KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

IMPACT OF LOGGING ON BIODIVERSITY AND CONSERVATIONAL STATUS OF THE FURE HEADWATERS FOREST RESERVE IN THE ASANKRANGWA FOREST DISTRICT, WESTERN REGION, GHANA

TSEGANU SAMUEL

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

BY

TSEGANU SAMUEL

APRIL 2014

DECLARATION

I hereby declare that this submission is my own work towards the award of M Sc., Environmental Science and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

The Fure Headwaters Forest Reserve forms part of the network of permanent forest estates in the High Forest Zone of Ghana which are noted for harbouring conservation values. Some conservation attempts have been made by the Ghana Forestry Commission through the creation of Globally Significant Biodiversity Areas. But there remains a critical need to address the conservation of social, cultural, unique flora and fauna values within production management zones. The study sought to assess the main conservational values in the Fure Headwaters Forest Reserve with focus on tree species and mammals and compare the impact of logging activities on these values. The survey was conducted in compartments 17, 26 and 40 of the forest reserve after they had been randomly selected from a group of homogenous compartments stratified according to their logging history. Three sample plots of sizes 100m x 100m were demarcated in each of the compartments. Each sample plot was subdivided into sixteen subplots of sizes 25m x 25m. Four subplots representing 25% of the sampled area were subsequently selected using simple random technique. Tree species with diameter greater or equal to 10cm at breast height (dbh ≥ 10cm) were identified and enumerated within each subplot for the assessment. The mammal survey was however conducted in each of the 16 subplots constituting the one hectare plot demarcated. This was done to ensure that enough ground was covered in the assessment and also to be able to determine promptly the mammal sign densities per hectare. Mammal species were identified with the help of a specialist (zoologist) from the Wildlife Division of the Forestry Commission using identifiable animal signs such as foot prints, skeletons, faeces/droppings, fur, left-over of eaten fruits, physical presence, and indicators of mammal habitats. Star rating species are high in Fure Headwaters Forest Reserve especially in the unlogged forest area but show decrease in the active logging and logged forest areas. It was also found out that logging activities have negative impacts on conservational status of a forest and it is evidenced that when these biodiversity are not carefully managed may result in eventual erosion of genetic resources in the forest reserve. The findings and recommendations may be useful to government agencies whose mandate is to ensure sustainable management of Ghana's forest resources. Some fundamental field operations especially stock survey need to be revised to include details of all conservational values to serve as a guide towards their careful management in production forest reserves.

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ACRONYMS

FAO	Food and Agriculture Organization
FC	Forestry Commission
FMU	Forest Management Unit
FSC	Forest Stewardship Council
GFTN	Global Forest Trade Network
GHI	Genetic Heat Index
GSBA	Globally Significant Biodiversity Areas
HCV	High Conservation Value
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature
NTFPs	Non Timber Forest Products
PFE	Permanent Forest Estate
TUC	Timber Utilization Contract
WWF	World Wide Fund for Nature

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of study

Ghana's forest reserves include internationally significant remnants of the Upper Guinea Moist Forest Biome, which are under severe pressure from habitat degradation and unsustainable management. Some portions of the Fure Headwaters Forest Reserve form part of the network of permanent forest estates in the High Forest Zone of Ghana which are noted to still contain high conservation values. Protection for some of these values has been helped by the creation of the network of Globally Significant Biodiversity Areas (GSBAs), which are strictly conserved. However, there remains a critical need to address the conservation of social, cultural, unique flora and fauna values within production management zones (Kyereh, 2007).

Undisturbed wet evergreen forest types are closely linked with species diversity since the continuous existence of many tree species depends on this forest type. Future development and overall quality of life are critically dependent on the quality of the environment. The natural resource base and the quality of air, water, land, and forest represent a common heritage for all generations. To destroy that endowment indiscriminately in the pursuit of short-term economic and social goals is detrimental to both present and, especially future generations and that a better environmental stewardship is essential to sustain development. Investigations into floral composition and the structure of forests are essential for providing information on species richness of the forest. The changes that forests undergo can potentially be useful for management purposes and as well assist forest managers in understanding forest ecology and ecosystem functions. The biological diversity of tropical forests is immune to physical

disturbances (Jordan, 1995; Swenson, 2009), not only at the genetic level but also at the species, community and ecosystem levels (Sandlund *et al*., 1992; Lewis, 2009). In a tropical forest community like the wet evergreen forest type, there is a lack of tree species dominance (Townsend *et al*., 2008), which coupled with the high species diversity, makes it very vulnerable to physical disturbances (Jacobs, 1998), particularly for unmanaged or ill-managed forests where the forest is disturbed as a result of human activities. Star rating species are threatened by over-exploitation and forest degradation; black star species, one of the star rated species is globally rare and require high priorities for careful management (Hawthorne and Abu-Juam, 1995).

Known for its high floristic diversity and conservation significance, the Fure Headwaters Forest Reserve is home to several tropical species including many threatened, endangered and endemic species. Additionally, some local communities fringing this forest reserve area have their livelihoods intricately linked with the forest, depending on it for various socio-cultural and economic needs (Hawthorne and Abu-Juam, 1995). However, for any forest ecosystem to be considered a high, medium or low conservational value, certain indices would have to be assessed and attained. These include genetic heat index, Shannon Wiener diversity index and when these parameters are assessed at the Forest Management Unit (FMU) level could be used to determine the impact of logging activities on conservational values in the forest.

1.2 Problem statement

Several forest reserves in Ghana contain biodiversity values, environmental service values as well as social and cultural values that are deemed to be of critical significance at the national level, making them high conservational values. Though conservational status assessment is essential in sustaining fragile ecosystems, there are no records of

conservational status assessment in most of the forest reserves in the country. The forest reserved areas are gazetted by the government of Ghana and dedicated to selective harvesting and sustainable management but unfortunately no conservational status assessment has been conducted in most of them to ensure strict protection of threatened and endangered species.

The presence of star rating species in a forest is one of the significant indicators of high biodiversity or richness of the forest. It also signifies the level of management of the forest since they cannot withstand physical disturbances such as wildfires and forest degradation. The abundance of star rating species determines the Genetic Heat Index (GHI) of the forest. A high Genetic Heat Index signifies that the area is relatively rich in rare species (Hawthorne and Abu-Juam, 1995). Consequently, the loss or degradation of the area would represent a highly significant erosion of genetic resources (Afrifa *et al.,* 2013). There are no records of assessments on conservational values in the Fure Headwaters Forest Reserve. In view of this, the survey was conducted to assess biodiversity and determine whether they are of high conservational status with the aim of delineating appropriate management options and prescribing management decisions to enhance the values that exist within the forest reserve.

1.3 General objective

The general objective of this research was to assess the impact of logging on biodiversity and conservational status of the Fure Headwaters Forest Reserve in the Asankrangwa Forest District, Western Region, Ghana.

1.3.1 Specific objectives

The specific objectives were:

i. to identify tree and mammal species (major components of biodiversity) in the Fure Headwaters Forest Reserve;
ii. to determine the conservational status of the forest reserve;
iii. to assess the impact of logging activities on biodiversity and conservational status of the forest reserve.

1.4 Research questions

The study sought to investigate and provide answers to the following research questions:

i. What are the tree and mammal species (major components of biodiversity) that are present in there Fure Headwaters Forest Reserve?
ii. How significant are the identified biodiversity and their conservational status that make them merit strategic management?
iii. How would the conservational status of the identified biodiversity be described?
iv. How has logging activities impacted on biodiversity and conservational status in the forest reserve?
v. What measures can be put in place to ensure the sustainability of identified biodiversity with reference to their conservational status?

1.5 Significance of study

Most timber companies have committed themselves to putting in place measures to ensure long term sustainable and socially responsible forest operations in their Timber Utilization Contract (TUC) holdings or forest concessions. In line with this objective, some companies in Ghana have initiated a process geared towards achieving Forest

Stewardship Council (FSC) certification for good forest management under the Global Forest and Trade Network (GFTN) programme being implemented by the Worldwide Fund for Nature (WWF).

The identification and management of the biodiversity (tree and mammal species) is an essential component of forest certification under the FSC standards. Principle 9 of the FSC principles, criteria and indicators (FSC, 2010) requires that any company undergoing forest certification must carry out an assessment of its forest holdings to identify all definite and potential High Conservation Values (HCVs) and ensure their sound maintenance and management. Although, the Forestry Commission (FC) of Ghana has a system for identifying and managing conservation areas in Ghana's forests, most companies have not conducted conservational value assessment in their concessions or Timber Utilization Contract (TUC) areas to ascertain whether such areas exist for strategic management to meet FSC certification requirements.

Significantly, this research could be used as a yardstick to the assessment of biodiversity (tree and mammal species) in tropical forest ecosystems especially in Ghana for most timber producing companies that seek to demonstrate to their consumers that their operations are environmentally appropriate, socially beneficial and economically viable.

The study could be put to two major uses: At the first instance, it could be used to demonstrate how biodiversity (tree and mammal species) are assessed and conservational status of forests is determined. Secondly, it could provide direct guidance to Forest Services Division staff on actions to be taken in order to improve the actual management and monitoring in order to enhance the conservational status of forests. The study could also be used as standard for evaluating tree and mammal species components of biodiversity in tropical forest ecosystems where assessment has never been conducted.

1.6 Scope of study

The coverage of this study or assessment covered forest management activities in an unlogged forest (compartment 40), active logging forest (compartment 26) and logged forest (compartment 17) of Fure Headwaters Forest Reserve. The forest reserve was initially stratified into three (3) areas depending on the logging history of the reserve. In this case, the forest was categorized into unlogged forest, active logging forest and logged forest.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Forest Resources and ecological zones of Ghana

Ghana is located on the west coast of Africa bordered by Togo in the east, Cote d'Ivoire in the west, Burkina Faso in the north and the Atlantic Ocean in the south. Ghana has a land area of 23.9 million hectares and in 2010 had an estimated population of 24.3 million people (United Nations Population Division, 2010). Ecologically, Ghana is divided into a high-forest zone in the south, accounting for about one-third of the land area (8 million hectares), savanna zone (14.7 million hectares), mostly in the north, and a transition zone (1.1 million hectares). FAO (2010) estimated that Ghana had 4.68 million hectares of natural forest in 2010, which constitutes about 20% of the land area.

