UNIVERSITY OF CAPE COAST

THE ECOLOGY OF LOWE'S MONKEY (*CERCOPITHECUS CAMPBELLI LOWEI*) IN KAKUM CONSERVATION AREA, GHANA

BY

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A Thesis submitted to the Department of Entomology and Wildlife, School of Biological Sciences, University of Cape Coast in partial fulfillment of the requirements for the award of Doctor of Philosophy in Zoology.

JUNE, 2012

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

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Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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ABSTRACT

The ecology of Lowe's monkey (*Cercopithecus campbelli lowei*) was investigated at Kakum Conservation Area of Ghana in both dry and wet seasons in 2009 and 2010. Analysis of satellite images and field survey was done to evaluate the dynamics in canopy coverage, species density and composition of the vegetation. Lowe's monkey density and relationship with other living and non-living components were determined. Foraging and feeding behavior were studied plus proximate analyses of three fruits consumed by the monkeys were determined by 'Weende system of Analysis'.

The number of tree species enumerated was 97, distributed from 37 to 92 trees per 0.20 ha in eight sampled areas. The mean density of Lowe's monkey was found to be 0.99 and 1.07 per km in the wet and dry seasons respectively. With reference to the implementation of conservation practices in 1993, the average density of the Lowe's monkeys has increased from 0.31 to 1.03 with an average group size of 10.2 in the wet season while in the dry season the mean group size was 11.8. Proximate analysis of three fruits found to be commonly consumed by Lowe's monkey indicated high carbohydrate (Maize = 67%, Banana = 75%, Spondias = 66%) and moisture (Maize = 8%, Banana = 14%, Spondias = 16%) contents.

Hunting which could negatively affect the population of monkeys has largely been controlled in the Kakum Conservation Area in recent times. The Lowe's monkey should be promoted as an icon species for it to get conservation, political and public attention and so as to save their populations from collapse.

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DEDICATION

In memory of late Professor Samuel Yeboah

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CHAPTER ONE

INTRODUCTION

Background

Biological diversity is a highly dynamic phenomenon, exhibiting complex patterns of variation over space and/or time. Humans are dramatically changing the nature of planet Earth. Not since the demise of the dinosaur about 65 million years ago has this planet witnessed changes to the structure and dynamics of its biological communities as dramatic as those that have occurred over recent millennia, and especially in the past 400 years (Caughley & Gunn, 1996; Cowlishaw & Dunbar, 2000). The root cause of these changes can be attributed to the direct and indirect effects of human activity since the end of the Pleistocene. These effects have been associated with the spread, growth and development of human populations around the planet, which have been strongly promoted by both agricultural and industrial revolutions (Cowlishaw & Dunbar, 2000).

It has been found out that it is human processes that are now destroying the very natural resources that have fueled these processes (Struhsaker, 1997). Habitats have been devastated, and an unknown number of plant and animal species have already been harvested or hunted to extinction.The closest relatives to humans, the other primates, have not been spared this ongoing catastrophe of biodiversity in crises. Their populations have come under increasing pressure from encroaching humans, and there is no doubt that several primate species are on the brink of extinction (Cowlishaw & Dunbar, 2000). Even the most common primate species, those that are well adapted to co-exist with humans, are not safe. Uncontrolled live-trapping, exacerbated by deforestation and the use of hunting as a pest control measure, resulted inthe collapse of rhesus macaque (*Macaca mulatta*) populations in India (to about 10% of its original size in less than two decades (Southwick, Siddiqi & Oppenheimer, 1983).

The combined numbers of all primates, account for the bulk of medium-sized mammalian biomass in many forests. Oates, Whitesides and Davies (1990) estimated that primates represent a considerable percentage of mammal biomass in their habitats, even exceeding a biomass of 1,050 kg/km^2 at some sites. Primates are important components of forest ecosystems with gorillas (*Gorilla gorilla*) having a major impact on plant regeneration, guenons pollinating flowers and dispersing seeds and colobus monkeys commonly destroying seeds (Gautier-Hion & Maisels, 1994).

In West and Central Africa where economic hardships have resulted in greater dependence on forest products, there has been a marked increase in commercial exploitation of primates in recent years (Davies, 2002). Primates and their products therefore contribute immensely to the socio-economic lives of the people in these sub-regions. Primates are typically thought of as acrobatic monkeys or impressive gorillas. However, the 230 species belonging to the order Primates represent a very diverse group ranging from the dwarf bush baby (*Galagoides demidoff*) (300 g) to the gorilla (*Gorilla gorilla*) (200 kg). The understanding of human evolution can be derived from ecological research on these species. Moreover, some African primates belonging to the primate genera *Cercopithecus, Erythrocebus, Papio* and *Pan* have been widely used in biomedical research which benefits humankind (King, Yarbrough, Anderson & Gordon, 1988).

Almost all the primates are located in the tropical band around the equator with diverse diets ranging from arboreal herbivores to omnivores which contribute greatly to the forest ecosystem. This arboreal feeding behaviour has direct and positive influence on fruit availability on the forest floor for terrestrial mammals like duikers, bush-pigs and cusimanse (Gautier-Hion & Maisels, 1994).

The family Cercopithecidae contains 82 species of baboons, macaques, guenons and colobus monkeys; popularly referred to as Old World monkeys. Lowe's guenon or monkey (*Cercopithecus campbelli lowei*- Thomas, 1923) is considered a subspecies of Campbell's monkey (*Cercopithecus campbelli*- Waterhouse, 1838) from which two sub-species have been described as *Cercopithecus campbelli campbelli*-Waterhouse, 1838 and *Cercopithecus campbelli lowei*-Thomas, 1923, though the taxonomy is still unresolved. The Lowe's monkey belongs to the kingdom Animalia, phylum Chordata, class Mammalia, order Primates, family Cercopithecidae, genus *Cercopithecus* species *campbelli* and subspecies *lowei* (Figure 1). The head and body measure between 40-58 cm, while the tail measures between 54-75 cm. The Lowe's monkey is a long tailed, arboreal monkey with grizzled brownish black, dark grey hind legs and rump, black outer arms, tail tip, hands and feet (Plate 1). The under parts are white and the finely grizzled cheek fur pales to form a sharp contrast with the blue-grey eye mask that typifies all guenons. A similar narrow margin edges the oval orange-yellow brow band. Ear tufts are grizzled and often yellowish; the temples are marked by a broad black band that separates the light cheeks and ears from dark crown and orange brow (Plate 1). This species is found from River Sassandra (Côte d'Ivoire) to the River Volta (Ghana), in most forest types: primary, secondary and galleries but not common in marshy areas or mangroves.

Lowe's monkey is less exclusively arboreal than most of the allied species and has no close association with riverbanks or water but stays close to cover and avoids exposure. Its food is mainly fruit, pulp of oil palm seeds, figs, cola and garden fruits. It frequently collects flowers and hunts insects but it takes a little interest in other invertebrates (e.g., snail) and leaves. Normally, groups average 10 individuals and comprise a single adult male with about four adult females and their young with a home range that extends from about 1.5 to 3.0 ha. Gestation lasts about six months and the species shows a distinct birth peak in December to January (Kingdon, 1997).

Though habitats and numbers have been greatly reduced, *Cercopithecus campbelli* remains common and widespread (Kingdon, 1997) and according to IUCN/SSC (2009) the Lowe's monkey is classified as Least Concern (L.C.) worldwide. Lowe's monkeys are prey to other animals, and some of the largest birds such as the African crowned hawk eagle (*Stephanoaetus coronatus*) have been observed to feed mainly on forest monkeys particularly the medium sized ones like Lowe's monkey. Lowe's monkeys use a special alarm call when an eagle flies over, and respond by dividing themselves into thick cover. Lowe's monkey is also the preferred meat of some people in West Africa (Davies, 2002).

Justification

To date, primate studies in Ghana have concentrated on the distribution and diversity of the general primate taxon (Booth, 1956; Asibey, 1978; Abedi-Lartey and Amponsah, 1999; Grubb *et al.*, 2003) and conservation of some threatened species (e.g., Lindsay, 1996; Curtin, 2002; Oates, 2006). Only few studies have been conducted in the sub-region on the Lowe's monkey particularly. An account of the geographic distribution and locations of collected specimens is given by Lernould (1988) and Oates (1988). Bourliere, Hunkeler and Bertrand (1970) described the general habitat, diet, habits and behaviour in Côte d'Ivoire. Galat and Galat-Luong (1985) investigated the habitat preferences, diet and aspects of Lowe's monkey's behaviour in a forested habitat in Côte d'Ivoire. No particular study has been conducted on the species in the natural forest habitat in Ghana. Particularly, there is lack of information on Lowe's monkey in a forest under regeneration from selective logging.

Apart from the initial expeditional survey of primate density estimation at the beginning of managing Kakum forest as a conservation area, about 20 years ago (Oates, Abedi-Lartey, McGraw, Struhsaker & Whitesides, 2000), there has not been any study on the population of conspicuous and vulnerable species like Lowe's monkey to investigate current trends. This study was therefore expected to provide an update of the population estimate of the species and shows the growth pattern of the population 20 years after logging.

Even though the Lowe's monkey has been classified as Least Concern by the International Union for Conservation of Nature/Species Survival Commission (IUCN/SSC) (2009), their populations have been observed to be decreasing (Oates, 1999; Deschner and Kpelle, 2003; Gatti, 2010). The monkeys can now be found only in some protected areas, such as Ankasa, Bia and Kakum Conservation Areas in Ghana. More ecological information is therefore required to enable its protection and conservation. This would provide certain vital information to facilitate the implementation of conservation initiatives such as re-introduction of species to some 'empty forests' (Oates, 1999).

Since the beginning of the 20th century, land has been demarcated for conservation with little or no regard for the impact of these on the livelihood of the inhabitants of rural communities in Africa. Consequently, these communities were alienated from the resources upon which their material well being depends. Instead of re-investment of the revenues derived from wildlife back into the area, they were channelled into the Government's central treasury. As a result, many local hunters and gatherers operate secretly for personal gain and it also forces many people into illegal, underground economy (Jachmann, 1998). Since the primates of rainforest protected areas interact with the illegal hunters, and their population can be controlled by these hunting activities, it is necessary to investigate the mode of operations of the hunters, the hunting frequency, and relative off-take of forest primates compared to other forest species as well as hunting methods normally used.

In order to survive and breed successfully, the animals must obtain adequate food. Even where food supplies appear to be abundant, such as in a tropical rain forest, particular components of the diet may be in short supply and competition for these could be intense at certain times of the year. Little information exists on the food items, food availability and factors regulating these for Lowe's monkeys. However, feeding is one of the most basic aspects of an animal's ecology andconservation measures such as quantifying suitable habitats, choosing areas for protection or species to be planted for remediation of degraded habitats are possible only if the food plants are known. Obtaining information on species habitat requirements is especially complicated for primates because there are often large changes in diet throughout the year, or over their geographical range (Barnett, 1995).

The interaction between Lowe's monkeys, the forest and other users of the forest, and non-living components as well as how resources are shared in space and time is a complex one. It becomes even more complex with disruption of their activities by human interference, like their being hunted for food and collection for medical research. Research is therefore required to give information about these complex interactions for informed policy-making and park management.

The functional role of Lowe's monkeys in rainforest ecosystems is poorly understood. For instance, there is poor understanding of factors determining the presence or absence, distribution and range pattern of forest dwelling Lowe's monkeys as well as the impact of their densities on the rest of the ecosystem. There is no documentary evidence on what the species contributes to forest regeneration processes like pollination and seed dispersal. Little is known about the species nutritional requirements at different stages of their life cycle or about how these requirements are met from one season to another, even though their survival and reproduction are affected by long-term patterns of food availability in the forest habitats in Ghana.

At present, in Ghana and the other countries of Upper Guinea, the need to obtain information on species specific ecological requirements and population dynamics is very critical to the formulation of informed conservation and management plans. Moreover, the conservation of the primates in Kakum Conservation Area (KCA) has been on adhoc basis without any empirical information on their population dynamics and ecology. It is against this background that the study of the ecology of Lowe's monkeys in the KCA has been undertaken. According to Chivers (1986) the study of primate ecology involves quantitative descriptions of:

i. the habitat in terms of plant form and species composition, distribution and abundance

ii. faunal composition including birds and mammals

iii. the size and composition of social groups in each primate species

iv. all aspects of foraging in relation to food acquisition and ingestion, food selection at different times of the year

v. all human activities that lead to hunting, capture or destruction of primate life

vi. the nature of activities with reference to movements through the habitat as well as nature and frequency of interactions with themselves and other species, to develop and understand the primates' community

Put together, the resulting information helps a great deal in the understanding of ecological systems of the non-human primates.

Objectives

The main goal of this research was to gather detailed information regarding the population density, changes in habitat type, foraging behaviour, food biochemistry of the Lowe's monkeys, and their interactions with other living and non-living components in KCA in Ghana.

The specific objectives of the study were to:

- investigate the plant species composition, structure and dynamics of the vegetation after logging period in Lowe's monkey's range.
- determine the density, troop or group size and distribution of the Lowe's monkeys in the KCA.
- ascertain the monkey community structure and poly-specific association with Lowe's monkeys.
- investigate human activities such as hunting, capture or destruction of the Lowe's monkey population in Kakum conservation area.
- determine the nutrient content and chemical composition of the food of Lowe's monkeys.

Hypotheses

The following hypotheses were tested during the study:

- Tree density occurring in the forest differs from one area of the forest to another area.
- The density of Lowe's monkey in the dry season differs from that in the wet season.
- The Lowe's monkey density occurring in the forest does not differ in different parts of the forest.
- The number of groups of Lowe's monkey and average group sizes encountered in dry season differs from those in wet season.
- Both density and diversity of trees correlates positively with the density of Lowe's monkeys.
- Incidence of indicators of hunting activities in the dry season did not differ from wet season.
- The higher the incidence of hunting activities, the lower the density of Lowe's monkey recorded.
- The avian densities occurring in the Lowe's monkey range were the same in different blocks of the forest.
- The number of times that Lowe's monkey visits one fruit plant was the same as visits to other fruit plants.
- The nutrient contents of all the fruits consumed by Lowe's monkey did not differ from one fruit to another.

Outline of the Thesis

This thesis consists of six chapters which start with an Introduction (chapter 1) which comprises of the background, justification, hypothesis, and objectives of the study. Chapter two provides a literature review and chapter three covers the Materials and Methods. Chapter four presents the results and chapter five provides discussion of the results. Chapter six deals with major conclusions of the research and provides some recommendations.

