly diversity. Warmer temperatures directly benefit butterflies because, it enables individuals to spend more time acquiring resources as butterfly diversity is said to be strongly influenced by the amount of energy available during favourable seasons (Grimaldi and Engel, 2005). Pardonnet *et al*. (2013) reveals that intermediate disturbances can increase butterfly species diversity.

This result is in agreement with a number of others studies on butterflies showing increases in species diversity in response to selective logging (Pardonnet *et al*., 2013; Ribeiro and Freitas, 2012; Harder *et al.*, 2008; DeVries *et al*., 1997). However, this research contrasts with other studies where selective logging resulted in a decrease in species diversity of butterflies (Hill *et al*., 1995; Tangah, 2000).

5.2 Impact of Plantation on the species richness and diversity of Butterflies

Significant differences were recorded between the unlogged and the *Cedrela odorata* plantations management zones for both Shannon Wiener and Simson‘s diversity index as well as species Richness. Obviously, this was due to the reduced complexity of the vegetation, ground coverage and canopy cover associated with the mixed plantation forest compared with the unlogged forest. Monocotyledonous and other herbaceous plant species which most butterflies depends were not sufficient in the mixed plantations and wider canopy openings in the plantation resulted in the lower diversity of butterflies recorded. Due the wide canopy openings, butterflies that are specialized in open and agricultural areas were the most common in the plantations. Human disturbance on a larger scale, such as conversion to plantations, will most probably result in a significant loss of both local and regional butterfly diversity as this is directly related to plant species richness, diversity, abundance as well as canopy cover Holloway *et al.,* 1992)..

Lower butterfly diversity observed in this study is in agreements with a number of other studies which found butterfly to be lower in plantations than the unlogged forest (Fermon, 2000; Barlow *et al.* 2007) However, this finding also contradicts with other studies which showed that diversity and richness of butterflies were higher in the plantations than the unlogged forest (Ramos, 2000; Lawton *et al.*, 1998; Bobo *et al.*, 2006).

5.3 Community characteristics of butterfly species in the Forest Reserve

Butterfly species differed among the forest management zones in the study area due to differences in canopy cover and levels of disturbance. Majority of the butterflies occurred in the unlogged and the selectively logged zones. Differences in canopy cover and level of habitat disturbance led to differences in butterfly faunal composition (Hill *et al.*, 2001; Schulze *et al.,* 2001). Ghana‘s forest butterflies also differ substantially in terms of their relative rarity and tolerance to forest degradation (Larsen, 2005). A total of 2314 individual butterflies are captured within a period of six months in the forest reserve; 38 species captured were species of all type of forest (ALF), 21species are centered in moist evergreen forest (MEF), 13 species are species in wet evergreen forest (WEF), 7 species are dry semi-deciduous and marginal forest (DRF) species, 4 species are practically ubiquitous in all the forest habitats in Ghana (UQB). Only two species were species centered in Guinea savanna (GUI) and Sudan savanna (SUD) and special habitats (SPE) recorded one species each. (Larsen, 2006; Emmel and Larsen 1997).

Family Nymphalidae recorded the largest number of individuals/species whiles Hespiridae recorded the least number of individuals. This might be due to the fact that most members of Nymphalidae are fruit feeders with a wide range of adaptations and environmental preferences (Larson, 1997). Addae-Wireko (2008) reported that Nymphalidae are the widely known butterfly species in Ghana. It is estimated that approximately 900 butterfly species occur in Ghana and most of these were identified to belong to the Nymphalidae which are fruit feeding butterflies (Larson, 1997). Humpden and Nathan (2010) also found Nymphalidae to be most dominant in tropical forests in Kenya.

Members of the genera *Euphaedra*, *Euriphene*, *Bebearia*, *Bicyclus* and *Charaxes* predominated in the reserve. The genera *Euphaedra*, *Euriphene*, *Bebearia*, and *Bicyclus* are known to feed exclusively on fruits (Larsen, 2005b; Molleman *et al.*, 2006) and are therefore more likely to visit baited traps. *Charaxes* species are also known to feed on a large range of food resources but their larvae on the other hand, are known to feed mostly on leaves of tree species in many plant families (Larsen, 2005b) which explains their preponderance in the forest floor.