2.1.1 Forest types and conservational concerns

The high forest zone is divided into nine forest types: wet evergreen, moist evergreen, moist semi-deciduous (northwest), dry semi-deciduous (inner zone), dry semi-deciduous fire zone, upland evergreen, southern marginal and southern outlier. The semi-deciduous and evergreen forests constitute the main timber producing areas and are the main focus of biodiversity loss and conservational status issues due to human activities especially logging. The main species in the semi-deciduous forests are *Triplochiton scleroxylon* (Wawa), *Mansonia altissima* (Mansonia), *Nesogordonia papaverifera* (Danta) and *Khaya ivorensis* (Mahogany); in the evergreen forests the main species are *Guarea cedrata* (Guarea), *Tieghemella heckelii, Tarrietia utilis* (Niangon) and *Uapaca spp.* (Assam) (ITTO, 2006).

2.1.2 Permanent forest estates

Ghana's forests are divided into forest reserves and 'off-reserve' areas: out of the 266 forest (production) reserves, 216 occur in the high-forest, timber producing zone where human activities through logging impacts negatively on biodiversity and conservational status, while the remainder occur in the savanna. Forest reserves were originally established by the state to promote ecological stability while seeking to guarantee the flow of goods and services for socio-economic development (Bird *et al*., 2006).

Ghana's permanent forest estate (PFE) is estimated at 1.43 million hectares, which are the area of forest in production forest reserves plus the area of planted forests and the area of forest in protected areas. Currently, the total area is 170,000 hectares less than reported in 2005 thereby affecting the conservational status and integrity of forest estates (ITTO, 2006).

2.2 Forest biodiversity

Ghana has some 1185 known species of amphibians, birds, mammals and reptiles according to figures from the World Conservation Monitoring Centre. Of these, 0.8% is endemic, meaning they exist in no other country, and 3.0% are threatened. Ghana is home to at least 3725 species of vascular plants, of which 1.2% are endemic. 4.6% of Ghana is protected under IUCN categories I-V I (IUCN, 2011). The main threats to Ghana's wildlife are habitat destruction in protected areas by agricultural encroachment, uncontrolled hunting and logging, fishing, and wildfires (Tufour, 2012).

2.3 Impact of logging activities on conservational values

The impact of logging and biomass harvesting on the future structure, biological diversity and ecological function of tropical forests is a topic of continuing debate. In

many tropical regions, including the Brazilian Amazon, natural forests are less often ‘‘managed’’ than ‘‘mined’’ for selected high-value timber species or fuel wood. Loggers rarely follow harvesting practices proven elsewhere and give little consideration to long- or even short-term environmental impacts (Uhl *et al*., 1991; Fredericksen, 1998).

If the capacity of these forested lands to produce economic, social and environmental goods and services is to be sustained for future generations, improved management techniques, based on a better scientific understanding of natural forest dynamics and disturbance ecology are required (Hartshorn, 1989; Dawkins and Philips, 1998; Kammesheidt, 1998; De Graaf *et a*l., 1999; Finegan and Camacho, 1999; Finegan *et al*., 1999; Mostacedo and Fredericksen, 1999). On-going work in many tropical countries on the assessment of reduced impact logging techniques is a promising development, one that is increasing our understanding of the critical disturbance factors (and operational methods) affecting post-harvest forest productivity and community structure (Hammond *et al*., 2000; Pinard *et al*., 2000b; Sist, 2000). For example, recent studies in this field have shown that soil compaction associated with the use of heavy machinery in forest harvest operations can have persistent negative effects on natural regeneration, and that minimizing the area used for access roads, skid trails and decking sites greatly diminishes the overall negative impact of logging on future stand productivity (Van Gardingen *et al*., 1998; Pinard *et al*., 2000a).

While it is generally accepted that most tropical forests that are selectively logged or cleared for short term agricultural production eventually regenerate both structurally and functionally (Brown and Lugo, 1990; Attiwill, 1994; Lugo, 1995; Fredericksen, 1998), the rates of recovery of biomass, structural complexity and biodiversity are highly variable. Biophysical factors such as site productivity, susceptibility of the local flora

and fauna to natural disturbances, and landscape-level biotic interactions, all influence post disturbance forest recovery (Uhl, 1987; Gorchov *et al*., 1993; Fredericksen, 1998; Liu *et al*., 1999). Superimposed on these biophysical factors and processes are the human impacts associated directly with logging or other forest disturbances, and those that often occur after the event (such as post-harvest forest clearance and increased susceptibility to fire). Just as the biophysical factors influencing post-disturbance forest dynamics, these impacts are site-specific, varying in their intensity, duration, and thus their influence on natural forest recovery (Hawthorne and Abu Juam, 1993).

2.4 Conservation status of species

The conservation status of a species is an indicator of how likely it is to remain alive at present or in the near future. Many factors are used to assess a species' conservation status, including: the number remaining, the overall increase or decrease in the population over time, breeding success rates and known threats. Geldenhuys (1999) also defines conservation status as the extent to which populations, species or communities have been modified by the influences of man and the degree to which they might be expected to maintain their genetic diversity and ecological processes in the medium term (10 to 100 years).

2.5 Major threats to forest biodiversity conservation

2.5.1 Fire

Fire is a critical factor that has shaped the current distribution and quality of Ghana's forests especially since the El Niño of the early 1980s and the associated droughts (Hawthorne and Abu-Juam, 1995). An estimated 50% of the country's vegetation cover has been destroyed since the wildfires of 1982/83 due to wildfires (MOES, 2002). Aside

the devastation caused directly by these fires, they have also given easier access to local communities to penetrate deeper into the forests for hunting and land clearance for farming. The high moisture levels in the Wet and Moist forests coupled with the short dry season means a somewhat reduced risk of wildfire. This nonetheless does not imply a complete absence of fire hazards as it has been demonstrated that disturbed wet forests are also susceptible to occasional fires. In the Semi-deciduous forests, the role of fire has been much more pronounced (Hall and Swaine, 1981).

2.5.2 Erosion

Water erosion is severe in the forest zones particularly in upland areas and forests that have been disturbed recently. The high rainfall levels and the poor nature of soils in these areas mean that top soil erosion rapidly reduces the capacity of the land to sustain agriculture. This should be observed in the light of the fact that majority of the population in rural Ghana depend on subsistence farming for their livelihoods. High levels of soil erosion and the associated run-off into the water bodies adversely affect the quality of water for domestic use in rural areas (ProForest, 2010). Soil erosion is also the removal of the soil's upper layers by the action of water, wind, or ice. Soil erosion occurs naturally, but human activities can greatly increase its severity. Soil that is healthy is fertile and productive. But soil erosion leads to a loss of topsoil, organic matter, and nutrients; it breaks down soil structure and decreases water storage capacity, in turn reducing fertility and the availability of water to plant roots. Soil erosion is therefore a major threat to soil biodiversity (Wikipedia, 2014).

2.5.3 Species invasion

Closely associated with wildfires in Ghana is the invasion by ground flora and savannah species that rapidly colonize burnt or cleared areas. These aggressive species become dried up in the dry season, creating new fire hazards and causing the forests to enter into a series of subsequent burns with a positive feedback mechanism. *Chromolaena odorata* is the most notorious invasive species in the high forest zones with the capacity of entirely colonizing some reserves and suppressing the regeneration of forest species (Hawthorne, 2002).

2.5.4 Impact of logging on forest structure and composition

Although a Chatham House report released in July 2010 (Lawson and MacFaul, 2010) indicates that illegal logging in Ghana has reduced by about 50% of the 1990 levels, the menace still remains a major threat to conservation in Ghana. There are also indications that illegal loggers have a preference for the most valuable (and often protected/threatened) species (Hansen and Treue, 2008). The effects of illegal logging and onsite chainsaw conversion has been severe in many forest reserves as this is usually done in a haste and with little regard for the impacts of the operations on the residual stand and the environment (Marfo, 2009).

Forest structure and composition and their implications for biodiversity are difficult to evaluate at broad geographic scales and may vary widely depending on (among other factors) the kinds and intensity of human activity and local ecological conditions. It is well-documented, for example, that logging increases the probability of recurrent fire in the Amazonian rain forests (Uhl *et al*., 1991; Nepstad *et al*., 1998), and that this in turn will lead to long term changes in species composition (Cochrane & Schulze 1998, 1999). Logging also affects animal community composition and ecological relationships (Johns,

1996; Lambert, 1992; Ochoa, 2000). Hunting activity near settlements substantially reduces the abundance of mammal species (Muchaal & Ngandjui, 1999) and the construction of roads facilitates logging and hunting as well as land conversion and colonization.

2.5.5 Illegal hunting

Often associated with illegal logging in Ghana is unregulated hunting. Bush-meat continues to be a major source of proteins for many households. There are laws aimed at protecting wildlife in Ghana, but very little in terms of capacity on the ground to enforce them. The creation of new forest roads by logging companies and the effects of wildfires provide hunters with access route to deeper areas of forests and that they are able to pursue the dwindling wildlife further into the forests (Gatti, 2009).

2.5.6 Farming

Ghana has been one of the top producers of cocoa in the past century. This feat has only been achieved through a state sponsored conversion of vegetation to cocoa farms. The country's first forest policy introduced by the colonial government in 1948 made provisions for forest reservations and also allowed for the liquidation without replacement of forests outside of the designated reserves (Hawthorne and Abu-Juam, 1993). The result is that currently, very few forests exist outside of the nationally protected areas. 'Encroachment' within forest reserves is also common as there are instances where commercial cocoa farms have been established (illegally) within protected areas. Some small farming communities that were legally admitted in forest reserves at the time of reservation have grown and subsequently extended their cleared areas within the forest reserves (CEPF, 2000).

2.6 Community organization and tenure

Lands in southern Ghana and the associated resources are owned by communities, families, clans and stools. A stool refers to a community governance/administrative structure that symbolises the social unit. The forests and woodland reserves are however managed by the government on behalf of the local communities who own the lands. Communal ownership of land outside reservation is controlled by the lineage or the clan based on the land-owning groups and allocated to individuals or households who are members of the landholding group. The land ownership system in most cases accounts for how forest fringe community dwellers encroach on forest lands for illegal farming and as a result contribute to biodiversity loss (Marfo, 2009).

2.7 Livelihoods and jobs

For centuries, the economic production, social organization and cultural identity of most communities in southern Ghana have depended on their proximity to forests and forest resources. Though access to these resources has declined in recent decades due to declining resource base, the socio-cultural and economic significance of forests nevertheless persists. ProForest (2010), observed that communities living close to the Fure Headwaters Forest Reserve are predominantly small scale farmers who also depend on other wild resources (such as game, mushrooms, snails, etc.) to complement the production from their farms. Over-dependence on some of these forest resources subsequently leads to the loss of biodiversity and affects the conservation status of the forest.