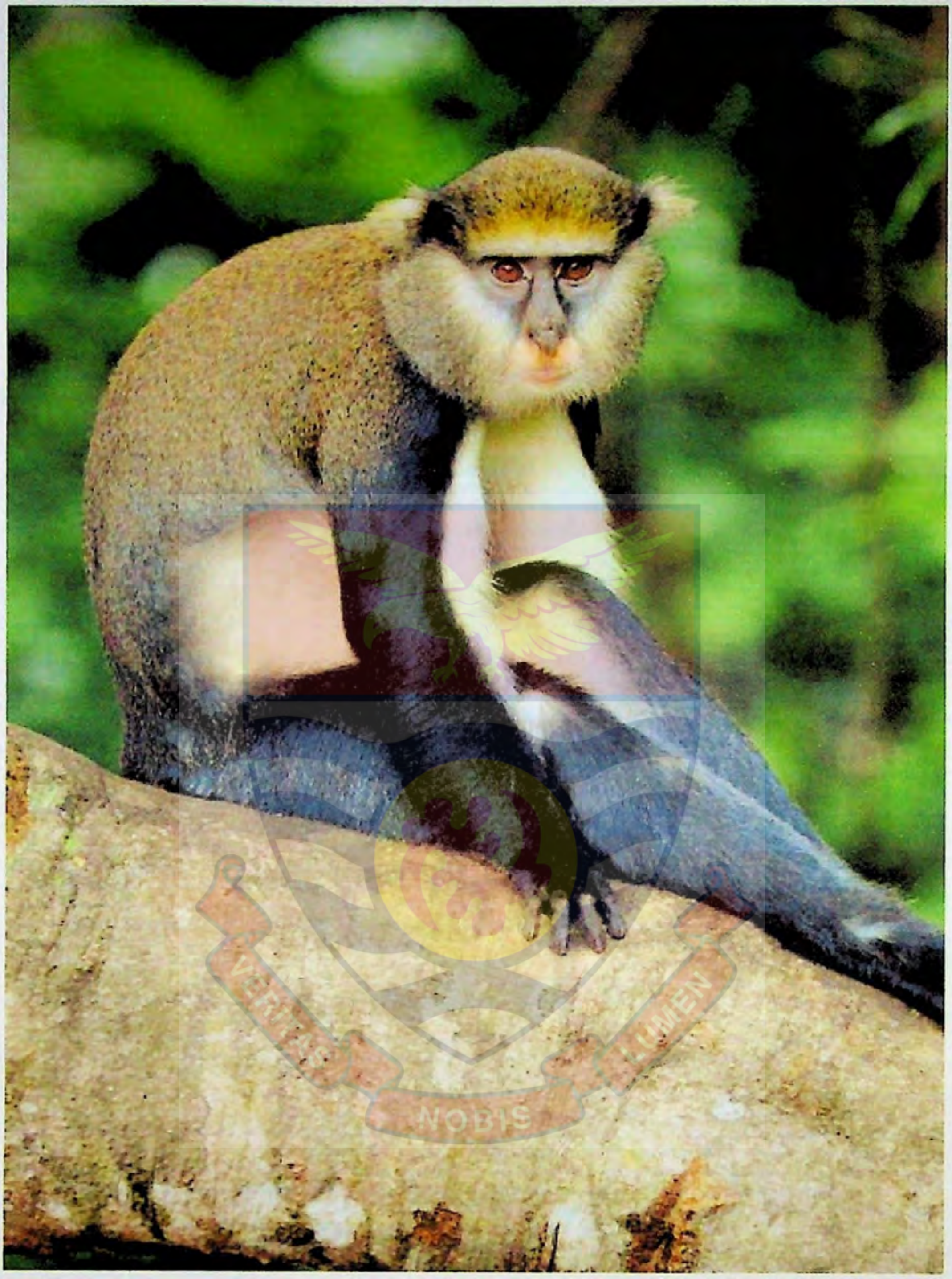

Plate 1: External features of Lowe's monkey (*Cercopithecus campbelli lowei*).

CHAPTER TWO

LITERATURE REVIEW

Introduction

The review of related literature focuses on both empirical and theoretical information relevant to the study. It was presented under the following sub-headings;

1. Primate Taxonomy, Distribution and Status in West Africa
2. Early knowledge and historical collections of primates in Ghana
3. Behavioural Characters of Lowe's Monkey (Cercopithecus campbelli lowei)
4. Justification for Primate Studies in Africa
5. Primates, Plant Reproduction and their Role as Keystone Species
6. Primate Feeding Ecology
7. Phenology of Tropical Plants Ecology
8. Hunting as an Extrinsic Factor Affecting Populations of Primates
9. Habitat Disturbances as Extrinsic Forces Affecting Population of Primates

Primate Taxonomy, Distribution and Status in West Africa

Taxonomic classification of primates

There is disagreement among taxonomists as to the classification of non-human primates. However, depending on the classification system used, there are two and sometimes three principal sub-orders recognized in the order Primates. According to Kavanagh (1983), the prosimians belong to the suborder Strepsirhini, and the simians are of the suborder Haplorhini. These suborders are similar to the suborders Prosimii (early monkeys) and Anthropoidea in other classification systems, most notably Napier and Napier (1985) who also added a third suborder, Tarsioidea (tarsiers) a group of tiny insectivorous primates in the East Indies. The Napier and Napier (1985) system of classification will be used in this study. The Anthropoidea, to which the study species, *Cercopithecus campbelli lowei* (Plate 1) belongs, would be emphasized.

The suborder Anthropoidea is categorized into New World monkeys of the infra-order Platyrrhini and Old-World monkeys and apes of the infra-order Catarrhini. These primates have catarrhine noses; so-called because their nostrils are separated by a narrow nasal septum. The narrow downward nostrils of the catarrhines help distinguish these Old World monkeys from the platyrrhines. Old World monkeys usually rest in a sitting position and accordingly are equipped with ischial callosities, which are tough pads of cornified skin located over the bony prominences of the buttocks. Ischial callosities are not present in New World monkeys, making this feature an important identifier. Some Old World monkeys are arboreal or terrestrial or both. They have nails rather than claws on all digits, similar to humans or apes. Their thumbs are truly opposable and all species are diurnal. None has a truly prehensile tail. The Old World monkeys (super-family Cercopitchecoidea) are all represented within the single family Cercopithecidae. Taxonomically, the family Cercopithecidae is divided into two distinct subfamilies: the Colobinae and the Cercopithecinae. The leaf-eating colobine monkeys include the genera *Colobus, Procolobus, Presbytis, Pygathrix, Rhinopithecus, Nasalis,* and *Simias*.

The Old World cercopithecine monkeys include the genera *Macaca, Cercocebus, Papio, Mandrillus, Theropithecus, Cercopithecus, Miopithecus, Allenopithecus*, and *Erythrocebus*. Most of the cercopithecines are omnivorous. All species within the subfamily Cercopithecinae have tails, but two groups are known by common names as long-tailed or short-tailed monkeys.

Long-tailed monkeys include *Cercopithecus* spp (guenons), *Erythrocebus patas* (patas), and *Cercocebus* spp (mangabeys). The Lowe's monkey belongs to this group (Figure 1). The short-tailed monkeys include the several species of the genus *Macaca* (macaques). Tail length, however, is not a consistent criterion. For example, within the macaques, tail lengths vary from long (50 - 60 cm) as for *Macaca fascicularis* (long-tailed macaque), to short (0.3 - 6.9 cm) (*Macaca arctoides*) (stump-tailed macaque), to almost absent in *Macaca sylvana* (once, because of the lack of a tail, mistakenly thought to be an ape, and taking on the common name of the 'Barbary ape').

The last catarrhine group is the Hominoidea, which are the Old World apes and includes the lesser apes, great apes and humans. The lesser apes family is the Hylobatidae, while the great apes are the Pongidae (Figure 1).

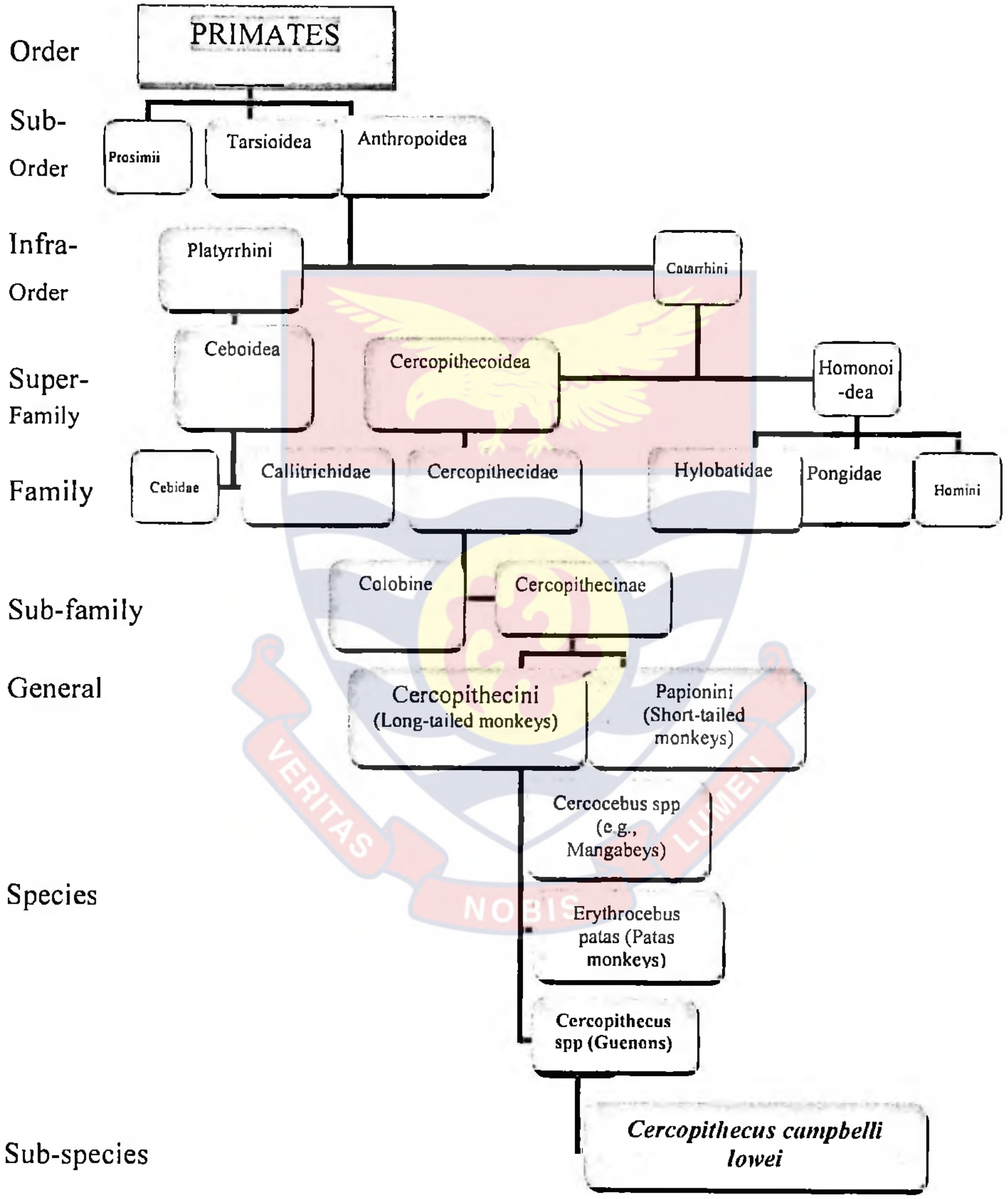

Figure 1: Summary of taxonomic classification of primates (after Napier and Napier, 1985)

Primates in the Upper Guinea

The African lowland moist forest zone shows a clear division into two blocks, separated by the 'Dahomey gap' (Figure 2). The chorological map of Africa identifies the African tropical forest as the Guineo-Congolian region (White, 1979). White (1979) further described the Guineo-Congolian region as an area divided into two sub-centers of specific endemism, namely the upper Guinea and lower Guinea sub-centers. Each of these sub-centers possesses a considerable number of endemic species although the proportion in each case is less than 50% of the total flora. He stated that the Dahomey gap is located between the upper Guinea and lower Guinea sub-centers and is caused by the offshore emergence of a cold Atlantic undercurrent. It forms a corridor of savanna reaching the coast from northern savannas. The West African lowland forests are among the most depleted forests in the tropics, due to the historically close links of the countries located there with Europe, by official policies and by high population densities (Parren and de Graaf, 1995).

According to Oates (1985), the Upper Guinea forests support eight endemic primate species namely *Cercocebus atys, Cercopithecus diana, Cercopithecus petaurista, Cercopithecus campbelli, Procolobus badius, Procolobus verus, Colobus polykomos,* and *Colobus vellerosus*. The sub-species of most of the monkeys change in southwestern Côte d'Ivoire (between Cowally and Sassandra rivers). He therefore suggested that Upper Guinea should be considered as consisting of two major sub-regions in terms of its primates: Upper Guinea west and Upper Guinea east (Figure 2). The upper Guinea west has a higher rainfall and exhibits higher faunal and floral diversity and endemism. It has been proposed that a major Pleistocene forest refuge was located in this sub-region which includes the extreme south of the Republic of Guinea as well as southern Sierra Leone, all of Liberia and the extreme southwest of Côte d'Ivoire. Endemic primates here are Western Black-and-white Colobus (*Colobus polykomos),* Sooty Mangabey (*Cercocebus atys atys*), Diana Monkey (*Cercopithecus diana diana*), Western Spot-nosed Monkey (*Cercopithecus petaurista buettikoferi*), Campbell's Monkey (*Cercopithecus campbelli campbelli*), *and* Western Red Colobus (*Procolobus badius badius*) (Oates, 1985; 2010).

The Upper Guinea east sub-region is smaller and has a denser human population than the west. Many of the major towns (e.g., Tarkwa in Ghana and Yamoussouro in Côte d'Ivoire) are located in or close to the sub-region. The area has a low level of endemism at the species level (although two larger colobus species living here are both sometimes regarded as distinct species): Miss Waldron's Red Colobus (*Procolobus [badius] waldroni*) and Geoffroy's Black-and-white Colobus (*Colobus vellerosus*), Roloway Monkey (*Cercopithecus diana roloway*), White-naped mangabey (*Cercocebus atys lunulatus*), Eastern Spot-nosed Monkey (*Cercopithecus petaurista petaurista*), Lowe's monkey (*Cercopithecus campbelli lowei*) and Olive Colobus (*Procolobus verus*) (Oates, 1985; 2010).

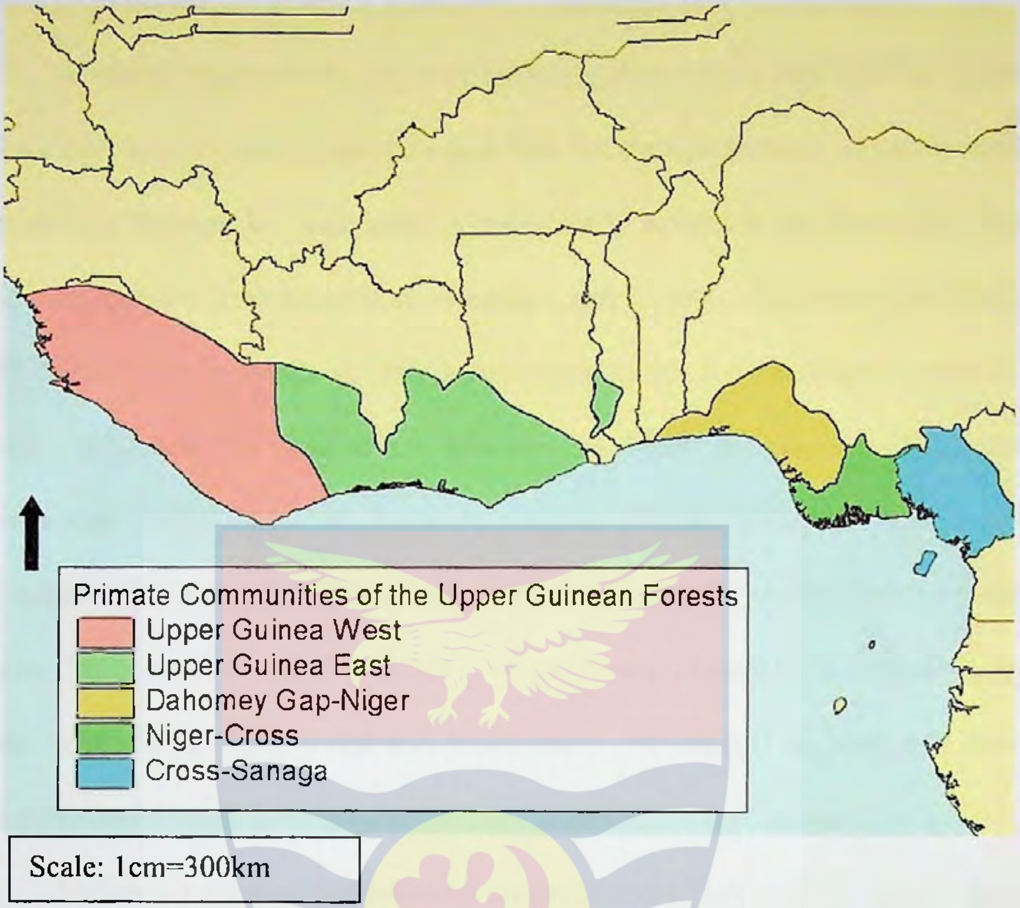

Figure 2: Map of West Africa showing Upper Guinea Forest with distinction into Upper Guinea West and East (after Oates, 2010).