5.4 Abundances and distribution of butterflies across the forest management types

Selective logged zone recorded the largest number of individual butterflies in the forest reserve. Selective logging resulted in significant openings which provided favourable microhabitat conditions in terms of food resources and microclimatic conditions for butterflies of good forest, species not strictly limited to forest and those with broad geographical ranges. Butterflies, like most insect groups, adopt well to the mild (intermediate) disturbance principle (Fermon *et al*., 2000). *Euphaedra* species were found to be most abundant in the selectively logged zone. *Euphaedra* species are known to feed exclusively on fruits (Larsen 2005b) and are therefore more likely to visit baited traps. Characteristic of these species-groups is their short intermittent flap-and-glide flight along forest trails, making them more abundant in the understorey (Molleman *et al.,* 2006). *E. phaethusa, E. medon, E. janetta, Papillio dardanus and Junonia terea* were the most abundant species recorded in the selectively logged forest. *E. phaetusa* which was the most abundant is known to visit disturbed areas (Larsen 1999), but also prefers the more mature patches inside secondary forest which accounted for their large numbers in the selectively logged zone. *Papillio dardanus* has been found to visit forests of all types but does not normally penetrate the wetter forest types. In theory, these species are those that can be found is all the forest types of Ghana, known to be generally common, have fairly wide ecological ranges, and can colonise both intact and disturbed forests (Larson, 2005) and therefore their abundance in the selectively logged forest was not surprising. According to Bossart *et al*. (2006) these are characteristics which facilitate the persistence of forest butterfly species in highly transformed landscapes. *Leptosia hybrid*, *L. medusa*, *Eurytela dryope*, *Melphenia malthina*, *Egris decastigma* and *Pentila pauli* were the least abundant species in the selectively logged forest. *Melphina malthina* is a rare forest butterflies that keeps to dense undergrowth. Likewise *Egris decastigma and pentila pauli* are also species of wetter forest in good conditions and occasionally visit disturb sites. Species associated with increasingly wet forests are much less rarely, if ever, found in disturb forests (Elbers and Bossart, 2009).

Eight species namely *Bicyclus medetes,Charaxes castor, E. ceres, E. thermis, E. zampa, Eurytela dryope*, *Pseudacrea eurytus*, *Salamis cacta* were only recorded in the selectively logged zone but not in large numbers compared to other species. *Charaxes castor, Eurytela dryope, E. thermis* are species of dry forest (Larson, 2005), but they also visit forests with open canopy cover. Elbers and Bossart (2009) reported that species specialized in dry forest habitat are not uncommon in wetter forests, in areas that are somewhat degraded or more open. The fact that some of these species were recorded in the selectively logged forest indicates that the sites surveyed have elements characteristic of dry forests.

In the unlogged zone which served as the control, the most abundant species were *J. terea, E. harpalyce, B. dorothea, Catuna crithea* and *N. thalasina.* These species are typical forest generalist (Larson *et al*., 2007) and therefore their large in numbers in the unlogged zone was not surprising. *E. harpalyce* is a species occurring in most types of secondary growth as well as intact forest (Larsen, 2005). In the upland evergreen forest of Addo – Fordjour *et al*. (2015) found *J. terea* and *N. thalasina* to be highly abundant in all the forest types surveyed in the forest reserve. *J. terea* is now known to be much more common in West Africa than they ever were due to the widespread destruction and fragmentation of forest cover that has taken place in this part of Africa where as *N. thalasina* is generally a common secondary butterfly with considerable ability to survive intact forest, disturbed areas and transitional zones (Larson, 2005). Nearly one-quarter of Ghana's forest butterfly species are habitat generalists found in all forest subtypes (Larsen *et al.*, 2007).

The least recorded butterfly species in the unlogged zone were *Papillio nireus, pseudopontia paradoxa, A. enotrea, Junonia sophus, A. tanobia and P. pecina.* They are specialized in degraded habitats and open spaces and very few would ever be found within forest of good condition. That why a few of them were trapped in the unlogged forest.

Acrea umbra, Neptis angusta, C. petersi, B. nobilis and A. tanobia were recorded only in the unlogged part of the forest reserve. *Acrea umbra* and *C. petersi* are rare butterflies normally found in rainforest in good condition. *A. tanobia* is also found in dense undergrowth of a mature forest where it may be difficult to capture (Lewis, 2002)

Among the sites surveyed in the forest reserve, plantation forest recorded the least abundance of butterflies. Factors such as resource availability for adults and larval host plants, behavioral traits and interaction with other species explain the decrease in number of butterflies recorded in this type of management zone. In the plantation forest zone, the most abundant species recorded were *C. cynthia, B. funebris. A. enotrea, Bicyclus vulgaris, and E. harpalyce.* These are species that survive in most types of forest habitats, open habitats and agricultural areas. Therefore their high abundance in the plantation zone was not surprising and is in conformity with findings from other studies.