2.8 Forest conservation attempts

Protection of conservation values in Ghana has been enhanced by the creation of a network of Globally Significant Biodiversity Areas (GSBAs), Hill Sanctuaries, Wildlife sanctuaries and other protected areas in the country. However, this does not totally guarantee the integrity of the forest within timber production forest landscapes. In the actual context of forest loss and degradation of all types, the major conservation objectives are to protect the last undisturbed patch of forest as well as avoiding any further fragmentation of forest blocks (ProForest, 2010).

2.9 Effects of forest degradation and deforestation on biodiversity

Forest degradation refers to any activity that affects the quality of the forest (Guuroh, 2010). According to FAO (2006), forest degradation is the changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services. Very often degradation does not show up so much in decrease of woody vegetation but rather as a gradual reduction in biomass, changes in species composition and soil degradation (FAO, 2000). Fiset (2008) stated that the consequences of degradation are loss of biodiversity, non-suitability of deforested areas for conversion, flooding and soil erosion.

2.10 Protective measures in production forests

About 100,000 hectares of the production Permanent Forest Estates are considered environmentally sensitive (i.e. on steep slopes or erodible soils, or in streamside buffers). Measures exist to minimize damage in such areas: for example, no logging operation is permitted within buffer strips (25 m on either side of streams, and 50 meters on either

side of rivers). No felling into buffer strips is permitted, and any tree or debris that falls within watercourses must be removed (FC, 1998).

CHAPTER THREE

3.0 MATERIALS AND METHOD

Field work for the conservation values assessments was undertaken from October, 2012 to May, 2013. This was preceded by a review of documents, reports and management plans on biodiversity conservation and potential conservational values in the Fure Headwaters Forest Reserve. The assessment involved field visits and observations in the forest and adjacent communities to evaluate trees and mammal resources.

3.1 Study area

The Fure Headwaters Forest Reserve covers an area of approximately 13,000 hectares and it is located in the Western Region of Ghana (Figure 1). The forest reserve is located in the Wasa Amenfi West and Prestea-Bogoso-Huni Valley District Assemblies of the Western Region of Ghana. The reserve however falls within the jurisdiction of the Asankrangwa Forest District of the Forest Services Division. The reserve is located between latitudes 5° 30′ and 5° 20′ South and longitudes 2° 20′ and 2° 10′ East. It has a total perimeter of 68.88km and an external boundary of 55.28km and it is made up of mostly cut lines of 1.85m wide except where the boundary is a stream or a river.

The Fure and Ankasa rivers form the eastern and southern external boundaries of the Fure Headwaters Forest Reserve. The cut lines by these rivers constitute inspection paths and do not form the actual boundaries. The external boundaries are pillared with concrete pillars at intervals of 800 meters (40 chains) and at major changes in direction. In the reserve the corner pillars are numbered consecutively with intermediate pillars on long length of the boundary and indicated by a letter suffix, e.g. BP12C is 120 chains from

BP12 towards BP13. Pillar numbering in the forest reserve were done in a clockwise direction.

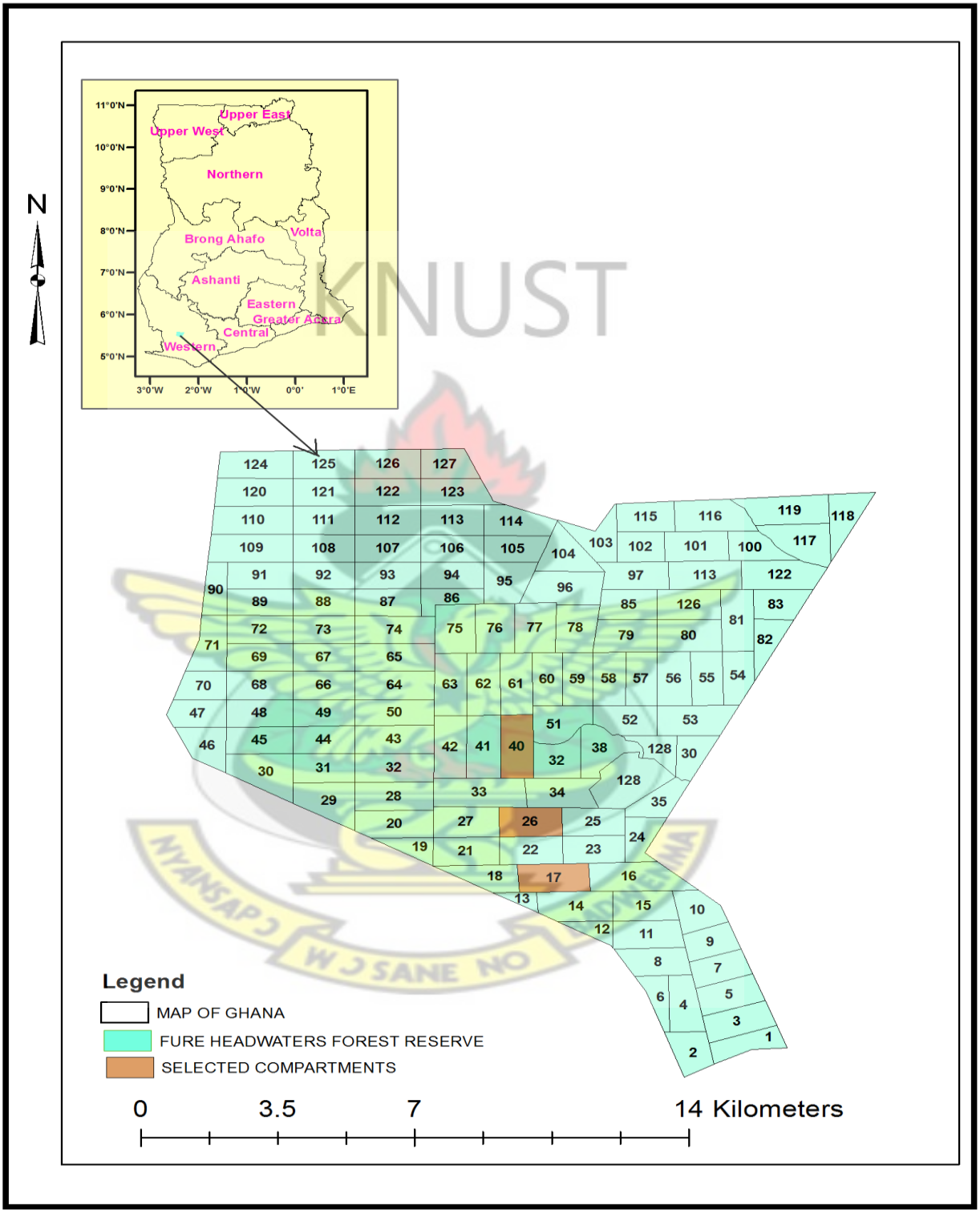

Figure 1. Map of Ghana showing Fure Headwaters Forest Reserve and Sampled Areas

3.2 Selection of sampling areas

The forest was initially stratified into three (3) strata based on the logging history of the forest reserve, after which simple random sampling was used to select the compartments (data collection sites) as follows:

(i). Logged forest: this forest was logged a year before data collection. The compartments identified in this category were 15, 16, 17, 21, 22, 23, 24, 25, and 35, out of these areas; compartment 17 was selected for the assessment.

(ii). Active logging forest: timber production was currently on-going in this forest during the period of the data collection. In this case, compartments 26, 27, 33, 34 were identified and out of these, compartment 26 was selected through simple random technique.

(iii). Unlogged forest: this forest type has not undergone any form of logging. The compartments identified in this category were 40, 41, 42, 36, 51, 52, 53, 54, 55, 56, 62, 63, and 39, out of which compartment 40 was selected to serve as control against which impact of logging activities in the other forest areas was evaluated.

3.2.1 Equipment for fieldwork

The following field tools and equipment were used specifically to measure field data:

- GPS (Garmin 12 XL), for locating positions of sample plots
- Photo guide to the forest trees of Ghana (Hawthorne & Gyakari, 2006) for the identification of tree species and their star ratings
- Handheld compass for taking directional bearings
- Measuring tape for measuring distance and plot size
- Diameter tape for measuring tree diameter

3.3.2 Demarcation of sample plots

Three (3) sample plots were demarcated in each of the forest areas selected: logged forest, active logging forest and unlogged forest. Each sample plot measured one hectare (100m x 100m) and was subdivided into sixteen (16) subplots of size 25m x 25m. Four (4) subplots representing 25% of each sampled area were subsequently selected using simple random technique (Figure 2).