Status of primates in Ghana's Rainforest protected areas in the past

A survey conducted in the three protected forest areas namely Bia, Ankasa and Kakum conservation areas indicated that not only have these forests become increasingly isolated by expansion of agricultural activities but have also been seriously degraded through excessive logging and hunting (Struhsaker and Oates, 1995). Struhsaker and Oates (1995) further revealed that the previous 15 years had greatly witnessed the decline in numbers of Miss Waldron's red colobus (*Procolobus badius waldroni*), Roloway monkey (*Cercopithecus diana roloway*), and white-naped mangabey (*Cercocebus atys lunulatus*) throughout south-western Ghana. The conclusion was that losses of mega fauna represent a major biodiversity crisis. When large highly vocal and conspicuous mammals disappear, it is likely that other less conspicuous species had also gone extinct before them.

Following a recommendation by Struhsaker and Oates (1995) further study was conducted by Magnuson (2003) which revealed that Roloway monkeys in Ghana occurred in four out of nine forest areas surveyed, with an encounter rate of 0.04 groups/km and 1.53 groups/km² in both off-reserved and reserved forest areas respectively. This density is far less than those for most other species of primates in these forests. Numerous studies conducted in a wide range of different forest patches in south western Ghana during recent decades have reported declining numbers of primate populations or even failed to confirm the presence of certain monkey species (e.g., Miss Waldron's red colobus) which once inhabited the rainforests of eastern Côte d'Ivoire and southwestern Ghana (Oates *et al.*, 2000). Deschner and Kpelle (2003) also concluded that primate populations in four different blocks of southwestern Ghana were steadily declining and face a serious extinction risk. Even the abundance of all the seven confirmed species of primates was so low for any density calculations. Since primates are relatively long-lived, large-bodied and slowly reproducing animals, they are especially vulnerable to environmental changes such as habitat destruction and hunting pressure.

Primates have received much attention from conservation measures and they are one of the few large Orders of mammals that have not lost a taxon (species or subspecies) in the twentieth century (Mittermeier *et al*., 1997). This suggests that the lack of recent primate extinctions is fostering complacency and this may allow taxa to become extinct that could have been saved by more vigorous and timely action. This danger is particularly acute in the case of taxa that have received little popular attention and live in parts of the world that are not a major focus of biologists and conservationists (Oates *et al*., 2000).

Concerns have been expressed by conservationists on the effects of growth of the global human population and economic development, especially in the tropics, on the rates of extinction of species and subspecies by the end of the 20th century. For example, there have been suggestions that an extinction spasm in the last 25 years of the 20th century would eliminate one million species of large-bodied, slow breeding rare mammals and birds (Myers, 1979) and about one-seventh of primate species could easily be extinct by the turn of the century (Mittermeier, 1986).

In the early 1950s, Miss Waldron's red colobus (*Procolobus badius waldroni*) was found to be threatened as a result of habitat destruction and hunting.

Booth (1956) expressed the view that the extinction of this species in Gold Coast (Ghana) in the near future was to be regarded as a probability and asked for an effective legislation that would protect both the animal and its environment. It appears nothing was done about his view and in 1973, another warning was issued by Jeffery Sonia against the continual harassment of monkeys living in the upper canopy of the high forest in Ghana. She stated that the monkeys were not only harassed by the destruction of their habitat but also by large scale organized hunting, which would cause their numbers to decline to a dangerously low level in the next few years (Sonia, 1975). Subsequently, the first rainforest protected area, Bia National Park, was commissioned in 1974 to protect primates and other associated animals.

Early knowledge and historical collections of primates in Ghana

Some of the early records from West Africa reflect early presence of the Dutch on the shores of the Gold Coast (now Ghana). Monkeys had long been sent to Europe and were often figured in some paintings (e.g., a Diana monkey-*Cercopithecus diana*) among three monkeys stealing food by Franz Synder (1579 - 1657) in Louvre-Paris, France) (Grubb, 1998).

Grubb (1998) further stated that some letters written by Bosman Willem, a leader of the crew for the Dutch East India Shipping Company for 14 years at Axim and Elmina gave an account of the Gold Coast and its fauna in 1704. In an English translation, Bosman referred to generic categories of mammals (e.g., apes, wild cats, 'tygers', wild boars and 'harts') so it is difficult to assess how much he knew particularly of primates. He certainly was aware of the Potto (*Perodicticus potto*), a monkey "as black as pitch" with a long white beard (Diana monkey- *Cercopithecus diana*), Chimpanzee (*Pan troglodytes*), grasscutter (*Thryonomys swinderianus*), porcupine (*Hystrix cristata*), civet cat (*Civettictis civetta*) and bushbuck (*Tragelaphus scriptus*).

The description of Lemur potto by P.L.S Müller in 1766 was based on Bosman's account and the vernacular name 'Bosman's potto' reflecting his version of the Akan 'aposso' became widely used in natural history books. In his account of political mission to the Ashanti capital, Kumasi, in 1817, Thomas Bowdich made some brief references to mammals. He found the flesh of wild hog and monkeys for sale in the market and alluded to 15 kinds of wild mammals and in most cases quoted Akan names. For example 'effoor' referred to 'efoo' in Akan for the white-thighed colobus (*Colobus polykomos*). The *Rijksmuseum van Natuurlijke Historie* in Leiden had received a leopard (*Panthera pardus*) and a civet cat (*Civettictis civetta*) from the Asantehene (the king of Ashanti kingdom, the Gold Coast) in 1836 and 1838, respectively but serious study of the mammalian fauna did not begin until the 1840s (Grubb, 1998).The first official faunal expeditions were made by a Dutch biologist, H. S. Pel, who made collections between 1840 to 1855 and today most of the large mammals have been described, though some as late as 1980s (Parren and de Graaf, 1995).

Behavioural Characters of Lowe's Monkey (*Cercopithecus campbelli lowei*)

Angus H. Booth, the first primatologist who tried to define the ecological niches of West African cercopithecines, summarized his observation as representatives of the mona-group are found throughout the high forest zone in both primary and secondary forests, and in forest outliners and fringing forests. The species are typical of lower and middle layers of the forest. They sleep in the middle storey, rarely ascending the tall emergent tree (Booth, 1956).

Bourliere *et al.* (1970) reported that in the Ivory Coast, Lowe's monkeys may be found at all heights and in all types of forests except marshy and mangrove areas. Although spending most of the time in the middle and lower layers, they often visit the canopy and may occasionally progress on the ground. Forest structure does not seem to concern them unduly. Bourliere *et al.* (1970) further stated that Lowe's monkeys were common in the old mature forest between River Cavally and River Sassandra as well as in the secondary growth of the Basse-Cote and the gallery forest along the river Bandama all in the Côte d'Ivoire. In Bia Conservation Area, Ghana, Martin and Asibey (1979) indicated that the population and structure of Lowe's monkeys were not affected by logging as they can thrive well in both old and secondary forests but observed that the social groups were affected by logging.

Extremely agile, Lowe's monkeys seem at ease on any type of branch or liana. The trees the monkey uses were described by Bourliere *et al.* (1970) as the three-dimensional universe which the monkeys rarely leave and where they take refuge at the first hint of danger.

The arboreal locomotion of Lowe's monkey is a mixture of walking, climbing and leaping which cannot be divided easily into clear-cut categories and which can be much better appreciated in a movie than by a written description. On horizontal or slightly sloping branches a more or less rapid quadrupedal walk is used, with hand and feet grasping the support and it is only when the substrate is wide that palms and soles rest flat upon it (Bourliere *et al.*, 1970).

Lowe's monkeys generally climb up lianas very rapidly but in climbing down especially if the liana is slender, they leap or slide head down, braking with their tails coiled around the support. When the support is very smooth they come sliding down with feet first. Bourliere *et al.* (1970) described this as being like a trapeze artist returning to the circus ring at the end of his performance. They usually seem to avoid broad vertical trunks, but when the occasion arises they climb up in a bear-like way, the two arms moving together followed by the two legs which propel the body upwards. On descending sloping trunks, even almost vertical ones, all animals except young infants may run down head first.

Leaps are extremely common and may roughly be divided into three types as 'aimed leaps', 'free falls' and 'sideway leaps'. The aimed leap: before springing, the animal briefly marks time, taking off only after a good look at the landing branch which may be five to seven meters away horizontally, and sometimes as much as 10m below the point of take off. If the take-off branch has been set in motion by a previous leap, the animal may wait for several seconds for it to settle. Between the starting and landing points the four limbs are partly extended. In 'free falls' the monkey lets itself drop on small trees or underlying bushes, sometimes in several stages, steadying itself on the way by catching hold of a branch or twig or even the tail of another monkey. This type of fall is frequent during play. In 'sideways' leap, the monkey jumps sideways against vertical support and ricochets at an angle from the direction of impact. It is used as a means of changing direction and also frequently seen in play (Bourliere *et al.*, 1970).

Lowe's monkeys come to the ground more often under cover than in the open. Bourliere *et al.* (1970) further recounted that locomotion on the ground comprises quadrupedal walking and galloping as well as bipedal running and hopping. When on the ground, movement is generally preceded by, and interspersed with, bipedal stances during which the monkey looks around. The tail may then be used as support ('tripod posture') or is raised and curled forward over the back. In Côte d'Ivoire, the monkeys were observed to maintain a bipedal stance for as long as two minutes and are also very agile when moving bipedally. For example, they have been recorded to have jumped at least 1.6 m bipedally from the ground to a low branch with both hands full of food and without losing their balance. The 'semi-prehensile' tail of Lowe's monkeys is used both in locomotion and at rest. It functions as a counterweight, a brake, support and grasping device. Babies anchor their tail to the base of their mother's tail. Tail twining is frequent as a means of social contact when dozing, sleeping, sitting or grooming.

Justification for Primate Studies in Africa

Primates are very popular animals that are of general interest to people. They are also good indicators of general ecosystem health and are easily helpful in conservation planning (Barnett, 1995). Primate populations, like those of other organisms, face the challenge of coping with the dynamics of their habitats which are continually changing. Primates must adapt to changes in order to survive; failure to adapt dooms a species to extinction (Isabirye-Basuta and Lwanga, 2008).

Because most primate species live in tropical forests (Mittermeier and Cheney, 1987; Chapman *et al.*, 2006; Lovett and Marshall, 2006), protection of forest habitats should be high on the agenda for primate conservation.

According to Isabirye-Basuta and Lwanga (2008), conserving the world's tropical forests is however not an easy task for several reasons. First, the forest habitats are mostly fragmented and scattered in many different countries. Hence international organizations that are key players in conservation need to work with many national governments, each with its own priorities and problems. Second, most, if not all tropical forests that are rich in primate diversity are in economically poor nations. For example, nine of the15 richest countries in terms of primate species are in Africa (Chapman *et al.*, 2006) and some of the nations are not only poor but also politically unstable. It is difficult to expect such countries to make forest protection a high priority. Even if foreign assistance were available, it is difficult to deliver during war. Third, the population growth rate in developing nations, particularly in Africa, is high and most people depend directly on natural resources such as land for survival. The need to clear forests to create land for agriculture is therefore high. This does not augur well for forest protection. Fourth, most developing nations are over burdened with foreign debts that compel national governments to encourage exploitation of forests. Though lenders have written off foreign debts for some developing nations, it is unfortunate that the nations have not invested the money saved in sectors that boost economic growth in the short term, without which future borrowing may be inevitable (Isabirye-Basuta and Lwanga, 2008). It is thus clear that saving forest habitats will need full commitment from governments and people of poor nations, international organizations, and governments and people of rich nations.

One can broadly divide habitat change into two categories: natural and human-induced. Natural habitat changes include changes as small as a wind throw of an important food tree, tree die back due to cohort senescence, and vegetation changes caused by large herbivores, landslides, hurricanes, and drought-related tree mortality. All of these changes may affect primate populations negatively (Johns and Skorupa, 1987; Isabirye-Basuta and Lwanga, 2008). However, some natural habitat changes such as forest colonization can boost populations of some primate species. The second category, human-induced habitat changes, includes factors such as forest degradation (mainly through mechanical logging), forest fragmentation, introduction of exotic species, and deforestation (i.e., replacement of forests with lands dominated by human activities, such as agriculture). Understanding how primate populations respond to the habitat changes is complicated by the fact that in nature, the factors are not isolated; some are interrelated while the effects of others are aggravated by external factors. For example, while the removal of a few trees via logging may not have a serious impact on primate populations, the out come will be different, if logging occurs in a large scale and immigration of people follows (Isabirye-Basuta and Lwanga, 2008).

Besides logging and associated consequences, hunting is a significant factor in wildlife decline in many timber concessions and indeed in unlogged forests (Robinson and Bennett, 2000; Fimbel *et al.*, 2001). Several studies have concluded that hunting can reduce or even eliminate species from sizeable forest areas (Walter, 1971; Bennett *et al.*, 2000; Bennett and Gumal, 2001). Hunting affects species sought for food or trade (e.g., pigs, deer, primates, mouse-deer, and turtles) although methods such as snaring are indiscriminate and can cause more general impacts. Even moderate hunting at low human densities can lead to changes in wildlife populations. Collection for the live animal trade is also a significant concern for certain taxa. Controlling hunting of vulnerable species, especially commercial hunting, is a difficult but important management goal in developing the wildlife conservation value of timber concessions (Meijaard *et al.*, 2005).

Primates, Plant Reproduction and their Role as Keystone Species

Primates play an important role in the dynamics of plant communities. Although some primates may damage or destroy the plants and seeds they feed on, there is increasing evidence that they play an important and, in some cases, crucial role both as seed dispersers and pollinators (Cowlishaw and Dunbar, 2000). It is in the course of feeding that they disperse some seeds through their movement from one place to the other and ability to carry food in cheek pouches. Sympatric primates living in a tropical forest display a variety of feeding behaviours, ranging from insectivorous through frugivorous to folivores. Even though fresh fruits are widely consumed by frugivores, many insectivorous and folivorous primate species such as *Cercopithecus* spp. (Gautier-Hion *et al.*, 1980) and *Pan troglodytes* (Reynolds and Reynolds, 1965) feed largely on fruits. It must be noted that certain species may be classified as either insectivorous or folivorous since the former sometimes do take fruits as supplements. The feeding behaviour of frugivorous primates may be affected by the distribution of fruit production in time and in space and are likely to influence their ranging behaviour (Mitani, 1989). This indicates that the presence of primates in certain forest ecosystem contribute to the welfare of the plants. On the other hand, the plants also contribute immensely to the survival of the primates.

Paine (1969) defines a keystone species as one which plays a key role in determining the presence or absence of many other species in a community. Forest primates play such a key role. Animals in general, are important to plants as predators that eat them or their reproductive parts and as collaborators in reproduction. This implies that animals' role as both pollinators and seed dispersers, can have critical implications for long term viability of forest habitats, in many of which primates seem to play a keystone role. Animals that destroy the vegetation of their habitat do not survive but in some cases those species may be restricted in their growth form or population dynamics by grazing pressure exerted by the animals including primates (Cowlishaw and Dunbar, 2000). This was manifested in the heavy consumption of the flowers of *Markhamia platycalyx* by red colobus (*Procolobus badius*) in the Kibale forest of Uganda which suppressed fruit production in this species.

A colobus group could strip a *Markhamia* tree of its flowers in an hour of concentrated feeding. The only *Markhamia* specimens that managed to fruit during a 24-period were outside the forest or in areas of forest with low primate densities. When the flowering of *Markhamia* trees subsequently became highly synchronized, the colobus were in effect swamped and a significant fruit crop resulted (Struhsaker, 1978). *Celtis africana* in Kibale adopted a different strategy by being cryptic in an attempt to outwit its predator (Cowlishaw and Dunbar, 2000). Primates may also damage plants while feeding on their structural parts (e.g., leaves in the case of folivores), though there is little direct evidence to support the claim that primate foraging pressure ever normally reaches a sufficient level to prevent recovery of damaged vegetation.

The evidence with respect to damage to seeds is perhaps less ambiguous. Mangabeys (*Lophocebus albigena*) destroy the seeds of *Diospyros abyssinica* by breaking them open and chewing them; chimpanzees (*Pan troglodytes*) destroy the seeds of palms (Wasser, 1977). The faeces of two guenons, *Cercopithecus mitis* and *Cercopithecus ascanius*, may contain many fragments of seeds and cases but no intact seeds larger than 2 mm in diameter; only the seeds of *Solanum giganteum* passed through the animal's alimentary canal undamaged (Rowell and Mitchell, 1991). Similarly, increase in seed damage by the forest guenons in Gabon has been reported with increases in seed size (Gautier-Hion, 1984). However, little is known about the real impact that this level of seed predation has on the population dynamics of the plant species concerned. Serious damage however probably occurs where the animals themselves are living under marginal survival conditions (Cowlishaw and Dunbar, 2000).