A. enotrea and *B. vulgaris* are known to fly in open country, often penetrating guinea savanna, open habitats of degraded forest parts as well as agricultural lands((Emmel and Larsen 1997; Larsen 1999). In Cameroun, Bobo *et al*. (2006) recorded high abundance of *B. vulgaris* in disturbed (cocoa and coffee farmlands) habitat and a significantly lower occurrence in the natural forests. *C. cynthia* is more common species. Even though they are forest species, they have adapted to gardens and the savannah and are highly polyphagous, with host plant records within several plant families and genera (Larsen, 1999).

Fermon *et al.* (2000) in their surveys of managed and regenerating moist semi-deciduous forests in Côte d'Ivoire found *C. cynthia* and *A. enotrea* to be more abundant in the plantation than in the natural forest. *Charaxes* species are capable of moving between fragments because they have large, robust-bodied and are strong fliers.

According to Larsen (2006) increased presence of these species is an apparent sign of forest disturbance. Hence, these species can be considered as clear-cut indicator species of forest disturbance. *Anthene wilsoni, P. hewitsonii, A. radiate, Liptena catalina* and *Euphaedra xypete* were the least abundant species recorded in the plantations. According to Larson (2005) these species are pure forest butterfly species and this explains why they were the least abundant in the plantations.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

Five butterfly families belonging to eighty seven species and 2314 individuals, were recorded in the Asenanyo Forest Reserve. Species diversity and richness varied with the levels of forest disturbance as there were significant differences in Shannon Weiner index and Simpson's inverse diversity index for the three management zones. The selective logged management zone recorded the largest number of butterflies and therefore species richness and diversity though significant differences were not recorded. There was a significant difference between the unlogged and the plantations in terms of species richness and diversity as well as abundance. Majority (43.67%) of the species captured were those that can inhabits all kinds of habitats. In the unlogged forest *J. terea*, *E. harpalyce*, *B. dorothea*, *C. crithea* and *N. thalasina* were the abundant species whiles in the selectively logged forest the abundant species were *E. phaethusa, E. medon, E. janetta, P. dardanus and J. terea.* The plantation forest also recorded *C. cynthia and B. funebris. A. enotrea, B. vulgaris, and E. harpalyce* as abundant species.

In Ghana a considerable proportion of the forests have been designated as production forests, to maintain biodiversity in these areas effective forest management systems that promotes biodiversity conservation are highly needed. This study highlights the potential importance of the native understorey vegetation for the abundance, richness and diversity of butterflies. Butterfly diversity and abundance were directly related to plant species richness, diversity, abundance and canopy cover, highlighting the important role vegetation play in determining butterfly assemblages in the forest.

Butterflies play important roles in maintaining the health of the ecosystem. They act as agents of pollination of flowers and also constitute a major source of food for birds, mammals, reptiles and other taxonomic groups of animals. Their demise will therefore result in the disruption of critical ecosystem services such as pollination and source of food. Changes in the relative abundances of these indicator species could give an indication of the impact of a management decision on biodiversity.

Considering the needs of the growing population with high requirements of timber resources, selective logging could be considered as a good alternative to preserve butterflies and many other taxa in production reserve where it is not possible to implement in situ conservation. It is also an economically viable option for local populations. Although plantations are generally poor substitutes for the butterfly habitat compared to intact forest, they do provide habitats for some forest species as shown in this study. Therefore complete conversion of natural forest for agricultural activities should be completely discouraged. Monitoring butterflies diversity and abundance is a cost-effective tool for assessing sustainable forest management practices. Conservation of habitats and maintaining species diversity within these areas is likely to be the best strategy in dealing with species loss and species extinction in the depleting Ghana‘s high forest.

6.2 RECOMMENDATIONS

Based on the finding of this study the following recommendations were made;

- Further studies should be conducted in the study area to examine the impact of seasonal variation on the butterfly species.
- This study focused on capturing only understory butterflies which represent only a fraction of the butterflies‘ species in the entire forest reserve. Therefore study which considers vertical stratification should be conducted in the forest reserve.

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