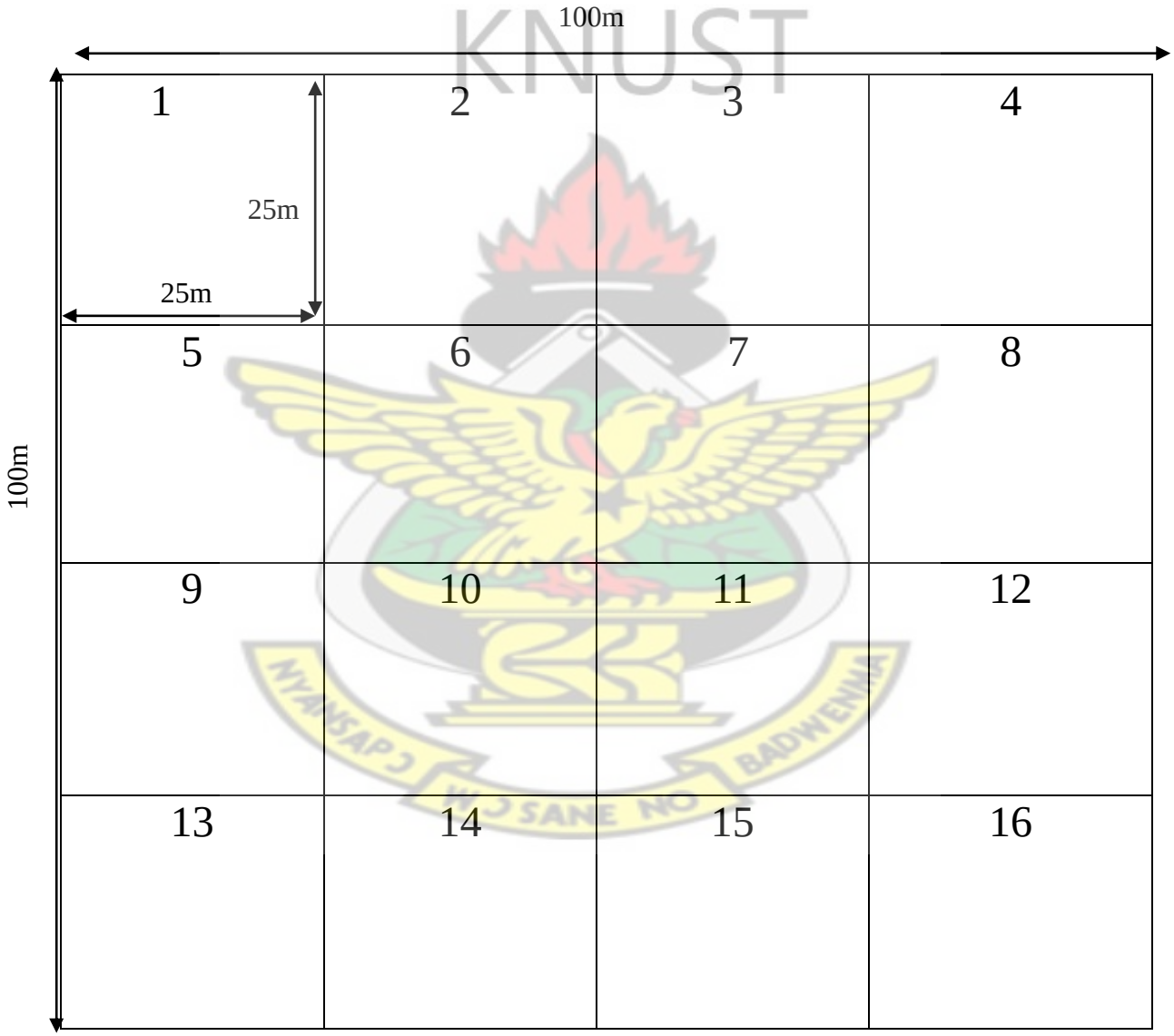

Figure 2. Diagram showing plot layout

3.3 Data Collection: trees species

Tree species with diameter greater or equal to 10cm at breast height (dbh ≥ 10cm) were identified and enumerated within each subplot (Plate 1). The tree species were identified with the help of a tree identification specialist (taxonomist) using identifiable features such as leaves, flowers, fruits, colour of latex and bark. Specimens of tree species that could not be identified on the spot were collected and later identified using standard reference manuals (Hawthorne and Jongkind, 2006; Hawthorne and Gyakari, 2006).

Plate 1. Measurement of tree diameter at breast height

3.5 Star categories and weight classes as defined for Ghana

The star rating categories and weight classes of tree species as defined for Ghana are as shown below (Table 1):

Table 1: Star rating categories and weight classes of trees

STAR	WEIGHT FOR GHI	COMMENT
BLACK (BK)	27	Urgent attention to conservation of populations needed. Rare internationally, and at least uncommon in Ghana. Ghana must take particular care of these species
GOLD (GD)	9	Fairly rare internationally and or locally. Ghana has some inescapable responsibility for maintaining these species
BLUE (BU)	3	Widespread internationally but rare in Ghana, or vice versa. It may be in Ghana's interests to pay attention to protecting some of these species.
SCARLET (SC)	1	Common, but under pressure from exploitation. Exploitation needs to be curtailed if usage is to be sustainable. Protection on all scales vital.
RED (RD)	1	Common but under pressure from exploitation. Need careful control and some tree by tree area protection.
PINK (PK)	1	Common and moderately exploited. Also non abundant species of high potential value.
GREEN (GN)	-	No particular conservation concern
OTHERS	-	Non forest species, or excluded from analysis for other reasons

(-) in weight means not applicable. Adapted from Hawthorne and Abu-Juam (1995), Hawthorne (1996)

The Genetic Heat Index (GHI) values of tree species are calculated as follows:

$$GHI = \frac{(BK \times BK\ weight) + (GD \times GD\ weight) + (BU \times BU\ weight) + (RD \times RD\ weight)}{BK + GD + BU + GN + RD} \times 100$$

Where:

GHI = Genetic Heat Index,

BK = Number of black star species,

GD = Number of gold star species,

BU = Number of blue star species,

GN = Number of green star species

RD = Number of red, scarlet and pink star species (Hawthorne and Abu-Juam, 1995).

3.6 Data Collection: Mammals

Mammal species were identified with the help of a specialist (zoologist) from the Wildlife Division of the Forestry Commission using identifiable animal signs such as foot prints, skeletons, faeces/droppings, fur, left-over of eaten fruits, physical presence, and indicators of mammal habitats (Plate 2).

Plate 2. Identification of mammal sign (foot print)

The assessment also recorded observations made on other activities such as hunting, illegal farming and other unapproved practices that usually militate against conservation of biodiversity and conservation status of the forest. Additionally, during the assessment, notes were taken on the structure of the forest canopy, the most abundant large tree species, the visibility of the understorey and nature of the terrain with the aim of determining the structure and conservation status of the forest.

Most parts of the mammal census began in the early hours of the morning and usually lasted for between five and six hours. The major determinant of the duration of a census in most cases was the extent of habitat and the availability of animal signs. To compliment information from field walks, informal interviews were conducted in some

forest fringe communities to determine the presence or absence of species of conservation importance as well as of cultural significance. It also helped in the study to know about local extinction of some species. Evidence of mammal presence in the sample areas and information from informal interviews taking into consideration the history of species known to have existed in the Fure Headwaters Forest Reserve were used to generate a species list.

3.7 Data Analysis

3.7.1 Determination of Genetic Heat Index (GHI)

Genetic Heat Index (GHI) uses a star rating for the different endemic plant species that are found in an area and uses this to identify areas of concentration of rare species. A star rating system, based on the work of Hawthorne and Abu-Juam (1995) and Hawthorne (1996) in Ghana is used to define the conservation status of each species in a study. The factors considered when categorizing species into star ratings are their distribution, ecology, local abundance, taxonomy, life history, interaction with ecosystem parameters and economic importance (Hawthorne, 1996). Therefore, species that are endemic, rare, threatened, or likely to represent a scarce genetic resource, are considered more valuable than others. Hence, forests richer in such species receive a higher score than others. The Genetic Heat Index (GHI) concept was developed by Hawthorne, 1996) to express the conservation value of a given forest. GHI is an attempt to provide a scale, on which to measure the genetic 'temperature' or value of a forest. The following GHI values are defined for the various conservation classes (Hawthorne, 1996): Very high conservation value for (GHI >200); High conservation value (150 ≥ GHI <200); Moderate conservation value (100 ≥ GHI <150); Low conservation value (50 < GHI <100) and very low conservation value (GHI <50).

3.7.2 Tree diversity

A diversity index is a mathematical measure of species diversity in a community. The Shannon Weaver Diversity Index was used to determine the diversity of tree species in each sampled area. The measures of the index were used to determine the impacts of logging activities on biodiversity and conservation status of the forest reserve. The formula used was $H' = -\sum_{i=1}^{s} pi \ln pi$, where H' = species diversity; s = number of species; *pi*= proportion of *i*th species in the sample and In = natural log of *pi* (Magurran, 1988). Diversity indices provide important information about rarity and commonness of species in a community. The ability to quantify diversity in this way is an important tool to determine biodiversity and conservation status of an ecosystem (Begon *et al*, 1996).

3.8 Statistical Analysis

Statistical analysis involved the use of one-way analysis of variance (ANOVA) at 5% level of significance using the computer programme Statistical Package for the Social Scientist (SPSS). The one-way ANOVA was used to determine the significant difference among the forest areas.

CHAPTER FOUR

4.0 RESULTS

4.1 Tree species composition and their star ratings

A total of 307 tree species were identified in the study area with most of the species belonging to the families Apocynaceae, Meliaceae, Sterculiaceae, Rubiaceae, Fabaceae, Olacaceae and Sapotaceae. Out of this, 62, 40 and 28 star rating species were recorded in the unlogged forest, the active logging forest and the logged forest respectively of the Fure Headwaters Forest Reserve (Figures 3-5). Conspicuously missing from the list of star rating species in the forest reserve is the Gold star species.

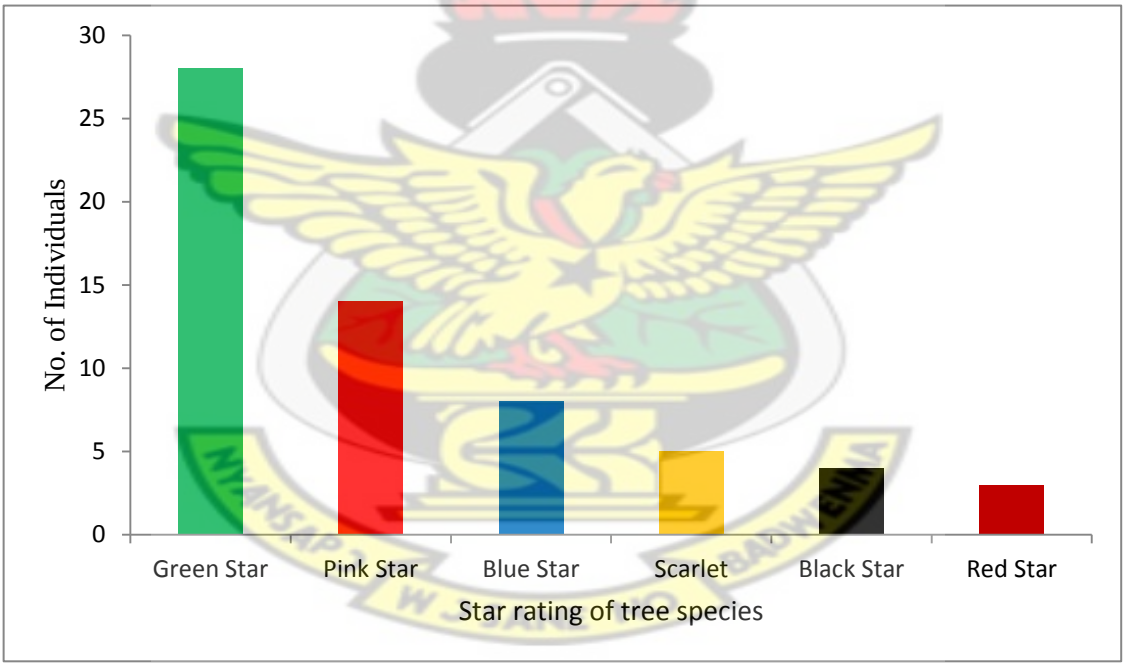

Figure 3. Star rating of tree species in the unlogged forest

In the unlogged forest, the highest number of individuals was recorded among the green star category followed by pink star category with the red star recording the least number of individuals (Figure 3).

Similarly, in the active logging forest, 40 star rating species were recorded with 19 green star species, 9 pink star species, 6 blue star species, 4 scarlet species, 1 black star species and 1 red star species (Figure 4).