Functional role of primates to plants

It has been estimated that an average of 21% of plant species eaten by a wide variety of tropical primates were climbers (Bongers *et al.*, 2004). In the rainforests of West Africa where fruiting and flowering of climber plants show no peaks, animals may switch to feeding on the reproductive parts of these lianas.

Traditionally, the assumption has been that most vectored plant pollination is done by insects, with birds and volant mammals being secondary sources. Circumstantial evidence accumulated in recent years tends to suggest that non-volant mammals may also be involved (Carthew and Goldingay, 1997). For example, Mongoose lemur (*Eulemur mongoz*) was reported to spend up to 84%of its time on nectar-related feeding, mostly on Ceiba (*Ceiba pentandra*) and Greater galago (*Otolemur crassicaudatus*) on nectar of Baobab (*Adansonia digitata*) in East Africa (Birkinshaw and Colquham, 1998). However, evidence that primates are active pollinators of plants is at best circumstantial, and no experimental trials to test the hypothesis have been run for any species (Cowlishaw and Dunbar, 2000).

A wide range of primate species including gorillas (Voysey *et al*., 1999), chimpanzees (Wrangham *et al*., 1994), orangutans (Payne, 1995), baboons (Lieberman *et al*., 1979) and guenons (Gautier-Hion, 1984) have been identified as contributing to the active dispersal of seeds. Some of them exhibit endozoochory, which refers to seed dispersal after ingestion by animals. Species differ markedly both in the intensity of their use of seeds (and hence their potential to act as dispersers relative to other sympatric vertebrate species) and how badly they damage seeds during ingestion (Cowlishaw and Dunbar, 2000). As pointed out by Rowell and Mitchell (1991), *Cercopithecus* species tend to destroy seeds by grinding them very finely during chewing, whereas *Cebus* species pass the seeds they ingest more or less intact.

Furthermore, seed dispersal always involves gut passage but in some cases the fleshy outer layers of fruits may be eaten while the seeds are spat out. Corlett and Lucas (1990) found that *Macaca fascicularis* could swallow only seeds smaller than 3-4mm in diameter and that 69% of all species eaten are spat out. Most studies have reported significantly improved germination rates after seeds have passed through the gut of a primate than do fresh seeds dropped off the branch as in baboons (Lieberman *et al*., 1979), chimpanzees (Wrangham *et al*., 1994), spider monkeys, howler monkeys and capuchin monkeys (Chapman, 1989). The role of the digestive system in stripping flesh from seeds and weakening the hard outer casing of the seed may promote rapid germination, and the additional soil fertilization provided by associated fecal material may also contribute (Cowlishaw and Dunbar, 2000). To support this, *Cola lizae* seeds were found to be significantly higher for seeds deposited in dung at gorilla nest sites than seeds deposited elsewhere (Tutin *et al*., 1991).

Hladik and Hladik (1967) however found that although germination rates for *Ficus insipid* were higher after ingestion by spider monkeys or capuchins; they were very poor after passage through the gut of howler monkeys. This suggests that ingestion by primates is not always beneficial for seeds. It has been suggested that leaf fermentation in old world colobines may provide the basis for detoxifying seeds in many of these species (Kay and Davies, 1994). Additionally, in a series of experimental studies, it was found that five species of West African monkeys destroyed seeds by chewing them. This was attributed to the bilophodont molar characteristics of the cercopithecine monkeys that might have evolved to crush and grind seeds so as to extract nutrients more effectively (Happel, 1988). Moreover, post defecation consumption by secondary predators can take a very heavy toll on both seeds and seedlings, even if seeds survive the ingestion process. Chapman (1989) found that spiny mice (*Acomys* spp) destroyed up to 52% of all seeds and seedlings in artificial dung piles in Costa Rica within five days of deposition.

Differences in behavioural ecology between primate species are important in seed dispersal. Since chimpanzees have larger home ranges and travel further each day than arboreal forest monkeys, they are able to disperse seeds over a much wider area (Wrangham *et al*., 1991). Old world monkeys are more likely to store the fruits in their cheek pouches and travel away from the parent tree to eat the fruit in a safe place (often in different tree species). This can be crucial for seed dispersal, since many forest trees actively suppress germination of their own seeds which fall beneath their canopy (Howe *et al*., 1985). Even seeds that are deposited as little as 5m away from the parent tree increased a seed's chances of germinating successfully by 340% (Schupp, 1988).

Since seeds may be transported some distance before being deposited, they may be deposited outside the immediate forest environs. This dispersion has the effect of spreading the forest species into the surrounding ecosystem (e.g., grassland) and so contributing to the expansion of some invasive species. Lieberman *et al*. (1979) suggested that baboons in the Shai Hills Resource Reserve in Ghana may be seeding new plots of woodland by depositing seeds of neem on rocky outcrops adjacent to the forested parts of the hills. By virtue of their numbers, Chapman (1989) argued that frugivorous primates may be among the most important seed dispersers in tropical forests. Hence, the consequences of losing primate communities may thus be potentially disastrous. This is substantiated by a recent comparison of tree recruitment patterns between forest containing an intact primate population and forest fragments where primate populations had been severely reduced. The fragmented forest had lower seedling density and fewer species of seedlings than the intact forest (Cowlishaw and Dunbar, 2000).

A three-month study of feeding ecology and seed dispersal by four species of lemurs in Madagascar's eastern rain forest found that three species, *Eulemur rubriventer*, *Eulemur fulvus,* and *Erecia variegate* were seed dispersers, and the fourth, *Propithecus diadema,* was a seed predator. In germination trials, seeds passed through the digestive systems of lemurs sprouted significantly faster and in greater numbers than those not treated in the same way. Analysis of fruit morphologies of 69 local plant taxa producing fleshy fruits during the study period found that these fruits fell into two well-defined colour categories that correlated significantly with fruit size (Dew and Wright, 1998).

Primate Feeding Ecology

Determinants of food choice in primates

Primates meet their nutritional goals by prioritizing certain nutritional parameters when choosing the types and qualities of different foods. There is a complexity of factors affecting food choice which includes calorific value and several kinds of qualitative differences between foods that are classified as important. Hence, several generalizations emerge from comparison of the diets of the different primate species (Clutton-Brock, 1977).

Most primates are highly selective in their choice of foods, often consistently selecting specific parts of particular species. For example, both red colobus and howling monkeys carefully eat the basal portion of the leaves of some tree species and the apex of the leaves of other species (Struhsaker, 1975). In general, shoots, flowers and fruits are more commonly eaten than mature leaves. Differences at this level are easily explicable in terms of the higher protein contents and the lower cellulose levels found in these parts (Hladik, 1978). The extent to which particular parts of leaves are selected is probably relative to variation in protein or sugar concentrations within the leaf. Differences between food species in the extent to which the various parts are eaten are also probably related to qualitative differences in energetic value or digestibility (Clutton-Brock, 1977). Primates that feed extensively on mature leaves such as *Colobus guereza* however tend to select the leaves of deciduous, colonizing tree species, which often contain lower levels of cellulose and are more easily digested than those of evergreen species (Oates, 1977b).

Three types of qualitative differences are likely to affect the extent to which primates select different species. Firstly, the leaves and fruits of different species vary in the specific nutrients they contain, and in order to achieve a balanced diet it may be necessary for both folivores and fruigivores to select particular food species for the chemical contents (Westoby, 1974). For example, Oates (1977b) reported that between two-to-four week intervals *Colobus guereza* groups descended from the trees to the valley bottoms, and fed on the water plants. It was subsequently found that the leaves of these species contained high levels of sodium which might have been relatively scarce in the rest of the animals' diets. Secondly, the seeds and leaves of many tropical tree species contain a variety of secondary compounds, including tannins, alkaloids and terpenes (Bates-Smith, 1972). Thirdly, animals may select particular foods to facilitate digestion. For instance, a variety of primate species eat small amount of soil (Oates, 1974). Though this may sometimes serve to correct mineral deficiencies, the mineral concentrations available in the soil do not exceed those present in many common foods and an alternative explanation is that phyllitous soil may aid digestion by absorbing secondary compounds (Hladik, 1978).

Struhsaker (1978) suggested that monkey species did not usually share their commonest foods with any other species and only four out of the 25 specific food items were shared between any two monkey species and none was shared by three or more.

Feeding behaviour of primates

According to Morse (1971), indices of food species diversity are used sometimes to classify animals as food generalists or specialists. The generalists have high indices, while the specialists have low indices. The rank of these indices varies with the time scale of the sample (Struhsaker, 1978).

In north-eastern Peru, Kinzey (1977) reported that the yellow-handed titi monkey (*Callicebus torquatus torquatus*) spent 26% of its day feeding. By percentage of time spent eating each item, it was found that 67% of the time were on fruits, 14% on insects, 13% on leaves and 6% was spent eating unknown items with feeding rates varying for different foods eaten. Kinzey (1977) obtained two measures of feeding time as (i) the time required by an animal to eat one individual fruit, from when it was placed in the mouth until all chewing stopped and another fruit was searched for; and (ii) time spent in the feeding tree divided by the number of fruits eaten. The feeding time spent in the feeding tree included both chewing and looking for edible fruit. *Colobus guereza* feeding records obtained throughout Africa between 1970 and1972 indicated that 3,084 feeding records were distributed across 63 plant species. In Kanyawara area of Kibale forest in Uganda, within a 12 month period (January-December, 1971), 2,366 individual feeding records were made which were distributed across 30 tree species including a strangling fig, nine climbers and two aquatic herbs. In addition, lichens growing on two different tree species were eaten but no animal material was definitely seen to be consumed. However, small animals especially insects may well have been ingested along with plant parts. This would usually apply to fig consumption, as these foods often contain huge numbers of pollinating and parasitic wasps and parasitic beetles. Three out of 43 food plant species were responsible for 69% of feeding records at Kanyawara, and this suggests strong differential selection of food by guerezas (Oates, 1977b).

In Bia National Park, Ghana, a total of 3,224 recorded food items visits (FIV) of roloway monkeys (*Cercopithecus diana roloway*) comprised 2,296 visits to trees, 888 visits to climbers and 40 visits to epiphytes. The monkeys fed on food items from 101 tree species, 42 climber species and eight epiphytes. Food trees visited in a month in Bia National Park included *Pycnanthus angolensis* (n=548), *Funtumia elastica* (n=139), *Piptadeniastrum africanum* (n=216), *Parkia bicolor* (n=134) and the climbers included *Landolphia hirsuta* (n=165), *Santaloides afzelii* (n=167) and *Salacia howesii* (n=106) (Curtin, 2002).

In analyzing food habits of five sympatric primate species notably red colobus (*Colobus badius tephrosceles*), black-and-white colobus (*Colobus guereza occidentalis*), mangabey (*Cercocebus albigeria johnstoni*), blue monkey (*Cercopithecus mitis stuhlmanni*) and red-tailed monkey (*Cercopithecus ascanius schmidti*) in Kibale National Forest in Uganda, Struhsaker (1978) found that *Cercopithecus ascanius* has the most varied diet of 80 plants followed by *Cercopithecus mitis* (59 plants) and *Colobus badius* (57 plants). *Cercocebus albigeria* has the fourth most diversified diet, and *Colobus guereza* had the least diverse by a wide margin of 43 species. On a monthly basis *Colobus badius* had a greater index of plant food diversity (H' = 2.61) on average, than both *C. ascanius* (H'=1.92) and *C. mitis* (H'= 2.17). The apparent need of *Colobus badius* for a wide variety of species each month seems to be satisfied by the year round availability of young plant growth and mature leaf petioles. In contrast, *C. ascanius* and *C. mitis* concentrated on one or a few plant species each month, and each (or every other) month they specialized on something different. Consequently, their plant dietary diversity was lower than *Colobus badius* on a monthly basis, but higher on annual basis. This pattern is often related to fruiting period. In both *C. mitis* and *C. ascanius*, the monthly proportion of fruit in the diet was inversely correlated with the diversity of plant foods. In contrast to the similar annual diets, the monthly diet of *C. mitis* was more varied than that of *C. ascanius*, making it intermediate in this regard to *Colobus badius* and *Cercopithecus ascanius* (Struhsaker, 1978).

Nutrient requirements of primates

Energy balance and protein gain are important factors for an animal's diet quality and overall well-being. Animals require energy for basal metabolic functions, muscular activity, tissue formation, reproduction, and lactation (National Research Council, 2003). Animals also require protein and its constituent amino acids for growth and maintenance of body tissues. The absence of both energy and protein results in protein-energy malnutrition (PEM; also known as kwashiorkor and marasmus) (Ausman *et al*., 1989). Thus, when evaluating diet quality of an organism, it is essential to determine the energy and protein requirements of the animal under study as well as the supply of these elements in its surroundings. N'guessan *et al*. (2009) found that the seasons of fruits of chimpanzee (*Pan troglodytes verus*) in Tai National Park in Côte d'Ivoire, were significantly distinct in fruit diversity, energy and protein providing rates but more similar in biomass quantity of fruit available. Yet there was no significant difference in energy balance across the categories of individuals. However, the inter-season comparison showed that energy balance varied for young and adult males. For adult females, energy balance was similar across all seasons, suggesting that they used the best strategy for energy management throughout the year. As certain organs of plants develop and mature their nutrient quality declines. Baranga (1983) suggested that as leaves mature, the nitrogen content and levels of a number of important minerals generally decline, while the fibre content increases as exhibited by *Celtis* leaves, whose levels of nitrogen, phosphorus and potassium decreased, while fiber and lignin increased. In general, young leaves generally contain more moisture, protein, phosphorus and potassium, all of which decrease with increasing maturity.

Dietary strategies of primates

In analyzing diet of primate species according to relative consumption of three principal food types which were grouped as animal matter; fruits and seeds; leaves, flowers, gum and sap. Chivers (1994) noted that most primates are folivorous or frugivorous and Cowlishaw and Dunbar (2000) concluded that most species are dietetically quite flexible. Folivores can subsist on low quality foods and have the advantage that leaves are widely available. Leaves however, pose their own problems of nutrients being locked up within the cell walls and the cellulose that compose the walls being often difficult to digest (Van Soest, 1982). Therefore, there are adaptations such as fermentation or long gut passage time to permit the absorption of nutrients. Dental specialization (e.g., hypsodont molar) for shredding or grinding leaves to promote microbial action has also been identified to be associated with folivory (Dunbar and Bose, 1991). Gut passage time is a direct function of the length of the digestive tract, and this in turn is a function of body size for the purely mechanical reason that a large body is needed to house a large intestine and this has been reflected in the fact that folivores are typically the largest of the primates (Milton, 1984). Leaves are often protected through chemical defenses. Leaves of tree species eaten by three colobine species were found to contain quantities of digestible protein which are inversely related to the quantity of digestion inhibitors, principally fiber and condensed tannins. Preferred items tend to have high digestibility (i.e., lower levels of digestion inhibitors) and more accessible protein (Waterman *et al.*, 1988). In addition, many of the folivores exhibit specialized adaptations to folivory in their digestive tract. These species rely on microbial fermentation to digest the plant cell walls so as to make the nutrients accessible by subsequently digesting the bacteria in the hindgut after these have extracted the cellular nutrients. In effect they are fermenters without the rumination seen in ungulates like cattle and antelopes (Kay and Davies, 1994). This strategy then allows them to subsist on leafier and more chemically defended diets.

Among primary consumers, the main alternative to folivory is frugivory, but frugivores are not well adapted to coping with leaves. Although many non-folivores, primates do eat leaves as a regular part of their diet and sometimes rely on them as subsistence foods, their ability to absorb nutrients from this food source is relatively poor (Cowlishaw and Dunbar, 2000). This has been demonstrated in Japanese macaques (*Macaca fuscata*) which fed on diet of leaves and had a calorie intake below that required to maintain body mass and thus lost weight overtime, whereas the same animals were able to maintain body condition quite satisfactorily on a predominantly fruit-based diet.