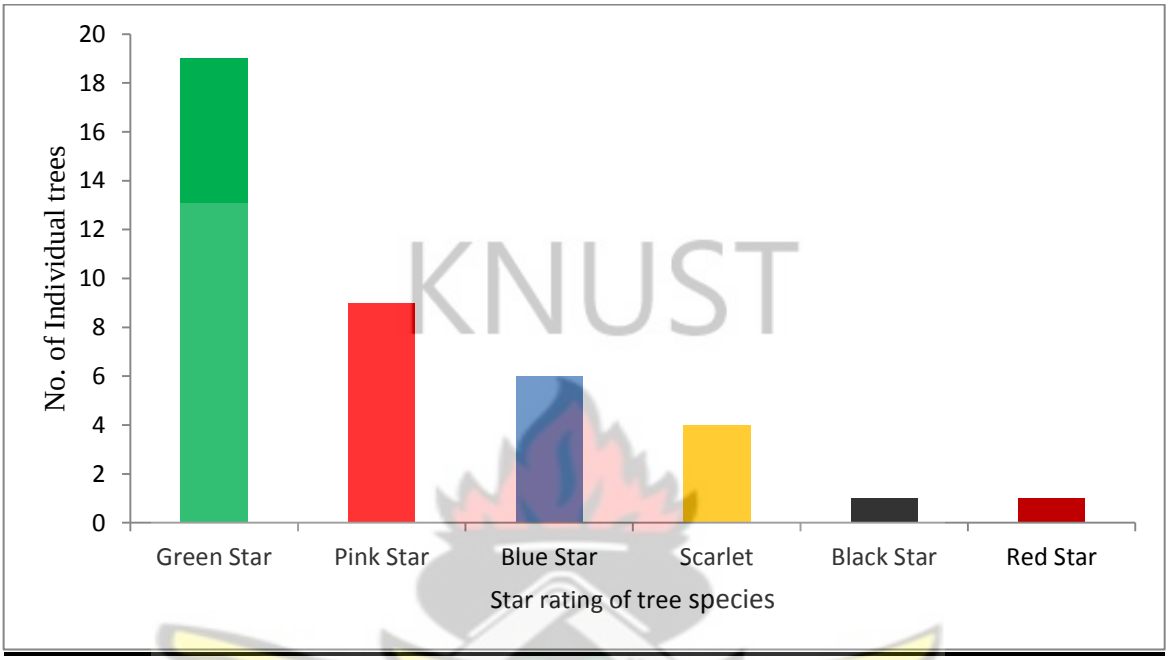

Figure 4. Star rating of tree species in the active logging forest

In the logged forest, 28 star rating species were recorded with 9 green star species, 8 pink star species, 5 blue star species, 3 scarlet species, no black star species and 3 red star species (Figure 5).

No Gold star species was recorded in any of the forest areas assessed. On the whole, green star species represented 43%, pink star species 24%, blue star species 15%, scarlet species 10%, red star species 5% and black star species 3% of the total star rating species encountered in all the forest types during the survey.

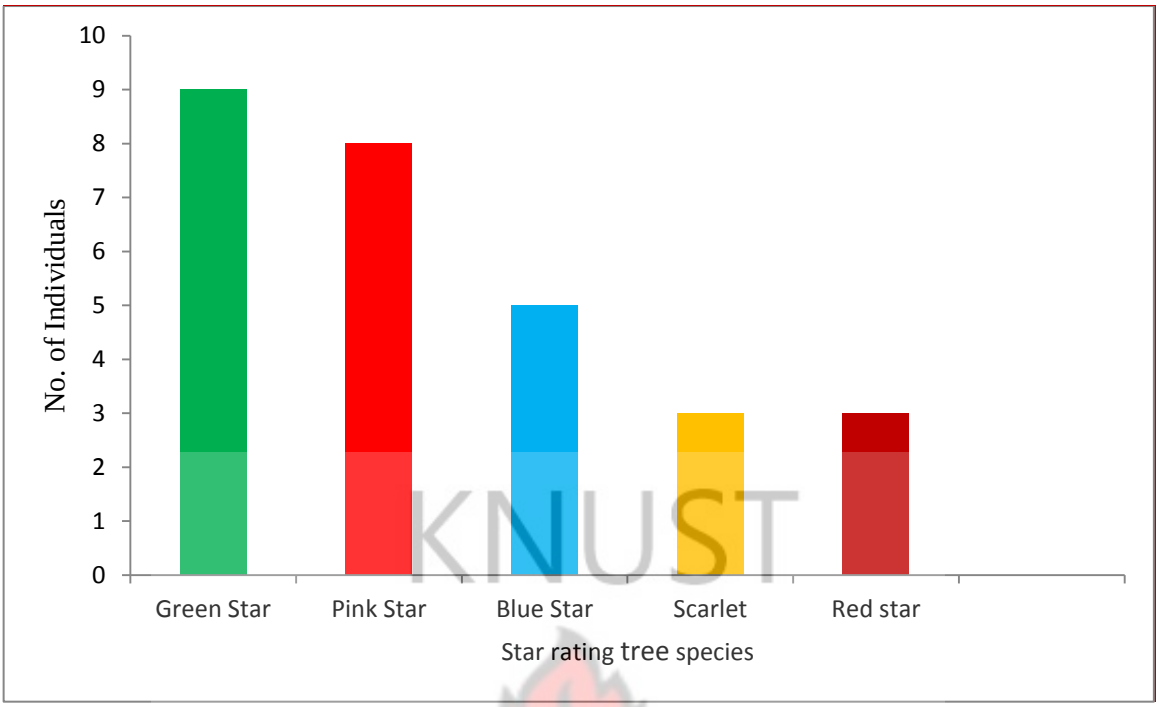

Figure 5. Star rating of tree species in the logged forest

4.2 Tree species abundance

The dominant tree species identified in the Fure Headwaters Forest Reserve in descending order of abundance are as follows: *Strombosia glaucescens, Allanblackia floribunda, Cola nitida, Turreanthus africanus, Dacryodes klaineana, Tieghemella heckelii, Piptadeniastrum africanum and Hannoa klaineana* (Figure 6). There were other tree species present in relatively low numbers in terms of abundance. These species include *Bombax buonopozense, Hannoa klaineana, Khaya ivorensis, Terminalia superba, Lovoa trichiloides, Entandrophragma cylindricum, Daniellia ogea, Nauclea diderrichii.*

For each of the species identified and recorded, the unlogged forest recorded the highest number of individuals representing 46% of the total number of trees enumerated. The active logging forest recorded 32% of the number of individual trees while the logged forest accounted for 22%. It could be deduced that the species abundance reduced in

numbers in areas with differing timber logging history. The unlogged forest area recorded the highest number of species, followed by the active logging forest area with the logged forest recording the least number of individual species.

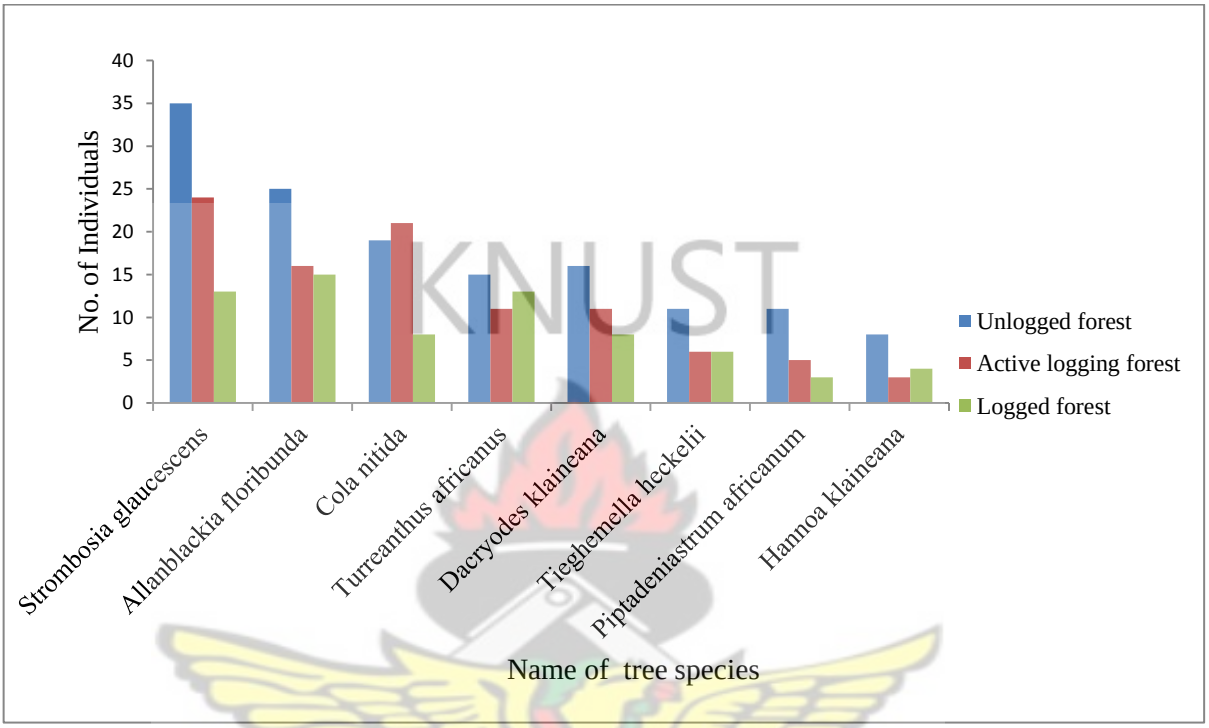

Figure 6. Dominant tree species in three forest areas

4.3 Genetic Heat Index (GHI) of the Fure Headwaters Forest Reserve

Some of the star rating species were relatively abundant in several parts of the forest, and those areas had high GHI ranking. The unlogged forest area had the highest GHI of 293 with the active logging and the logged forest areas recording GHI of 195 and 135 respectively (Figure 7). This gives an indication that the unlogged forest is very high in conservational values followed by the active logging area as high and the logged area as moderate.

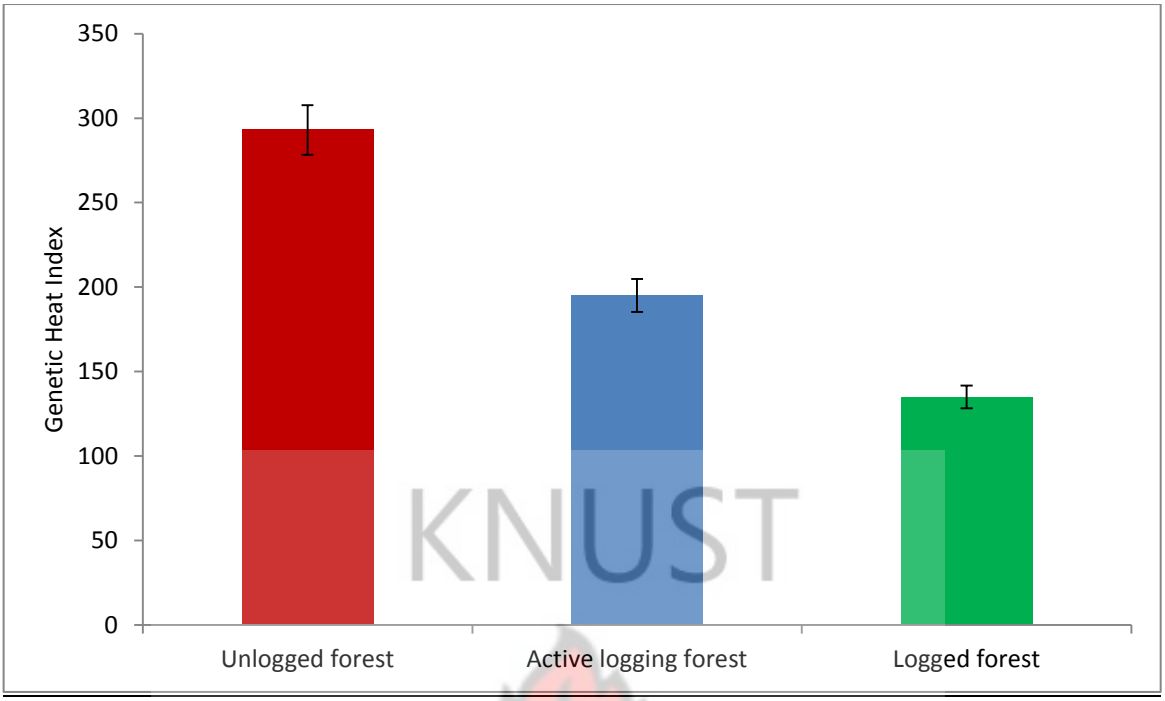

Figure 7. Genetic Heat Index of Fure Headwaters Forest Reserve

4.4 Tree species diversity

The results for the tree species diversity in the three compartments of the Fure Headwaters Forest Reserve are presented in Table 2.

Table 2 Mean Shannon Diversity Index of Trees in Fure Headwater Forest Reserve

Forest area	Shannon Weiner Index*
Unlogged forest	3.124[a]
Active logging forest	2.029[b]
Logged forest	1.134[c]

**Means in the same column that have different superscripts are significantly different at the 5% significance level.*

The Shannon Wiener Diversity indices (Table 2) showed that, tree species were significantly higher in terms of species diversity in the unlogged forest than in both the active logging and the logged forest areas. The unlogged forest recorded a diversity index of 3.124, while the active logging and the logged forest areas recorded a diversity index of 2.029 and 1.134 respectively.

4.5 Mean basal area

The mean basal area of tree species in the unlogged areas of the Fure Headwaters Forest Reserve was significantly higher compared to those in the active logging and the logged areas (Table 3). The impact of logging in these two forest areas are reflected in the reduced mean basal area of 21.3m²/ha and 19.4m²/ha respectively.

Table 3: Mean basal area of trees in three different forest areas

Forest area	Mean Basal Area (m²/ha)*
Unlogged forest	31.9[a]
Active logging forest	21.3[b]
Logged forest	19.4[c]

**Means in the same column that have different superscripts are significantly different at the 5% significance level.*

4.6 Diameter class distribution of trees

The unlogged forest area had abundant tree species of higher diameter class 110–129cm whilst the active logging and the logged areas showed fewer individuals in the higher diameter class. Peak abundance for the unlogged forest was within the diameter class 50-

69cm, just the same as in the active logging area but peak abundance for the logged area was within diameter class of 70-89cm (Figure 8).

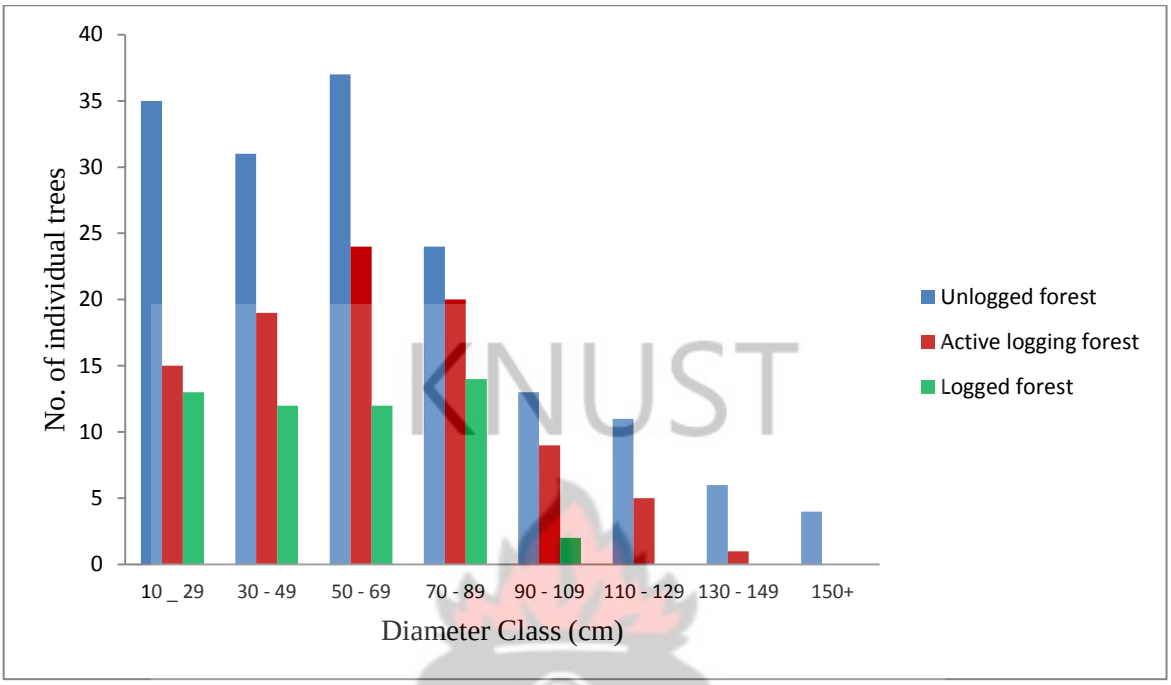

Figure 8. Diameter class distributions in the different forest areas

4.7 Mammal composition and diversity

A total of 21 actual sightings of animal signs indicating the presence of nine different mammal species were recorded in the Fure Headwaters Forest Reserve (Table 4). The mammals identified were of the following groups: primates, carnivores, ungulates and rodents. The highest number of mammal signs was sighted in the unlogged forest area. The active logging forest area recorded the least number of mammal signs.

Rodents were the most dominant animal species and accounted for about 42% of the total animal signs that were recorded (Table 4). Primates recorded the least number of individuals representing 2% of the total number of mammals enumerated. Ungulates and carnivores recorded 23% and 33% animal signs respectively. The Giant Rat (*Cricetomys emini*) were the most frequently observed and accounted for about 20% of all detections

followed by the Maxwell's Duiker (*Cephalophus maxwelli)* comprising 11% of the observations (Figure 9). It was evident from the survey that the activity of primates through feeding was very low. However, a few feeding signs of Demidoff's galago were recorded in the unlogged forest (APPENDIX I).

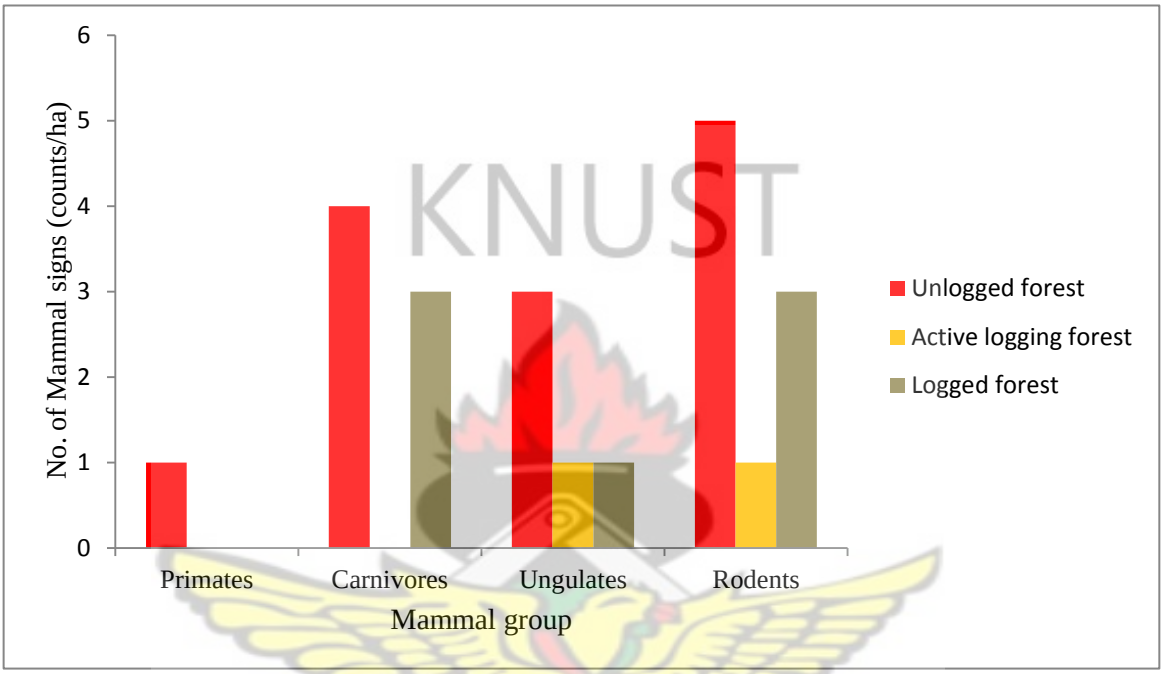

Figure 9. Mammal sign densities in in the Fure Headwaters Forest Reserve

4.8 Conservational concern

From informal interviews, a further eight large mammal species could be present in some portions of the forest reserve. These are the African Forest Elephant (*Loxodonta africana cyclotis*), African Forest Buffalo (*Sycerus caffer nanus*), Bongo (*Tragelaphus euryceros*), Chimpanzee (*Pan troglodytes verus*), Leopard (*Panthera pardus*), Yellow backed Duiker (*Cephalophus silvicultor*), Bush-buck (*Tragelaphus scriptus*) and Red river hog (*Potamochoerus porcus*). Some of the respondents indicated that animal tracks indicators were confirmed by hunters who roam far into the forest reserve in search of game.