Generally, fruits provide animals with more readily accessible nutrients than leaves do. Energy is likely to be especially important although other nutrients may be important in particular cases (Altmann, 1998). But fruits suffer from their own intrinsic disadvantages: Firstly, fruits tend to be more patchily-distributed than leaves and are often highly seasonal in their availability. Secondly, although many plants may require primates to swallow their seeds whole (since primates are often a vehicle for seed dispersal) but not to consume seeds before they are mature or to destroy seeds by chewing them into pieces. Hence many plants have evolved defences to protect their seeds from premature dispersal or predation (Cowlishaw and Dunbar, 2000). Fruits typically come in two varieties: (i) those that consist of just the seed, often in some kind of casing or pod (e.g., seeds of many palms) and (ii) those whose seeds are encased in a soft, fleshy outer covering (e.g., figs). Plants that produce the first kind of fruit tend to rely on physical defences such as shells that may require considerable strength to break open in order to minimize seed predation. Plants that produce the second kind tend to rely on chemical defenses including a whole range of toxic materials such as tannins and phenolics that inhibit digestion to avoid both seed predation and premature dispersal (Waterman *et al*., 1988). Coping with physical defences often requires considerable strength and/or specialized features. For example, the strong molars that Pithecines and Cebus monkeys use for cracking open palm nuts (Kinzey, 1992) and the nut cracking skills of chimpanzees (Boesch and Boesch, 1981). In most cases the toxins used to prevent premature dispersal are designed to deteriorate naturally as the fruit ripens, so that the fruit becomes chemically accessible once the seeds are capable of independent survival (Cowlishaw and Dunbar, 2000). However, some Old World cercopithecines have evolved the ability to detoxify unripe fruits and therefore can exploit these food sources first before other frugivores (Andrew and Aiello, 1984).

Another dietary specialization of some importance in primates is gumivory which refers to feeding on plant gums and other exudates as in some prosimians (e.g., Lemur- *Phaner furcifer*). It should be emphasized that leaves, fruits, seeds and gums are not the only plant foods primates consume. Flowers and nectar are commonly eaten, particularly by frugivores like *Miopithecus talapoin* (Gautier-Hion, 1970). Bark may sometimes be eaten during lean seasons, particularly by folivores such as gorilla (*Gorilla gorilla*) (White *et al*., 1995). Some primate species have specialized in feeding on particular plant like the gelada baboon (*Theropithecus gelada*) a true grazer, and the only living primate that feeds exclusively on grasses (Dunbar, 1977).

Although most primates are vegetarians, most of them also eat small amounts of animal matter which contains vitamin B_{12}, which primates cannot synthesize or obtain from non animal sources. In most cases, carnivory involves predation on insects and other invertebrates (e.g., worms, small birds and their egg or nestlings) or small vertebrates like lizards and frogs (Cowlishaw and Dunbar, 2000). In contrast to feeding on small animals, the active hunting of animals as large as ungulates or even medium sized primates is exclusive to chimpanzees (Boesch and Boesch, 1989; Davis and Cowlishaw, 1996). Accounts of predation in a number of Old World monkeys including baboons, vervets and green monkeys, suggest that hunting is more characteristic of dry than wet habitats and within habitats of the dry season than the wet season (Dunbar, 1988). Categorizing primates dietetically into folivores, frugivores and faunivores is therefore a gross oversimplification.

The emphasis on one or other dietary category can vary from one habitat to another, even within a species. For example, African colobines are more folivorous in East Africa, where forest on nutrient rich volcanic soils are characterized by a high diversity of palatable species (Dunbar, 1987) but more typically gramivorous in West Africa, where the nutrient-poor soils tend to produce forests whose vegetative parts are heavily defended chemically (Oates, 1994). For instance, gorillas in Rwanda are typically terrestrial folivores, whereas those in Gabon are more typically arboreal frugivores (Tutin *et al.*, 1991).Thus though species can be characterized as favouring on one type of diet (indeed may exhibit morphological specializations to that effect) this indicates that dietary flexibility is an important feature of the ecology of all primates.

Seasonality in Food Availability

Nutritional values and availability of different food items peak at different seasons of the year and these differences were observed in the nutrient levels of *Celtis durandii* leaves and *Markhamia platycalyx* leaf parts in the analysis of changes in chemical composition of food parts in the diet of colobus monkeys in Kibale forest, Uganda. *Celtis* showed strong correlations between its chemical constituents while similar correlations for *Markhamia* were generally weak and varied among different leaf parts (Baranga, 1983).

The chemical composition of a plant varies with its stage of maturity as well as soil conditions and climate (French, 1956). Rainfall was identified as highly correlated with food availability for roloway monkeys in Bia National Park in Ghana (Curtin, 2002). Fruits of trees and climbers were more abundant in the dry season and young leaves, flowers and arthropods were more abundant in the wet season. Comparing dry and wet season samples, it was concluded that the higher numbers of feeding trees/day and feeding visits/day in the dry season correlate with longer day ranges in the dry season (mean=2,280) versus the wet season (mean=1,505) (Curtin and Olson, 1982). The roloway monkeys travel wider, feeding in more individual trees and making more feeding visits per day overall in the season with greater food and moisture scarcity. The major components of the diet measured by food item visits in the dry season are the pulp of matured fruit of woody climbers and trees, seeds of mature fruits, mainly *Pycnanthus angolensis* and insects.

In the wet season however, insects become even more important and the pulp of mature fruit remains a significant food item, seeds drop off and new leaves and flower buds produced by the rains assume greater importance (Curtin, 2002). Though the compositions of the acquired food varied from season to season, a strong dependency on fruit was recognized at each season in the environment of Mangabey (*Cercocebus torquatus*) in south-western Cameroon. Fruit accounted for over 60% of the diet even in the major rainy season, when the smallest ratio of fruit feeding was observed. A considerable seasonal difference was noted in leaf eating, mainly on monocotyledon shoots. A larger amount of monocotyledon shoots may be produced in the rainy season and this variation in productivity possibly affected the diet composition, although shoots were continuously available all year round (Mitani, 1989).

In southern Vietnam, Black-shanked douc langurs (*Pygathrix nigripes*) consumed significantly more fruit and fewer flowers in the morning and vice versa in the afternoon. The sample size in the dry season was small, but even so the proportions of food items showed a significant seasonal variation. During the dry season, black-shanked douc langurs ate mostly leaves, followed by flowers, then fruit and other items. In the wet season, the monkeys also ate leaves in greatest proportion but the proportion of fruits was almost double that in the dry season (Duc *et al*., 2009). In south-western Cameroon where there is seasonal variation, Mitani (1989) suggested that neither the fruit species abundance nor diversity differed considerably from season to season, which suggests that the Mangabeys have evolved adaptive feeding and ranging behaviours in response to such an environment.

Though food availability may be among the most important constraints on abundance of primates (Cowlishaw and Dunbar, 2000), several authors have suggested that food may not always be limiting. It has even been suggested that some primates live under conditions of food surplus (Coelho *et al*., 1976, 1977; Butynski, 1989). Cowlishaw and Dunbar (2000) suggested that ‘ecological crunches’ and ‘nutritional bottlenecks’ might be particularly important for frugivorous primate populations. For instance, the low abundance of frugivorous primates in the Urucu forest of the Brazilian Amazon is due precisely to the strong seasonality of fruit production there (Peres, 1994). The effect of this nutritional bottleneck is not however confined to this single dietary group and during lean periods the populations have to rely on keystone food resources.

However, at the level of the entire community, it was found that the estimated metabolic requirements of frugivorous mammals at Cocha Cashu, Peru, was only 20% less than the total annual production of fleshy fruits (Janson and Emmons, 1990). This indicates that the major resources consumed by fruit-eating primates limit their population density (Janson and Chapman, 1999). A generalist pattern of consumption suggests that Lowe's monkeys are flexible in relation to feeding options (Di Fiore *et al*., 2008). Therefore, the main threat to their existence seems to be poaching and the loss of forests with continuous canopies.

Phenology of Tropical Plants Ecology

Tropical ecology has been recognized as having a number of features which distinguish it from temperate ecology (Ewusie, 1980). One of the features is the presence of significant and conspicuous activity of the plants and animals at any time of the year (Ewusie, 1992). As a result, at any time of the year, some plants could be in flower, fruiting, losing leaves or forming new leaves in the tropical forest. Thus there is extreme complexity or lack of order in the phenology of tropical plant populations (Ewusie, 1992).

Environmental or exogenous control over flowering has been established in many tropical species. Day length, though varying very slightly in the tropics has been shown to induce flowering in some tropical species. Some tropical plants must exceed the juvenile stage with a certain number of leaves before the plant becomes sensitive to photoperiod (Goldsworthy & Fisher, 1984).

It has also been observed that lower latitudes in the tropics receive rainfall before higher latitudes. For example Ewusie (1992) observed that *Adansonia digitata* and *Acacia* flower and fruit earlier in the year in southern Ghana and Nigeria than in northern parts of these countries. The importance of rainfall as a distal factor for flowering in the same species is reinforced by the observation of species which flower twice a year in lower tropical latitudes, corresponding to the two annual periods of rainfall. The rainfall pattern may however be modified by some local factors, such as relief in some places. Quite often, in the tropics, the rains come with such severity that there is more than needed water during the period of rain, but outside the period there can be serious scarcity of water. In much of the tropics there is accumulation of mineralized nitrogen at the beginning of the rains, but this is leached as the rainfall continues (Goldsworthy and Fisher, 1984). Plants in the tropics, therefore, seem to have evolved a number of different adaptations to enable them go through vegetative and reproductive phases within the context of the climatic factors. This ensures that some flowers and seeds are provided each year (Ewusie, 1992).

In many cases tropical plants flower at such times that their seeds are available at the end of the rains. Any local environmental change that leads to early flower development will mean fruiting before being affected by insects or fungal attack. If certain factors delay flowering (or anthesis), there may not be enough water for proper fruit production. Ewusie (1969) made a detailed analysis of 136 flowering period in 92 West African woody species. The study was based on the months of initiation of flowering which share two main peak periods. The main or primary flowering period of the year seems for most species to take place before, during and just after the second (and shorter) minor rainy season which lasts from October to November. During this period, the sun is little obscured by the clouds and the humidity is low. The secondary (or moderate) flowering period occurs before the end of the dry period and the beginning of the long rains in April. At this time, the sky is again partially clear of clouds.

The main and secondary flowering periods constitute the two peak periods of the year. The lowest flowering period takes place during the wet period when the sun is regularly obscured by heavy clouds and the period includes May or June to July (Ewusie, 1992). Among the 44 species that flowered twice a year, Ewusie (1969) found that only seven initiated flowering during the rainy season.

The synchronous production of a new leaf is a characteristic of tropical species and is often referred to as "flushing" which may occur at regular or irregular intervals (Ewusie, 1992). Annual foliar periodicity is known to occur more in older plants of a species, as in *Albizia falcaba*, but not in younger ones (Richards, 1952; Ghazoul and Sheil, 2010), but Njoku (1964) reported that regular annual foliar cycles are apparent even in the first year of growth in some Nigerian dry forest species but irregular and non-annual cycle type of leaf change in *Magnifera indica* in West Africa (Ewusie, 1968).

Flushing would appear to be an important anti-predator strategy. Thus, the sudden appearance of a large food supply "swamps" the extant insect population. By the time the population increases in response to the food supply, the leaves would have hardened to some extent and may be protected chemically (McKey, 1974) and newly flushed leaves of some species are not normally available for predators for a number of reasons.

Baranga (1986) found in two of the top-ranking food species of *Colobus* in Kibale National Forest that *Cetis durandii* lost its leaves once a year in the dry season, after which it stood bare for less than a month and flowering occurred when the canopies were leafless. For *Markhamia platycalyx*, flushing and leaf shedding were continuous activities, flower buds were rare and flowers were never observed in the seasonal forest. The tendency for flushing to increase toward the end of the major dry season, just before the onset of the rains, was high. For example, in Costa Rican wet semi-deciduous forest, Daubenmire (1972) reported some flushing throughout the year with a peak (when about 70% of the species) flushing in the dry season, about a month before the rains. Similar observations have been made in the seasonal forests of West Africa (Njoku, 1963; Ewusie, 1969).

Baranga (1986) demonstrated that mature leaves were the most abundant structures of *Celtis durandii*. The lowest mean monthly score for leaf buds and young leaves coincided with the period when mature leaves had a maximum mean score. Sometimes, *Celtis* flushed new leaves at the beginning of the dry season while at other times this activity occurred at the end of the dry period. On the other hand, peaks in the flushing of new leaves of *Markhamia* coincided closely with rainfall peaks, but on some occasions the flushing occurred after the periods of heavy rainfall. The relative importance of factors triggering leaf production and fall has been argued at length. Richards (1952) indicated that both external and internal factors influence leaf flush and fall and that external factors, most importantly water supply, are influential as cues even in non-seasonal climates. He concluded that deciduous behaviour confers no advantage on rain forest and that they could in fact retain their leaves throughout the year without risk of harm such as increased loss of water. Whitmore (1975) considers that even in per-humid tropical climate, leaf fall and flushing are commonly related to water stress. Other factors that may be important in triggering leaf changes include rising air temperatures (Walter, 1971) and day-length as an environmental cue in the tropics, especially where rainfall and temperature are essentially non seasonal (Richards, 1952; Ghazoul & Sheil, 2010).

The phenomenon whereby some tropical plant species flower or shed leaves more than once in a year, is of special importance in tropical forest ecology. Ewusie (1968) observed that out of 100 woody species studied, 48 flowered once a year, 44 flowered twice a year, and then there was a sharp drop to six which appeared to flower three times in a year and one about four times in a year. The latitude (6-8) at which Ewusie (1968) conducted his study receives two peaks of rainfall a year and he showed that the high proportion of species flowering twice a year in this region was related to the double peak of rainfall. When he analysed the timing of the species that flowered once a year compared with those that flowered twice a year, Ewusie (1969) showed that the major peak period was due more to those species that flowered twice a year. It appears also that species of the same genus may differ in their phenophase frequency and Keay *et al.* (1964) demonstrated that of the 31 different species of the genus *Ficus* in Nigeria on which observational data are available, 12 flower and fruit once a year, 18 twice and one , three times a year. This phenomenon does not occur to the same extent in every genus. For example, among the 21 species of *Diospyros* in Nigeria, 17 flower once a year, three twice a year and one three times a year (Keay *et al.*, 1964). Species which flower and fruit twice a year do so at different times of the year and with different intervals between the two respective periods in the year; these intervals are generally of unequal duration (Ewusie, 1968).

The period in which flower buds are initiated in woody species appears to have special significance, since the buds are likely to be quite sensitive to the prevailing weather conditions. As a result, an unsuitable weather for flower bud formation may prevent flowering altogether. However, the flowering of species more than once a year (frequency multiplication) has been observed to be significant in some trees of tropical forest. This suggests that there might be genetic control of flowering frequency which may not be affected to the same extent in different species by the same environmental factors (Ewusie, 1992).

Apart from the phenomenon of frequency of multiplication, another feature of tropical phenology is where some species flower more than once a year (frequency of de-multiplication). Examples include some Malayan forest species of Hopea *(Hopea acuminata*) and Shorea (*Shorea parvifolia*) which flower every sixth year (Schimper, 1963) and *Triplochiton scleroxylon* in Ghana which flower every five years (personal observation).

One of the complexities of tropical phenology is the occurrence of flowering intermittently at any time of the year in some species. Richards (1952) studying *Wormia suffructicosa* and *Adinandra dumosa* in Malaysia and Ewusie (1968) working on *Lawsonia inermis, Senna siamea* and *Moringa rufescens* in southern West Africa gave these species as examples of species that flower sporadically throughout the year.

Generally, it appears to be the same range of leaf change frequency as there is of flowering. This is because flowering is associated with leaf change in a number of species. Thus, species which flower twice a year and also show leaf change which occurs twice a year. Leaf-change involves the shedding of leaves and flushing of new ones. The frequency of flushing may, however, vary between two species of the same genus. Thus even though *Cola millenii* and *C. acuminata* flower once a year, the former produces new leaves once and the latter twice a year (Ewusie, 1992).