Interactions with some fringe communities suggested that four other mammals which were believed to be present in the reserve have not been encountered for over 20 years. These are the Ogilby's duiker (*Cephalophus ogilbyi*), Giant Forest Hog (*Hylochoerus meinertzhageni*), Giant Pangolin (*Smutsia gigantea*) and Crested Porcupine (*Hystrix cristata senegalica*). Hence they are believed to be locally extinct. This scenario raises concerns on conservational values and how they are managed in production forest reserves. At most sites where indicator signs of mammals were detected, used gun cartridges, traps and other hunting devices were found giving an indication of illegal hunting.

Table 4: Mammal presence sign densities (counts/ha) for different logging regimes in Fure Headwaters Forest Reserve

Mammal Group	Common Name of mammal	Scientific Name of mammal	Mammal tracking indicators	No. of Signs Detected in Unlogged/Active logging/Logged forest		
Primates	Demidoff's Galago	*Galagoides demidovi*	Feeding sign (left over food)	1	0	0
Carnivores	Mangoose	*Genetta digrina pardina*	Footprint	1	0	1
	Cusimanse	*Crossarchus obscures*	Fur	2	0	1
	African Palm Civet	*Manis tricuspis*	Skeleton	1	0	1
Ungulates	Maxwell's Duiker	*Cephalophus mawelli*	Footprint	2	0	1
	Black Duiker	*Cephalophus niger*	Footprint	1	1	0
Rodents	Grass cutter	*Swinderianus*	Feeding signs (left over food)	2	0	1
	Giant Rat	*Cricetomys emini*	Habitat	2	1	1
	Squirrel	*Funisciurus sp*	Actual sighting	1	0	1
Total				13	2	7

CHAPTER FIVE

5.0 DISCUSSION

5.1 Tree species composition and their star ratings

Strombosia glaucescens (pink star) was found to be the most abundant plant species in the forest reserve followed closely by *Allanblackia floribunda* (pink star) and *Cola nitida* (pink star). These species are mostly found in undisturbed evergreen forests and the presence of these species in abundance could be considered as an indicator of forest richness in terms of biodiversity. This confirms the observation by Hawthorne and Jongkind (2006) that *Allanblackia floribunda* is commonly found in evergreen forests. The other star rating of species, green, pink, black, red, scarlet, and blue stars were also found in the Fure Headwaters Forest Reserve. Investigations into the star rating of the plants showed a high proportion of green star species. These species are common in Ghana and are of no particular conservation concern (Hawthorne and Gyakari, 2006). The pink star species constituted over 20% of the star-rated plant species but are much higher than the scarlet star species which in turn were far higher than the red and blue star species. The pink star species are of greater conservation concern because of threats from exploitation (Hawthorne and Abu-Juam, 1995).

Serious pressure from heavy exploitation in the past (Hawthorne and Gyakari, 2006) might have undermined the status of the scarlet and red star species which are of conservational concern. According to Todaro and Smith (2000), due to ignorance or economic and/or social necessity, communities might have inadvertently destroyed or exhausted the resources on which they depended on for survival. This is unacceptable because the destruction of that endowment indiscriminately in the pursuit of short-term economic and social goals could be detrimental to both present and especially future

generations and that a better environmental stewardship is essential to sustain the resources (Todaro and Smith, 2003). From the study, the low proportion of black star species (3%) and blue star species (15%) is due to the fact that they are rare in Ghana as reported by Hawthorne and Gyakari (2006). Consequently, the gradual reduction or absence of rare species in the logged and the active logging forest areas of the Fure Headwaters Forest is an indication that logging activities is detrimental to the sustainable development of forest resources.

5.2 Tree species abundance

Comparatively conservational values based on the abundance and star rating of tree species identified in the three forest areas assessed indicates that conservational values decline when the forest environment is disturbed through logging. For each of the star rating species identified there was some form of decline in the number of individual species in the logged and the active logging forest areas of the Fure Headwaters Forest Reserve. This is a clear indication that logging activities in the forest have negative impacts on biodiversity and integrity of conservational status of the forest.

Forestry Commission through its Forest Services Division is mandated by law to manage and strictly monitor the operations of timber logging companies in forest reserves. In view of this, major management prescription is provided for logging activities after a field stock survey operation has been conducted. Field observations and logging activities observed during the research indicated that very little or no attention was given to biodiversity and conservational values. This prescription is left out when management strategies are spelt out to logging companies. For instance, most black star species are not harvested for timber and subsequently are seldom enumerated during stock survey operations to the detriment of the survival of these species of global concern. Data from

this thesis confirms the viewpoint of Hawthorne and Abu-Juam (1995) that if star rating species are not treated with care, most conservational values could be lost through commercial logging activities.

5.3 Genetic Heat Index (GHI) of the Fure Headwaters Forest Reserve

Tree species richness of a forest ecosystem depends on the number and category of species per unit area (Hawthorne and Abu-Juam, 1995). The star ratings of a species define its weighted average referred to as Genetic Heat Index (GHI), and this provides a framework for defining the conservation value of a tract or sample of forest of any size. Some of the star rating species were relatively abundant in the unlogged part of the forest, and had a high GHI ranking. This may be attributed to the impacts of the logging activities in the other two forest areas (i.e. the active logging and the logged forest areas). The relative ranking of the conservational values indicates that timber logging impact negatively on biodiversity and genetic resources. Field observations revealed that little or no attention is given to tree species of global significance especially when no management prescription is given in the logging plan of the operating company or Timber Utilization Contract holder. In view of this, the logging company operating in the forest areas assessed gives no attention to other species not prescribed in the yield allocation list.

Additionally, the research results indicate that the active logging forest area had a relatively higher GHI than the logged forest area. This could be due to the fact that the logged forest was yet to recover from logging shocks and might have contributed to the lower GHI. The logging histories of the two forest areas assessed indicated that compartment 17 had completely been logged and closed some two years ago before the conduct of the survey, while logging operations were still on-going in compartment 26

with about 60% area covered. This implies that a logged forest area takes some considerable length of time (years) to recover from logging shocks. The unlogged forest has the highest GHI with the value of 293 which indicated that it has a very high conservational value with higher biodiversity. This might be due to the absence of human disturbance. These findings are in agreement with the observations made by Hawthorne and Abu-Juam (1995) who reported that high GHI values are due to the presence of many diverse star rating species in an undisturbed forest. Similarly, low GHI in the logged forest implies that the area have low biodiversity which could be due to inability of the environment to support the development of star rating species because of forest degradation resulting from logging activities in agreement with the findings made by Afrifa *et al*, 2013.

Timber logging involves the use of heavy equipment and machinery which tend to impact on the forest ecosystem in various ways. The decrease in the GHI of the forest cannot be explained without mentioning how machinery affects fragile forest ecological environment. Chazdon (2003) observed that disturbance that impacts on soils as well as above ground vegetation, such as the use of bulldozers and skidders during logging operations, can significantly slow down the rate of forest structural recovery and can have long-lasting effects on species composition. The recovery of soil fertility is closely linked with the recovery of above-ground biomass. The timber logging company operating in the Fure Headwaters Forest Reserve was observed to be using heavy equipment and machinery such as two D7 CAT bulldozers, two CAT skidders. These heavy machinery were spotted to be operating in only one compartment of the forest area and might explain the reason behind the reduced GHI in the active logging and the logged forest areas.

5.4 Tree species diversity

The diversity of tree species encountered during the survey show a decreasing trend in the active logging and the logged areas of the forest reserve. It could be seen from the results of the study that the tree species diversity in the unlogged forest is much higher than in the active logging and the logged forest areas. The decline could be due to the effect of human disturbance that had taken place or still on-going in the other two forest areas assessed. This observation corresponds with studies conducted by Begon, 1996 who stated that different levels of disturbance have different effects on diversity. The interpretation also stated that if one's goal is to preserve biodiversity in a given area, there is the need to be able to understand how diversity is impacted by different management strategies.

5.5 Mean basal area

The mean basal area of the trees in the unlogged forest recorded was comparatively higher than the active logging and the logged forest areas studied. The mean basal area as explained by Glover and Barlow (2009), is the total cross-sectional area of all stems in a stand measured at breast height, and expressed as per unit of land area (m^2/ha). The reduction in mean basal area in the active logging and logged forest areas could be attributed to the effect of logging activities and thus signifies that some practices are not well managed to ensure sustainability of the forest resources. The mean basal area of a forest stand may be linked to the conservation status of a forest in that higher mean basal area signifies less threat to biodiversity loss. In view of this, the relatively high mean basal area recorded in the unlogged forest means that the integrity of biodiversity can be sustained over a long period of time.

5.6 Diameter class distribution of trees

Diameter class distributions can be used to indicate whether the density of smaller trees in a stand is sufficient to replace the current population of larger trees and to help evaluate potential forest sustainability. The lower number of economic trees at higher diameter class is an indication of over exploitation. There were also high numbers of young trees within the unlogged forest, which indicated that regeneration would be sufficient to maintain and sustain the occurrence of older age class size in the future. On the other hand, there were fewer young economic trees in both the active logging and logged forest, indicating that regeneration would be insufficient to maintain and sustain the existence of older class size in the next felling cycle of 40 years. These are all issues of conservational concern and should be made part of management decision to ensure sustainable forest resources development.

5.7 Mammal composition and diversity

Rodents were identified as the most occurring mammal species in the forest coupled with other mammal species. Generally, this is an indication of rich biodiversity of the forest reserve. The study however revealed that the active logging forest recorded the least mammal signs density and this may be attributed to the presence of heavy logging machinery in the area during the period of data collection. The logged forest recorded a few more mammal signs than the active logging forest probably due to the closure of the area to logging activities some two years prior to the data collection.

5.8 Conservational concerns

Reduced mammal sign density recorded in the active logging forest is a biodiversity loss threat which indicates that mammals are affected during and after logging operations and

it is expected that appropriate care be taken to maintain adequate populations of mammals. This finding agree with that reported by Alexander *et al* (2002) who stated that protection of micro-habitat features during logging operations may be one of the critical factors in maintaining populations of forest mammals in an area. Decayed logs, stumps, pieces of bark and leaf litter provide the predominant shelter for ground dwelling mammals in the forests. Ungulates which are predominantly herbivores not only need to survive the immediate effects of logging, but they also require sufficient cover as refuge against predators. Logging roads might benefit predators and illegal hunters by allowing easy access into previously untracked forests.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

One hundred and thirty star rating species were identified in the Fure Headwaters Forest Reserve with the most dominant plant species being *Strombosia glaucescens* (pink star), even though, the species is of commercial interest. Green star species recorded the highest star rating species; the least star rating recorded was the red star species. The Fure Headwaters Forest Reserve though relatively small, is rich in biodiversity. Generally, the Fure Headwaters Forest Reserve has high Genetic Heat Index in the range of 135 - 293. This implies the forest reserve has high biodiversity and could be considered as a "hotspot" in Africa. It could be deduced from the trend of decreasing genetic resources in the active logging and logged forest that little or no attention is paid to conservational values during timber logging activities.

Star rating species are high in Fure Headwaters Forest Reserve especially in the unlogged forest area but show decrease in the active logging and logged forest areas. Genetic Heat Index (GHI) indicates the presence of very high conservational values in the forest but declines with logging.

Comparatively conservational values based on the abundance and star rating of tree species identified in the three forest areas assessed indicates that conservational values decline when the forest environment is disturbed through logging

Mean basal area of the forest tends to decline in the active logging and logged areas. The study also revealed that logging also impacts negatively on mammal groups.

Comparative analysis in the logging and logged areas indicates gradual decline in biodiversity and conservation status due to lack of their careful management.

Reduced mammals presence in the active logging and logged forest indicates biodiversity loss and this may be attributed to the presence of heavy logging machinery in the area during the period of the survey.

The impacts of timber logging activities on conservational values in the Fure Headwaters Forest Reserve cannot be over-emphasized. All the indices or indicators of conservational values identified in in the active logging and the logged forest areas shows a decline in biodiversity when compared with those in the unlogged forest which served as control.

6.2 Recommendations

If the current trend of biodiversity loss persists, Ghana risks losing its forest conservational values completely in the next few decades, therefore for conservational status of the nation's forest resources to be enhanced, the under-listed are recommended for effective implementation:

i. Stock survey enumeration details should include all star rating species so that they can be accounted for during timber logging operations.
ii. Post-harvest checks should aim at careful management of biodiversity and enhancement of conservation status of the forest to ensure their sustainable development.
iii. A detailed stock mapping will allow for an accurate pre-planning of logging activities and operational controls and help in the robust implementation of reduced impact logging techniques and fine grain protection measures during

harvesting and extraction activities. Currently, stock surveys are not being translated into stock maps that will allow for precise positioning of access routes which take into consideration the location of important biodiversity and terrain features. It is essential that stock surveys record and map out mature trees of black and gold star species, and concentrations of fruiting trees in addition to the commercial species of immediate commercial interest. Additionally, important terrain features such as steep slopes, especially those beyond 30% where logging is not permitted by law, should be indicated on maps. These will be necessary in the planning of yield selection and extraction activities.

iv. Animal habitat details should also be noted in stock survey operations and should be part of fine grain protection areas within timber production reserves.

v. Stock survey teams still require further training in the identification of faunal traits (such as foot prints, breeding sites and nests, feeding remains, etc.) and reading of slopes which should be recorded and mapped along with tree locations. These indications are essential in the careful management of biodiversity.

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APPENDIX

APPENDIX I: WILDLIFE CONSERVATION REGULATION SCHEDULE

SCHEDULE 1: ANIMALS COMPLETELY PROTECTED. The hunting, capturing or destroying of any species listed in this schedule is absolutely prohibited at all times.

ANIMAL	SCIENTIFIC NAME	IUCN STATUS
PRIMATA		
Chimpanzee	*Pan troglodytes*	Endangered
Black and White Colobus	*Colobus polykomos*	Lower Risk
Olive colobus	*Procolobus verus*	Lower Risk
Red colobus	*Procolobus badius*	Endangered
Diana monkey	*Cercopithecus diana*	Endangered
Bosman's potto	*Perodicticus potto*	Least Concern
Bush baby	*Galago senegalensis*	Least Concern
	Galagoides demidovi	-
Giant pangolin	*Uromanis gigantean*	-
Long tailed pangolin	*Uromanis tetradactyla*	Least Concern
Tree pangolin	*Phataginus tricuspis*	Near Threatened
Aardvark	*Orycteropus afer*	Least Concern
Manatee	*Trichechus senegalensis*	Vulnerable
Lion	*Panthera leo*	Vulnerable
Leopard	*Panthera pardus*	Near Threatened
Cheetah	*Acinonyx jubatus*	Vulnerable
Honey Badger	*Mellivora capensis*	Least Concern
Clawless otter	*Anonyx capensis*	-
Golden cat	*Profelis aurata*	Vulnerable
Elephant	*Loxodonta africana*	Vulnerable

Palm squirrels	*Epixerus ebii*	Data Deficient
Hippopotamus	*Hippopotamus amphibious*	Vulnerable
Pygym hippopotamus	*Choeropsis liberiensis*	Endangered
Senegal hartebeest	*Damaliscus lunatus*	Lower Risk
Sitatunga	*Tragelephas spekei*	-
Eland	*Taurotragus derbianus*	-
Water chevrontain	*Hyemoschus aquaticus*	Data Deficient
Bongo	*Boocercus eucrycerus*	-
Roan antelope	*Hippotragus equinus*	Lower Risk
REPTILES		
Nile crocodile	*Crocodilus niloticus*	-
Long snouted crocodile	*Crocodiles cataphratus*	-
Broad fronted crocodile	*Osteolaemus tetraspis*	-
Nile monitor	*Veranus niloticus*	-
Chelonia: all marine turtle		
Hawksbill turtle	*Eretmochelys imbricate*	-
Green or Edible turtle	*Chelonia mydas*	-
Leathery turtle	*Dermochelys coriacea*	-
Falconidae:		
Falcons, hawks	*Falco peregrinus*	-
BIRDS		
Eagles, buzzards, kestrels		-
Tytonidae and Strigidae:		
Owls	*Tyto alba*	Near Threatened
Great white egret	*Casmarodius albus*	-
Little egret	*Egretta garzetta*	-

Cattle egret	*Bubulcus ibis*	-
Secretary bird	*Sagittarius serpentarius*	-
Marabou	*Leptoptilos crumeniferus*	-
Jabiru or saddle-bill	*Ephippiorynchus*	-
Sacred ibis	*Threskiornis aethiopicus*	-
Hadada	*Hagedashia hagedash*	-
Spotted brested ibis	*Lampribis rara*	-
Goliath heron	*Typhon goliath*	-
Crowned crane	*Balearica pavonina*	-
White breasted Guinea fowl	*Agelastes meleagrides*	Vulnerable
White-Necked picathartes	*Picathartes gymnocephalus*	Vulnerable

(-) Status not known

SECOND SCHEDULE: The hunting, capturing or destroying of any species listed in the schedule is absolutely prohibited between 1st August and 1st December in any year. The hunting, capturing or destroying of any young or adult accompanied by its young of any species listed in this schedule is absolutely prohibited at all times.

SERIES A – MAMMALS	**SCIENTIFIC NAME**	**IUCN STATUS**
PRIMATA:		
White colored mangabey	*Cercocebus torquatus*	Vulnerable
Mona monkey	*Cercopithecus mona*	Least Concern
Spot nosed monkey	*Cercopithecus petaurista*	Least Concern
Green monkey	*Cercopithecus aethiops*	-
Patas monkey	*Erythrocebus patas*	Least Concern
CARNIVORA:		
Lynx	*Felis caracal*	-
Serval	*Felis serval*	-
Africa civet	*Viverra civetta*	-
Two spotted palm civet	*Nandinia binotata*	Least Concern
Forest genet	*Genetta maculate*	-
Bush genet	*Genetta tigrina*	Least Concern
Wild cat	*Felis libyca*	-
Gambian mongoose	*Mungos gambianus*	Least Concern
Cusimanse	*(long nose mongoose)*	-
	Mungos obscurus	-
Dwarf mongoose	*Herpestes sanguinus*	-
Marsh mongoose	*Atilax paludinosus*	Least Concern
White tailed mongoose	*Ichenumia albicaudas*	-

Egyptian mongoose	*Herpestes inchneumon*	-
Spotted hyena	*Crocuta crocuta*	Lower Risk
Hunting dog	*Lycaon Pictus*	Endangered
Side striped Jackal	*Canis adutus*	-
LAGOMORPHA:		-
Togo hare	*Lepus capensis*	Least Concern
RODENTIA:		
Creste porcupine	*Hystrix sp.*	-
Brush tailed porcupine	*Artherurus africanus*	-
Pel's flying squirrel	*Animalurus peli*	-
Flying squirrel	*Animalurus spp.*	-
Pygmyn flying squirrel	*Idiurus spp.*	-
HYRACOIDEA:		
Tree bear	*Dendrohyrax arboreus*	Least Concern
Rock hyrax	*Procavia capensis*	-
ARTIODACTYLA:		
Warthog	*Phacochoerus aethipicus*	-
Red River hog (bush dog)	*Potamochoerus porcus*	LC (Least Concern)
Giant forest hog	*Hylochoesrus meinertzhagenei*	-
Bush buck	*Tragelaphus scriptus*	Least Concern
Buffalo	*Syncerus caffer*	Least Concern
Reedbuck	*Redunca redunca*	Least Concern
Western hartebeest	*Alcelaphus bucelaphus*	-
Waterbuck	*Kobus defassa*	-

Kob	*Kobus kob*	Least Concern
Oribi	*Ourebia ourebi*	Least Concern
Royal antelope	*Neotragus pygmaeus*	Least Concern
Red fronted gazelle	*Gazella rufifrons*	Vulnerable
Yellow backed duiker	*Cephalophus sylvicultor*	-
Black duiker	*Cephalophus niger*	Least Concern
Bay duiker	*Cephalophus dorsalis*	Least Concern
Red flanked duiker	*Cephalophus rufitatus*	-
Red duiker	*Cephalophus natalensis*	Least Concern
Maxwell's duiker	*Cephalophus maxwelli*	Least Concern
Gray duiker	*Sylvicapra grimmia*	Least Concern
SERIES B – REPTILES		
OPHIDIA:		
African python	*Python saba*	-
Royal python	*Python regia*	-
CHELONIA:		
Bell's hinged tortoise	*Kinixys belliana*	-
Common hinged tortoise	*Kinixys sp.*	-
Gaboon terrapin	*Pelusios sp.*	-
Marsh terrpin	*Polemedusa subrufa*	-
Soft shelled turtle	*Trionyx triunguis*	-
SERIES C – BIRDS		
PSITTACIDAE:	*All parrots*	-
COLUMBIDAE:	*All doves and pigeos*	-

MUSOPHAGIDAE:	*All touracos and plaintain eaters*	-
PLOCEIDAE:	*All weavers, waxbills, man-nikins, bishop bird, fire finches, cordonsbleus, whydahs and canaries*	-

(-) Status not known