Hunting as an Extrinsic Factor Affecting Populations of Primates

Two major factors identified to be the critical extrinsic forces driving primate populations to extinction are hunting and habitat disturbance (Cowlishaw and Dunbar, 2000). For example, forest fragmentation can increase bush meat hunting and hence put additional pressures on already threatened primate species (Fa *et al.*, 1995). Human predation on primates has a long history. Primate hunting dates back to between 400,000 and 700,000 years ago from Olorgasaille in Kenya (Cowlishaw and Dunbar, 2000). Humans have been hunting their non-human primate relatives throughout the ages. For example, giant gelada baboons (*Theropithecus oswald*) were butchered and possibly hunted by *Homo erectus* at one fossil site in East Africa between 400,000 and 700,000 years ago (Shipman *et al.*, 1981). More recently, prehistoric hunting has been implicated in the extinction of the Orangutans (*Pongo pygmaeus*) in Java (Rijksen, 1978) whereas extinction of 15 species and eight genera of lemurs in Madagascar have been recorded during the past 1,000 years (Godfrey *et al.*, 1997).

The most important reasons contemporary humans hunt other primates are for food and control of agricultural pests particularly in Africa and Asia (Mittermeier, 1987). The remaining incentives for hunting include national and international trade in live primates and primate parts. According to Mittermeier (1987), hunting intensity tends to be low in Asia and Madagascar and high in the Americas and Africa. The factors that underlie these trends might include the availability of prey animals, and alternative protein sources such as fish and livestock production as well as the cultural traditions of the people (Cowlishaw and Dunbar, 2000).

Throughout human history, the relentless harvest of wild meat (bushmeat) by subsistence hunters around in tropical countries has resulted in conspicuous population declines and extinctions at local to global scales for many species of birds and mammals (Diamond, 1989). Different definitions of hunting have been evaluated over millennia. The ancient Greeks and medieval visitors distinguished different kinds of animal harvest by humans based on the methods used. Hunting is the active pursuit of large mammals, and has been distinguished from trapping, fishing and other means of catching animals such as falconry (Cartmill, 1993). Bennett and Robinson (2000a) defined hunting as "all capture by humans of wild mammals, birds and reptiles, whether dead or alive, irrespective of the techniques used to capture them". This usually involves killing animals for human use, especially meat for eating, for traditional medicines or trophies, but it also includes taking of live animals as pets or for the biomedical and/or zoo trades. Hunting also encompasses taking animals both for personal consumption and for commercial sale. This definition is an ecological one, since it is based on the extraction of the wild animal from its environment which affects the species population being harvested as well as the entire biological community. From this perspective, it does not matter how an animal is killed: whether through shotguns, blowpipes, dogs, spears, arrows, machetes, traps, snares or nets (Bennett and Robinson, 2000b).

Hunting trends

Hunting is generally done for nutritional, economic, cultural and recreational reasons. Nutritional reasons for hunting can be highly significant in at least 62 countries worldwide with wildlife contributing a minimum of 20% of the animal protein in rural diets (Prescott-Allen and Prescott-Allen, 1982). In Amazon region in South America, wildlife provides significant calories to rural communities, as well as essential nutrients such as protein and fats (Dufour, 1983). In West Africa, Asibey (1974) estimated that 75% of the protein sources consumed consisted of the meat of wild animals (i.e., 'bushmeat' or viande de brousse' as locally known in Ghana and Côte d'Ivoire respectively) (Parren and de Graaf, 1995). More than 13, 600 animals are harvested from the Arabuko-Sokoke forest in Kenya each year (Fitzgibbon *et al.*, 2000). In Amazonia state, Brazil, the rural population annually kills about 3.5million vertebrates for food (Robinson and Redford, 1991). For instance, in Korup National Park, Cameroon, each square kilometre of the forest produces wild meat with an animal value of about US$106 (Infield, 1988). In Arabuko-Sokoke forest in Kenya, production is about US$94 (Fitzgibbon *et al.*, 1995) whilst Ituri Forest, Democratic Republic of Congo, it is about US$318 (Wilkie, 1989). In general, subsistence hunters consume a minimum of 23,573 tons of wild meat per year (Bennett *et al.*, 2000).

Cultural values for hunting wild animal can also be viewed as the acquisition of animal trophies in the form of cultural artifacts or personal adornment (e.g., feathers, skins and teeth) which is widespread throughout the tropical forest regions (Bennett and Robinson, 2000b). Another cultural reason is that animals and hunting are inextricably woven into the world view of many cultures with being a hunter essential in gaining respect, achieving manhood, or winning a bride (Kwapena, 1984). For recreational reasons, hunting is largely for enjoyment with a wide range of hunters from children with catapults, to townsfolk spending large amounts of time, and often money, hunting in either their own country or overseas. Most tropical forest hunters seldom make a clear distinction between recreational and other forms of hunting. Whereas most tropical forest hunters would like to hunt as part of their culture, they also hunt to fulfill their nutritional and economic needs and to obtain trophies. They also hunt for wild meat because they prefer it to other forms of protein (Bennett and Robinson, 2000b).

Primate hunting is widespread over much of the Guinea-Congolian rainforest zone of Africa and especially in certain west and central African countries. Both subsistence hunting for local use and large-scale market hunting are important factors in these countries and are undoubtedly a major reason for the decline of many primate species. Hunting can be considered a more serious threat to primates in the Guineo-Congolian rainforest zone of West and Central Africa than anywhere else in the world (Mittermeier, 1987). Out of 100 farmers in Equatorial Guinea interviewed, Sabater-Pi and Grove (1972) found that 30% preferred higher primates to all other sources of food. In the Bendel State of Nigeria, Oates *et al.* (1992) reported that monkeys accounted for 16.7 % of 1,084 animals sold as bushmeat. Mittermeier (1987) noted that with heavy hunting pressure, it is almost certain that primate populations have been greatly reduced or even exterminated in many areas and certain rare and endangered species with very restricted ranges are under serious and immediate threat because of hunting.

Subsistence hunting has been a critical source of protein for tropical forest dwellers since the earliest period of the Stone Age (Stanford and Bunn, 2001) and this raises the question as to why it is only now having a massive impact on wildlife populations. In fact, even this is not entirely true, judging by the mass extinctions of mega-fauna across the Americas, Eurasia, and Australia after the last Ice Age. Some extinction events were caused, at least in part, by human hunting, as were the mass extinctions of bird species in Pacific Islands after humans arrived (Duncan *et al.*, 2002). As a rough rule of thumb, the human population density limit for subsistence hunting in the tropics has been estimated at about one person/km^2 (Robinson and Bennett, 2000). This model has a sound theoretical basis, but makes numerous and often poorly-founded assumptions, such as stable demographic traits in unhunted wildlife populations.

Many erratic and poorly understood population processes can lead to extirpation, even when the annual harvest rate is well below the calculated maximum sustainable level. Many species in a bounded ecosystem can go extinct in a relatively short time through completely natural processes (Brown *et al.*, 2001). Animal populations thought to be harvested at sustainable levels might, in fact, be under-or over harvested (Slade *et al.*, 1998; Milner-Gulland and Akçakaya, 2001).In any case, in many parts of Borneo, human population densities are higher than 1/km^2. The Kayan Mentarang National Park (Indonesian Borneo), for instance, occupies an area of about 14,000 km² with a total human population of 16,645 in 2001. The population has been estimated to grow to 26,773 by 2025 (Effendi *et al.*, 2002). This suggests that even in remote and mountainous areas, human population densities are too high for sustainable subsistence hunting, especially where forests have been degraded.

In the upper Malinau watershed in Indonesia, human densities appear to be less than1/km² (Sheil, 2001), although these could increase in the near future with increased road building. Some communities greatly depend on a regular supply of forest-derived protein. Puri (1997) estimated that hunting provided between 20% and 40% of the food calories in the Penan people's annual diet in Kayan Mentarang National Park. However, because of the considerable annual variation in wildlife availability, there were times when hunting provided all or none of the Penan's food.

Caldecott (1988) suggested that declining wildlife populations might partly explain the chronic under nutrition and growth stunting which Anderson (1979) reported in various rural areas in Sarawak that if wildlife populations decline significantly these people will have to start paying for food. A clear understanding of this might be a good incentive to work towards sustainable hunting techniques. Traditional hunting is often non-selective. Using dogs, traps, or snares, animals are often killed irrespective of their condition (fat or thin, with litter, pregnant or not) and hunting is sometimes wasteful, with only part of the animal taken. Other factors increasing hunting's impact on Borneo's wildlife include (i) increased forest accessibility (ii) improved transport with cars, motor bikes, motorized canoes, and light planes, guns and ammunition (iii) erosion of traditional prohibitions on killing and eating certain animals (iv) increased immigration by non-indigenous people to interior areas and (v) an increasing market for wildlife products either as food, trophies, or medicine. The latter factor does appear to be increasing in Malinau, however. Together, these factors often result in hunting becoming commercialized rather than for subsistence alone.

Sheil (2001) found that many villagers in Malinau perceive a decline in important resources, especially the animals they hunt for food and plants they rely on for daily needs and trade. The villagers generally blame the decline on logging, with indigenous hunters now having to compete with immigrants working in the logging and mining industries. Unlogged forest is considered the most important land for communities, with wild pigs and timber trees among the most important species found there. Local communities give low preference to logged-over forest. The reasons include diminished key resources, lower quality habitats for fish and wildlife, reduced physical accessibility and reduced access rights. Pigs, a preferred food species, are said to number fewer in logged areas, although this is hard to assess reliably given the species' large population fluctuations. Logging also unnecessarily depletes certain emergency forest foods for animals. For example skid trails have been found to often damage *Eugeissona utilis*, the most important sago palm, which grows on ridge tops (Sheil, 2001). Such impacts may affect demand for other forest foods.

Contributions of concessions and roads to hunting

Hunting pressure increases with improved access through forest roads and supplies for logging camps (Robinson *et al.*, 1999; Wilkie *et al.*, 2001). Reliable data are not always easy to collect, but research elsewhere shows that hunting associated with concession activities should be cause for concern. For example, in Sarawak in 1996, the annual catch for a single logging camp of 500 people was 1,150 animals, or 29 tonnes of meat per year. Workers in such camps throughout the whole of Sarawak were estimated conservatively to have hunted approximately 55,045 animals or 1,400 tonnes of wild meat per year for their own consumption (Bennett and Robinson, 2000b). In a single logging camp of 648 people in the Republic of Congo, the annual harvest was 8,250 animals, equivalent to 123.5 tonnes of wild meat, which was partly used for personal consumption and partly traded on markets (Auzel and Wilkie, 2000). Such activities cause wildlife densities to thin considerably, particularly those species with inherently small or reduced ranges due to deforestation rendering their sustainability uncertain.

Bennett *et al.* (2000) reported a relationship between the quality and density of the transport network and hunting in Sarawak and Sabah. Until about 1960, large parts of Sarawak and Sabah were inaccessible to all but occasional hunters trekking for many days on foot. Since then, both logging and other roads have spread and river transport and rural air services have improved. Most forest areas are now less than a day's travel from the nearest settlement, and readily accessible from towns. This has led to a significant increase in hunting pressure. Auzel and Wilkie (1989) and Wilkie *et al.* (2001) also investigated how roads affect species conservation. They found that in the Republic of Congo, roads established and maintained by logging concessions intensify bushmeat hunting because they open up relatively unexploited wildlife populations and lower costs to transport bushmeat to markets. Roads result in over-harvesting and greatly depleted wildlife populations (Bennett *et al.*, 2000; Bennett and Robinson, 2000b). This may be due to:(a) facilitation of increased immigration, increased forest clearance along road sides reducing and fragmenting habitats and increasing human population density in the remaining forest; (b) loss of inaccessible and undisturbed 'source' areas to replenish populations and increased access to markets.

This allows local people to sell wild meat, use technology such as shotguns, cartridges, snare wires, batteries, vehicles and fuel. These technologies facilitate indiscriminate and excessive hunting while obscuring permitted subsistence hunting and raising the catch to unsustainable levels as well as increasing access by locals and outsiders, often from towns many tens of kilometers away. Some people are hunters; others are traders who buy bush meat or wildlife body parts.

Several researchers have recently investigated the local use of non-timber forest products (Falconer, 1992; Puri, 2001; Sellato, 2001; Sheil, 2001) like exudates (e.g., resins, latexes and gums), rattans, aromatic woods, and various vegetable and animal products. Many wildlife species are used for a variety of purposes, including food, medicine, tools, rituals, decoration, bait, as pets, or as trade items (Cowlishaw and Dunbar, 2000; Puri, 2001). Trade in wildlife products includes swift nests, gallstones from leaf monkeys, bears and porcupines, pets like monkeys and bears, teeth, claws and paws, trophies, meat and fat from Bearded Pig

(*Sus barbatus*), various deer species, pangolins, pythons, and primates, to mention a few (Puri, 2001). Little is known about the sustainability of non-timber forest products, but at least some products are used unsustainably.

Hunting methods

Hunting normally takes place during the day but night hunting by torch-light or spotlight is also common in some areas, usually involving shot-guns. Primates are usually trapped or shot using shotguns, blowguns and bows and arrows the last two invariably firing poisoned projectiles. Traps may range from simple snares to elaborate cage traps (in the case of live-trapping) (Cowlishaw and Dunbar, 2000). Shooting tends to be a more common method for hunting primates, perhaps because it is hard to trap intelligent arboreal animals. Muchaal and Ngandjui (1999) found that primates in Southern Cameroon were captured more frequently in the dry season, when fire arms replaced snares as the primary means of obtaining wild animal meat. A more specialized hunting technique is used to hunt some primates like the drill (*Mandrillus leucophaeus*) is hunted with a combination of guns and dogs. The dogs help to locate drill groups and eventually chase them up into trees for the hunters to shoot them with guns (Gadsby, 1990). Less sophisticated is the method used by the Hadza people of Tanzania to hunt baboons. The hunters make lots of noise and shoot arrows at the baboons. The animals are finally clubbed to death as they attempt to escape the circle of hunters (Shipman *et al.*, 1981). In West Africa, there are communal hunts of wild animals to control crop raiding (Starin, 1989).

The choice of hunting technique depends on the technology available and most important change for subsistence hunting has been the adoption of the shotgun, which possesses a potential killing power (Cowlishaw and Dunbar, 2000). The maximum killing distance for monkeys with traditional weapons is 17 m with blow guns while it is 25m with arrows; but shotguns are effective up to 45 m (Hames, 1979). Shotguns are more likely to hit prey because of their wider projectile spread (Cowlishaw and Dunbar, 2000). It appears from first glance that the use of traditional methods (bow and arrows and blow guns) reduced harvesting intensity. However, Ache hunters of Paraguay using bows harvested 0.14 kg of capuchin (*Cebus capucinus*) per hunting hour compared with 0.02 kg among shotgun hunters (Hill and Hawkes, 1983).This suggests that the introduction of shotguns may actually reduce harvesting intensity for some species but may substantially increase the harvest for those species profitable enough to remain in the shotgun hunters diet (Cowlishaw and Dunbar, 2000). Hames (1979) found that predominant shotgun hunters of Ye'Kwana in Venezuela, captured monkeys at a rate of three animals per 120 hours spent hunting whereas the bow–hunting Yanomamo tribe, also in Venezuela, captured only one monkey per 120 hours of hunting in the same area. Though shotguns can lead to a massive increase in hunting pressure, the presence and severity of the increase depends on the profitability of the prey and the weapon the shotgun replaces (Cowlishaw and Dunbar, 2000).

Few studies address cable snares and those that do so generally do not provide detailed and comprehensive analyses of hunting methods, economic returns and impacts on wildlife. Snares account for majority of methods employed by illegal hunters encountered. It is illegal and dangerous because it is elusive and nonselective of species, sex or age. The predominant type of trap used is the cable snare, a noose set along an animal trail. When an animal steps on a pressure pad, it releases a bent over pole, which springs up to tighten the noose around the animal's leg. The neck snares capture animals as they try to pass through a cable noose that is perpendicular to the ground. A variation of the neck snare method is to build a fence of branches and leaves (often palm) to direct animals to paths through the fence where possible snares are set two to five meters apart (this normally occurs at off-reserve areas or on farmlands). Most snares are set in places where animal trails are more visible and snares remain in place for a month or longer. The hunter visits the snare every other day or every three days depending on the distance from the village, trapping success and patrol frequency of the park guards. This also allows the scent of human beings to disintegrate in order not to scare the animals. Individual snares are moved when the hunter judges that animals are not using the trail any longer. Captured animals are butchered on the spot or in camp and the meat is then smoked over hot fires for storage and transportation to town. The resulting blackened 'bushmeat' can be stored for several weeks and is found in all market centers across West Africa. Cable snares are probably the most widespread and preferred hunting method in the area because they are relatively inexpensive, effective and quiet and also very difficult for park guards to control (Noss, 2000).

Reasons for not hunting primates

Hunting remains an important social and cultural activity for traditional inhabitants of tropical rainforests. People will hunt even when they have alternative sources of income or nutrition (Bennett *et al.*, 2000; Eve and Ruggiero, 2000). Food taboos can play an important role in determining hunting intensity in primate communities (Mittermeier, 1987), but the most important reason for not hunting primates is religion. Certain religions forbid the killing or eating of primates while others pay no attention to this practice. For example Islam prohibits the eating of primates because they are considered unclean and not fit for human consumption. However, most other religions do not have restrictions on the consumption of primates and other wildlife and hence primate hunting can be quite common in some areas, especially those dominated by Christians and pagans and in general, in areas where religious structures are not closely followed. Closely connected with tribal religions are local taboos against eating primates and these can vary from region to region, tribe to tribe and individual to individual (Mittermeier, 1987). Around some villages in Ghana (e.g., Boabeng- Fiema), monkeys are not hunted because they are believed to be the children of local gods (Fargey, 1992). The Fang states of Equitorial Guinea, do not also hunt black colobus monkeys (*Colobus satanas*) because it is claimed its meat is dry and bitter to taste (Cowlishaw and Dunbar, 2000).

Taboos are difficult to ascertain as some proximate reasons may differ from reason underlying the original adaptation of the taboos. It has been suggested that taboos may arise from external constraints on hunting such as the availability of alternative prey animals (Cowlishaw and Dunbar, 2000). For example, in Amazonia, taboo against eating primates is practiced only where alternative food sources are abundant (Peres, 1990). However, Cowlishaw and Dunbar (2000) cautioned that the existence of personal food taboos does not guarantee reduction in hunting pressure. For example in Africa, a hunter may have a taboo against eating a particular primate, but he may still kill those he encounters and trade them with someone who does not share that taboo as happens in Nigeria (Gadsby,1990) and Democratic Republic of Congo (Aunger, 1994). Moreover, hunters from outside a certain locality can enter an area with a flourishing population of primates owing to local taboos, to hunt and export the meat to other parts of the country where these species are eaten (Cowlishaw and Dunbar, 2000).

The adoption and abandonment of taboos appears to be very flexible, for though some primates may be currently protected by taboos, it cannot be assumed that their hunting will not take place in the future. Medway (1976) reported that the Iban tribe of Sarawak, who previously had a taboo against killing orangutans, has recently started hunting them for food. Dei (1989) also reported that in Ghana Akyem taboos are being abandoned, as game animals become scarce in Ghana and this suggests that reasons for taboo abandonment may be scarcity of the resource.

Reasons for hunting primates

Wildlife is an essential source of animal protein that otherwise would have to be raised or bought, if wild meat is replaced with domestic meat. The economic value of wild meat consumed by rural people, if replaced by domestic meat is about $75million per year (WSC/SFD, 1996). Hunting of wild animals is done to obtain income from sale of the animals for their meat and pelts, or as pets or trophies. For example, in Bioko, Equatorial Guinea, 63kg of wild meat per square kilometer of forest per year was extracted for commercial sale (Fa *et al.*, 1995).

Wildlife sales by rural peoples can be an important source of cash as each gun owner in Bomassa, Democratic Republic of Congo, sells wild meat worth about US$395 per year (Eves and Ruggiero, 2000) and the total estimated value of the wild meat sold in Sarawak is about US$3.75 million per year (WSC/SFD, 1996). The importance of wild animal products should not be underestimated in the economies of most tropical countries.

In Côte d'Ivoire alone, annual bushmeat consumption has been estimated at over 50,000 tonnes and all this meat finds its way onto the markets, even in the capital. For example, in late afternoons 'illegal' bushmeat markets sprout up at street corners all over Abidjan (Parren and de Graaf, 1995). At the end of the 1970s the Nigerian bushmeat market was estimated to be worth between US $150 and US$3,600 million which indicates that a large percentage of the Gross National Product is spent on bushmeat (Martin, 1989). Falconer (1992) confirmed the popularity of bushmeat in the economy of Ghana and stated that the central market in Kumasi is controlled by 50 full-time traders who sell smoked meat. At another market 'Atwemonom' 15 wholesalers sell fresh meat of assorted wild animals. It was further estimated that the bushmeat trade in Kumasi, Ghana, involved 17,600 kg of assorted species of meat, worth £23,090.00 over a four week period and hence it was projected that the annual bushmeat consumption in this town alone was 160,000 kg.

A substantial proportion of the primate harvest may not be for personal consumption but for sale at markets. These outlets, which provide a direct source of income, play an important role in influencing hunting pressure (Mittermeier, 1987). Whereas subsistence hunting for personal consumption may be sustainable at low human population densities, markets hunting for commercial gain can be devastating. The meat trade poses the most serious threat to primate populations, though trade in live primates or primate parts can also present a very real risk of extinction for those species with high demand (Cowlishaw and Dunbar, 2000). The primate meat trade revolves around roadside stalls, local markets that often supply villages, towns or cities with wild meat. With the potentially large pool of consumers, the demand for this meat can be extremely high and assorted as the animals may be sold alive, as fresh carcasses, smoked or preserved parts (Cowlishaw and Dunbar, 2000). The route wild meat takes from the hunter to the consumer depends on the hunter, either subsistence or professional/commercial and the market (either village or city) but also may involve a chain of intermediaries such as taxi drivers and stall owners (Fa, 2000).

In one instance, Falconer (1992) reported that the fresh bushmeat came almost entirely from within a 75km radius of Kumasi, whilst the smoked meat originated from as far as Bolgatanga, about 450km north of Kumasi, Ghana. Though 95% of the interviewed Ghanaians and Nigerians confirmed that they ate bush meat either regularly or once in a while, it cannot be found registered in any statistics (Parren and de Graaf, 1995). This confirms the lack of any organized market authority which has been able to attach economic values to these rural products, in the West African sub-region. This commercial, unregulated, and uncontrolled hunting for wild meat currently poses a significant threat to primate populations in many areas where they were previously hunted only on a subsistence basis (Cowlishaw and Dunbar, 2000).

A common pattern of commercial hunting in West and Central Africa is the high tendency for hunters to prefer selling larger prey and to consume the smaller ones (Cowlishaw and Dunbar, 2000). On the contrary, 90% of hunters in southeastern Nigeria hunt purely for local markets (Gadsby, 1990). As with subsistence hunting patterns, a very small number of species make up most of the market and these are rarely primates (Cowlishaw and Dunbar, 2000). For example in Equatorial Guinea, blue duikers (*Philantomba monticola*), giant rats (*Cricetomys gambianus*), African brush-tailed porcupines (*Atherurus africanus*) account for more than half of all market carcasses (Juste *et al*., 1995). In Nigeria (Bandel State) cane rat (*Thryonomys swinderianus*), giant rat (*Cricetomys gambianus*) and Maxwell's duikers (*Philantomba maxwellii*) account for 67% of the market and roadside carcasses for sale (Anadu *et al*., 1988). In Ghana, Falconer (1992) reported that fresh bushmeat consists mostly of black duiker (*Cephalophus niger*), Maxwell's duikers (*Philantomba maxwellii*), cane rats and bush-buck while the smoked meat is normally composed of cane rats, warthogs (*Phacochoerus africanus*), red river hogs (*Potamochoerus porcus*), kobs (Kobus *kob*), oribis (*Ourebia ourebi*) and roan antelope (*Hippotragus equinus*) in Kumasi central market. The fact that a harvest is small does not necessarily mean it is sustainable. With respect to primates, the genus *Cercopithecus* is consistently the most common at the following markets: Rio Muni (Equatorial Guinea) - *Cercopithecus nictitans*, Bioko (Equatorial Guinea) – *C. erythrotis* (Fa, 2000), Bandel state (Nigeria) – *C. mona* (Gadsby, 1990).

Trade in live primates is both domestic and international. Domestically, most live primates are traded as pets whereas internationally it is largely driven by bio- medical research, though trade in pets, zoo animals and circus exhibits also contribute (Cowlishaw and Dunbar, 2000). Furthermore, live primates may also be traded for subsequent slaughter for both meat and components for traditional medicines especially in Asia where Vietnamese export parts of primates to China (Li Yiming and Li Dianmo, 1998). The severity of the impact of the domestic trade can be viewed from the angle where this trade occurs as a by-product of subsistence hunting (Mittermeier, 1987; Teleki, 1989). Demand for primate parts for medicinal and ornamental purposes may have a devastating effect on primates, though subsistence hunters may also use parts of their kills for those purposes (Rijksen, 1978). However, commercial demand for such products is much more serious as in frontier trading post between Vietnam and China, where primate parts are sold in larger quantities than any other mammalian order (Li Yiming and Li Dianmo, 1998). The trade in ornamental primate products mainly involves skins, but other varieties include skulls, necklaces made of teeth, stuffed individuals and limbs (Mittermeier, 1987). A classical example is the skins of Black-and-white Colobus (*Colobus guereza*, *C. angolensis* and *C. polykomos*) which feature in outlets in Kenyan and Ethiopian tourist shops, where circular rugs were sold or exported to foreign markets (Oates, 1977a).

It has been realized that the international primate trade progressively diminished between the 1960s and 1980s. In terms of imports, the U.S. reached its peak in the late 1950s when the development and production of the polio vaccine was at its maximum. Between 1968 and 1972, annual U.S. imports dropped from 127,000 to 20,000 individuals; U.K. also declined from 30,000 to 8,000 between 1965 and 1975 and Japan from 22,000 to 4,700 between 1972 and 1981 (Kavanagh *et al.*, 1987). These declines can be attributed to technological advances combined with increasing costs of primate subjects in vaccine development, and widespread introduction of stringent laws to regulate traffic in live primates (e.g., Convention on International Trade in Endangered Species – CITES) which have been implemented both in major importing and source countries (Cowlishaw and Dunbar, 2000).

The main reason for hunting of primates appears to be for the consumption of their meat. Hunting of primates as a source of food is a serious factor in the Guineo-Congolian forest region of west and central Africa and Amazonian region of northern South America. Although hunting and eating of primates is alien to most western cultures, many people in tropical countries consider primates perfectly appropriate sources of meat, and some even prefer primates to larger, more traditional game animals. In tropical forest areas, where primates are among the larger and more conspicuous mammals and animal protein may be in short supply, the main reason for hunting primates is for food (Mittermeier, 1987). Closely connected with meat hunting, is the use of primates or certain primate body parts for their supposed medicinal value.

Though this is a minor factor in primate conservation, it can be far more serious if it involves a particular endangered species that happens to be in heavy demand (Mittermeier, 1987). Examples include (i) the use of the Slender Loris (*Loris tardigradus*) in black magic ceremonies in Sri Lanka (ii) the use of slow Loris (*Nycticebus coucang*) as charms, (iii) the killing of *Presbytis hosei* to obtain bezoars' stones in Sarawak, and (iv) the use of monkey fat, applied either externally to the back or chest or taken internally with hot water as a cure for respiratory ailments in Costa Rica (Cowlishaw and Dunbar, 2000). Crab-eating macaques (*Macaca fascicularis*) are thought to be a cure for asthma in Philippines; and in South India the meat of the Nilgiri Langur (*Presbytis johnii*) and the lion-tailed macaque (*Macaca silenus*) is thought to have value as aphrodisiac as well as other medicinal properties. In some parts of the world primates are hunted for their meat to be used as bait to capture other animals, as in Amazonia, where larger species of monkeys are shot to bait traps for spotted cat (*Prionailurus rubiginosus*) (Mittermeier, 1987).

Primates are occasionally hunted for their skins or other body parts to produce various kinds of human ornamentation as in the case of African Colobus Monkeys (*Colobus polykomos, C. guereza*).Traditionally, the pelt of these monkeys was used by a number of African tribes to make head dresses, caps and cloaks, a custom which still exists in a number of African countries (Mittermeier *et al.*, 1997). Colobus skins were also popular at the end of the 19th century and the early part of 20th century in Europe and United States. The species whose skins were most used in this trade was the West African *Colobus polykomos*, with those from the areas that is now Ghana and Ivory Coast (*Colobus polykomos vererrus*) being most in demand because of the length and glossiness of the hair (Oates, 1977a). Between 1871 and 1891, 1,750,000 skins of "Afrikanische Affen" (almost entirely colobus) were auctioned in London with yearly figures ranging from 19,814 in 1871 to 223,599 in 1889. Germany was the destination for most of these skins, but many went to the U.S, Canada and Italy as well (Oates, 1977a). This trade accounted for the loss of thousands of Colobus monkeys in the 1960s and early 1970s. Another reason for hunting primates is to obtain infants as pets. In areas where primates are regularly hunted as a source of food, capture of pets is usually a by product of meat hunting, and it is rare that a hunter will go out only in search of primates for pets.

Primates can be hunted neither for profit of the meat nor for trading in the whole animal or body part, but rather as population control strategy when they are considered as agricultural pests. This is especially true in parts of Asia and Africa, where primates like baboons, vervets and macaques can be quite significant crop raiders and are persecuted as a result (Mettermeier, 1997). For instance, between 1947 and 1962, the Sierra Leone government sponsored regular "monkey drives" to eliminate primates from agricultural areas. About 245,000 primates were destroyed in this period at a yearly average of 18,885 (range 4,500 – 39,021). Monkeys were either shot or driven into nets and clubbed to death (Tappen, 1964). This kind of "monkey drive" is not the rule but this example indicates that primates are considered a menace to agriculture in some areas and that large numbers of them may be killed as a result. Examples of major crop-raider primates include Campbell's monkeys (*Cercopithecus campbelli*), green monkeys (*Chlorocebus* *aethiops*) and mangabeys (*Cercocebus atys*) in Sierra Leone, *Colobus guereza* in Uganda, *Pan Troglodytes* and *Erythrocebus patas* in Cameroon and macaques (*Macaca* spp) in Asia (Mittermeier, 1987).

Actors in wild animal hunting for meat (Bushmeat)

According to Cowlishaw *et al.* (2005) there are five different actors involved in the bushmeat trade: (i) commercial hunters, (ii) farmer hunters, (iii) wholesale traders, (iv) market traders and (v) chop bar (local restaurant) owners. The idea behind the distinction between commercial hunters and farmer hunters lies in their livelihood diversification. For commercial hunters, hunting would be their main source of income, whereas for farmer hunters it would be a side-activity along their farming work. However, in practice this distinction is not very strict. Most commercial hunters do have a farm and some may even get more income from their farming activities than from their hunting trips. In a group discussion with six commercial hunters, Bokhorst (2010) found that farming is subsistence and considered their main job, hunting is for money and considered their main source of income. Still, when asked if they considered themselves primarily as hunters or farmers, they all immediately answered: ‘hunter’. It therefore appears to be more useful to make the distinction on basis of the hunting method used. Usually, commercial hunters actively go out to hunt (mostly at night), whereas farmer hunters go to their farm during the day carrying their guns, just in case they came across an animal. According to the six commercial hunters in the group interview there are very few (if any) people who hunt like the latter, hence they didn’t entirely agree that there is such a category as ‘farmer hunters’.

Another difference between these two types of hunters is suggested by Bowen-Jones *et al.* (2003), who stated that farmer hunters use snares around their farmland to prevent crop raiding, especially by rodents. This suggests that farmer hunters use passive hunting methods in contrast to the active hunting trips that commercial hunters undertake, which is in line with the distinctions mentioned above. Wholesale traders generally buy their meat from the hunters, in bulk with or without interference of a middleman. In Kumasi, special employees at Atwemonom will burn off the hairs and disembowel the carcasses, after which the small animals are sold whole and the bigger animals are chopped into pieces and sold to chop bars, market traders or direct consumers. Market traders sell the smaller pieces of bushmeat to direct consumers and chop bars. They are stationed at the regular food markets throughout the city, or they travel to different chop bars to which they sell the meat (Bokhorst, 2010). Most urban market traders in Kumasi sell the dried bushmeat that comes from northern Ghana. This type of bushmeat has already been smoked, so that it is still edible when it arrives from the remote north (Falconer, 1992). Bushmeat is part of many traditional dishes (especially *fufu*, which is the main staple food in the Ashanti region), but is not available in every chop bar. It is often signposted outside if bushmeat is served. Chop bars in rural areas are usually more likely to serve bushmeat than those in urban areas. Because of increased bushmeat prices, many urban chop bars have stopped selling it, since many of their customers cannot afford it anymore. There are a number of other actors who play a minor role in the bushmeat commodity chain, such as wholesale market workers, middlemen/transporters and roadside traders (Bokhorst, 2010).

Effects of hunting on primates

Though early formulations of sustainability (IUCN/WWF /UNEP, 1980) assumed that wildlife could be harvested without significantly affecting the wild population, these were clearly erroneous. Hunting has a significant impact on population size, population structure and behaviour of individuals as well as on the structure of ecological communities (Cowlishaw and Dunbar, 2000).

Hunting is generally a factor in natural mortality and reduces population densities of tropical forest wildlife species (Bennett and Robinson, 2000a). According to Cowlishaw and Dunbar (2000), populations of primates under continued unsustainable hunting pressure will rapidly and inevitably diminish in size and once the population is very small, local extinction may be inevitable once hunting has ceased. Local extinctions through hunting have been reported by many authors such as Southwick and Siddiqi (1977) for rhesus macaques and Oates *et al.* (2000) for Miss Waldron's red colobus. Most evaluations of effect of hunting studies have concentrated on differences in population density between areas of high and low hunting pressure in the same area but during different periods. These include non-flying mammals in Amazonia (Emmons, 1984), monkey densities in Peru and Panama (Freese *et al.*, 1982; Glanz, 1991) and Humbolt's monkeys in Amazonia (Peres, 1991). None of the studies was however able to determine whether a change in abundance is the result of direct hunting mortality or due to the abandonment of an area, which might indirectly elevate mortality (Cowlishaw and Dunbar, 2000).

Tutin and Fernandez (1984) have argued that these factors are likely to influence chimpanzee and gorilla densities in Gabon, where hunting is common. In addition, reports of reduced abundance may reflect not a genuine drop in population size but a failure to detect animals because they have become wary of humans (Hill *et al.* 1997). All these studies appear to be concluding that reduction of population, in areas subject to hunting tended to be lowest where hunting intensity was greatest. Cowlishaw and Dunbar (2000) noted that hunting intensity frequently correlates with the accessibility of forest. For example, *Cebus paella* densities were found to be lower within 6 km of the nearest access point in Mbaracayu Reserve (Hill *et al.*, 1997).

Also, in Arabuko-Sokoke forest, *Cercopithecus mitis* densities were found to be lower on the forest edge where most trapping takes place than in the forest center (Fitzgibbon *et al.*, 1995). A study conducted on effects of hunting at 56 hunted and unhunted Amazonian forest sites, found that a sharp decline of the total primate biomass from an average of 60% in unhunted sites to 15% in heavily hunted sites. The selective removal of those species at hunted sites increases the relative abundance of smaller species even if their densities remain unchanged. This resulted in profound shifts in the size structure of primate communities across varying degrees of hunting pressure. For example, average weight of primates occurring at different sites crashed from a mean of 2,550 g (range = 1,790-3,420 g, n = 9) at unhunted sites to 1,020 g (range = 700-1,500g, n=13) at persistently hunted sites (Peres, 1999b).

Hunting may precipitate substantial changes to population structure, which may in turn bring about genetic changes in the population. Mortality from hunting is rarely distributed equally across age-sex classes and this may partly be as a result of some individuals being more conspicuous than others and therefore more easily detected and killed, like the males that give loud calls (Cowlishaw and Dunbar, 2000). Since most primates are grouped, the hunter can usually choose his target from the entire group once the most conspicuous group member has been detected. Perhaps most commonly, the value of live infants encourages many hunters to target lactating females when hunting. The mothers are then eaten by the hunter or sold as bushmeat while the infants, if they survive, are sold as pets for example, wooly monkeys (*Lagothrix lagotricha*) (Peres, 1991) and chimpanzees (Teleki, 1989). This results in a strongly male-biased population. But for species in which males have the greater economic value, the resultant can be a female-biased population. The periodic selective hunting of prime age male gelada baboons (*Theropithecus gelada*) by Galla tribesmen in Ethiopia to acquire male capes for use as ceremonial regalia, led to the near disappearance of prime age adults from the population at the time of the harvest and consequently led to dramatic changes in grouping patterns and social structure (Dunbar, 1988).

Detailed observations of two rhesus macaque populations-one unprotected subjected to trapping and the other semi-protected by local people was examined. A comparison of the demography of the two populations suggested that live-trapping particularly affected juveniles, which trappers probably preferred because their smaller size made transport easier (Southwick and Siddiqi, 1977). As a result, populations across India showed a marked deficit in the number of juveniles at that time. For instance in 1959-1960, only 6% of the population was composed of juveniles compared with 25% infants. After trapping stopped, this deficit diminished so that by 1990-1991 juveniles accounted for 25% of the population while the infants' contribution remained the same (Southwick, 1994).

On the social structure of a population, if hunting is high, it is plausible that groups will be smaller because mortality rates in each group will be higher (Cowlishaw and Dunbar, 2000). Such effect is precisely observed in red colobus groups under heavy predation by chimpanzees (Stanford, 1995). On the other hand, if group size is flexible in response to hunting, then it must be expected that groups would become either smaller (if this reduces the risk of detection by hunters) or larger (if this reduces the risk of attack by hunters). Empirical evidence suggests that smaller groups are more common in areas of heavy hunting (Cowlishaw and Dunbar, 2000). For example, drill (*Mandrillus leucophaeus*) groups have become smaller and their large ephemeral congregations are more uncommon in recent years in Nigeria (Gadsby, 1990). Similarly, Watanabe (1981) found that where hunting pressure was high, snub-nosed langur (*Simias concolor*) groups were typically half the size of those where hunting was minimal.

However, it remains unclear whether this change was due to hunting or to habitat disturbance since the two seriously threatens the drill (*Mandrillus leucophaeus*) populations throughout their range. In this case, the variation in group size was also associated with differences in social systems. The smaller group was monogamous rather than polygynous and if hunting pressure was responsible during female song bouts. However, since inter-population difference in patterns of singing behaviour may be strongly influenced by other aspects of ecology and demography, it is difficult to confirm unequivocally that hunting pressure is responsible (Cowlishaw and Dunbar, 2000). This has been manifested in two *Hylobates klossii* alarm calls, (siren and alarm trills) that were performed only after detecting human hunters, the animals' chief predators unlike their other vocalizations, these calls are as loud as territorial songs and can therefore be heard from neighboring territories. Tenaza and Tilson (1977) suggested that gibbons that have detected hunters are alerting not only other members of their group. They also stated that vervet monkeys (*Chlorocebus pygerythrus)* have a special alarm call that is elicited only in response to unfamiliar humans usually Masai herdsmen with their cattle. Though these herdsmen do not themselves appear to harass the vervets, their children may throw stones at the monkeys. Another anti-predator behaviour observed at Siberut Island involving *Hylobates klossii* concerns sleeping tree selection. They appear to avoid sleeping in trees with lianas, which indigenous hunters use to climb the trees and shoot the primates at close range with poisoned arrows (Tenaza and Tilson, 1985).

Habitat Disturbances as Extrinsic Forces Affecting Population of Primates

Patterns of primate habitat destruction

The loss of tropical forest is occurring at a rate of 9.4 million ha per year (FAO, 2001). In West Africa in particular, the forest cover has decreased by 1.5% per year from 1990 to 2000, with most recent surveys (in 2000) estimating forest cover at 850,790 km^2 (FAO, 2001).

The reduction of the forest cover often results in the fragmentation of large forest blocks (Whitmore, 1975). Primate species are vulnerable to forest fragmentation, which with its accompanying habitat disturbance affects group size, group composition, and population density (Decker, 1994; Gonzalez-Kirchner, 1996; Menon and Poirier, 1996; Tutin, 1999; Onderdonk and Chapman, 2000). The size and isolation distance of the fragments can also influence whether a primate species is present (Estrada and Coates-Estrada, 1996; Chapman *et al.*, 2003; Onderdonk and Chapman, 2000), as suggested by the island biogeography theory (MacArthur and Wilson, 1967). The theory of island biogeography proposes that the number of species found on an undisturbed island is determined by immigration and extinction, and that the isolated populations may follow different evolutionary routes, as shown by Darwin's observation of finches in the Galapagos Islands. Immigration and emigration are affected by the distance of an island from a source of colonists (distance effect). Usually this source is the mainland, but it can also be other islands. Islands that are more isolated are less likely to receive immigrants than islands that are less isolated (MacArthur and Wilson, 1967).

Human activities that impact on tropical forest habitats can be classed broadly as agriculture, forestry, mining and human activities causing changes in climate indirectly leading to large scale forest disturbance (Cowlishaw and Dunbar, 2000). Yet it is impossible to attribute the responsibility to the different factors since each is inevitably linked. For example, while timber operations may harvest relatively few trees (typically less than 10% of the canopy level trees) the timber operators construct roads and open areas up for agriculture and provide economic incentives for immigration to regions which increases human population, leading to hunting pressure (Chapman *et al*,. 1999). It has been estimated that 8% of the world's tropical forests was lost in the decade between 1980 and 1990 (WRI, 1996). The rain forest of Africa originally covered 3,620,000 km^2 prior to agricultural clearing but habitat alterations by people have drastically reduced the remaining area of forest (Chapman *et al*., 1999).

Within Africa, tropical forests and animals they support are increasingly threatened by accelerating rates of forest conversion and degradation and by commercial and subsistence hunting and logging (FAO, 1993; Oates, 1996). The West African lowland moist forests are among the most depleted forests in the tropics which may be as a result of the historically close links of these countries with Europe, by official policies and by high population densities (Parren and de Graaf, 1995). Of the original moist forest zone of 31.3 million ha from Guinea to Ghana at the turn of the 20th century, some 8.7 million ha has remained by the end of the century. This is about a quarter and includes highly depleted forest areas still classified as forest but biologically not functioning as such (Parren and de Graaf, 1995). In Sierra Leone, deforestation began as early as the 1840s and resulted in a closed forest cover of only 6% by the 1930s and even this low forest cover has diminished further. During the 1970s the annual deforestation rate in Côte d'Ivoire was over 10 times the pan-tropical average rate of 0.6%. Forestry has been put at par with mining activities, and the forest has been exploited as a non-renewable natural resource. Ghana has also not been spared from this deforestation menace where the forest cover at the beginning of the 20th century was 2.1 million ha but has been reduced to 1.6 million ha at an annual rate of 2.19% (FAO, 1993).

Dimensions of primate habitat alteration in the tropics

Traditionally, conservation efforts have concentrated on protecting plant and animal populations through the establishment of national parks in pristine or semi-pristine habitats. Within the countries of Africa with closed canopy forest, an average of 3.2% of each country's area has been protected in national parks or similar protected areas (IUCN, 1985). The level of protection for primate communities within different regions is clearly limited and constantly changing.

The investment of different countries in national parks is dynamic, making it difficult to interpret the significance. New parks are being created in some countries, while in other countries parks are being degraded or even degazetted. For instance, in the northern part of Tai National Park, 770 km^2 (i.e., 21% of the total park area) was temporarily ceded for exploitation and is now heavily impacted (IUCN, 1987). Similarly, Bia National Park in Ghana was gazetted in 1974 to include 306 km^2, but was reduced in size to 230 km^2 in 1979 and further reduced to 77.7 km^2 in 1980. The area excised from the park was re-classified as a Game Production Reserve or Resource Reserve, and has been largely opened up for timber production (Chapman *et al.*, 1999). In contrast, the 360 km^2 contiguous Kakum and Assin Attandanso Forest Reserves were re-gazetted as a National Park and Resource Reserve respectively in Ghana, and timber extraction was stopped in 1990. Similarly, the amount of protected land in Uganda has increased from 7,698 km^2 in the 1980s to 11,145 km^2 as of 1995. In Gabon, a recent decree recognized a central core where hunting and logging are banned and a peripheral zone which is open to logging. However, due to lack of funding in many regions for the enforcement and education of existing wildlife laws, many national parks are suffering from serious encroachment (Chapman *et al.*, 1999).

Evidence from West Africa suggests that timber trees can contribute disproportionately to the diets of some primate species, indicating that logging could have severe impacts on these species, unless they have extremely flexible diets (Chapman *et al.*, 1999). In Bia National Park, 43% of the plant species found in the diet of the red colobus were from economically valuable timber species and Diana monkeys and black and white colobus also fed on the timber species (Martin, 1991).

Early silvicultural practices dealt a big blow to the forests of West Africa. At the beginning of the 20th century, foresters assumed that moist tropical forest could be managed in a sustainable fashion similar to European forests. On the basis of this assumption, too much forest has been lost as a consequence of opening up forests for exploitation. In 1945, the Tropical Shelter-wood System which involves the cutting of vines and the poisoning of unwanted species of medium-sized trees was introduced to manage the forests of Ghana and Nigeria. As a result, many valuable secondary species were destroyed. Between 1958 and 1970, 188 tons of sodium arsenite was used in Ghana to poison trees, and an area of 2,590 km² was managed under this system (Martin, 1991). The system was abandoned when it was realized that natural regeneration under this system did not meet expectations (Chapman *et al.*, 1999).

Historical logging activities and some effects on primates

Logging activities in Ghana can be traced back as far as the 16th century when samples of Kaku (*Lophira alata*) were sent to the United Kingdom. The Ashantis, a tribe dominant in the hinterland of the Gold Coast had had another principal export commodity next to slaves and gold, which were seeds of *Cola nitida* (Wilks, 1985). Later, British and French companies began harvesting mahogany (*Khaya* and *Entandrophragma* species) of the family Meliaceae. Around 1833, the first trunks of African mahogany appeared on the British market, and from 1878 onwards their importance increased (Parren and de Graaf, 1995).

A brief study of the impact of logging on primates in Bia area of Ghana indicates that four out of six diurnal primates had reduced densities of social groups in logged forest. These were the Miss Waldron's red colobus, olive colobus (*Procolobus verus*), Diana guenon (*Cercopithecus diana roloway*) and sooty mangabey (*Cercocebus atys*) (Martin and Asibey, 1979). Two guenons *Cercopithecus campbelii lowei* and *Cercopithecus petaurista petaurista* were apparently unaffected by logging and are known to be abundant in secondary bush throughout their range (Fimbel, 1994). A survey of the Gola forest in Sierra Leone found that light and heavy logging appeared to reduce the numbers of red colobus (*Procolobus badius badius*) and pied colobus (*Colobus polykomos*) but the trends for three species of guenons, the sooty mangabey and chimpanzee were less clear (Davis, 1987). Similarly, a study comparing old forest at Tiwai, Sierra Leone with young secondary forest less than 20 years old that developed after farming found that *Cercopithecus campbelli, Cercopithecus petaurista* and *Cercocebus atys* selectively used secondary forest; while *Cercopithecus diana, Colobus polykomos* and *Colobus badius* selected old growth forest (Fimbel, 1994). Furthermore, primate forest in Western Malaysia supported higher densities of primates than adjacent logged forest. These differences were four to five-fold in recently logged areas, but only 28% less in an area logged 25 years earlier. This led to the conclusion that differences in primate densities between logged and unlogged forests may depend on the age of the secondary forest (Marsh and Wilson, 1981).

An evaluation of the impact of logging on primate populations revealed that out of 38 primate species examined throughout the tropics, 71% showed an appreciable decline in numbers with forest disturbance, which 22% increased and 6.7% showed no change (Johns and Skorupa, 1987). Reviewing 13 African species, 76.9% were apparently not affected numerically (Struhsaker, 1997). Johns and Skorupa (1987) concluded that the primates most susceptible to logging were the large species that fed primarily on fruits, seeds and flowers, as opposed to browsers and small insectivores. Struhsaker (1997) stated that mammals that are relatively large, long-lived, late-maturing, and slowly reproducing may show a delayed population response to major changes in the habitat. For example, in the vervet monkeys of Amboseli, Kenya, it was nearly 10 years after the loss of approximately 90% of a major food source (fewer tree) before a statistically significant decline in population could be detected (Struhsaker, 1976).

Similarly, Kibale National Forest was estimated to require more than seven years before there is a statistically significant decline in primate populations following moderate to heavy logging (Skorupa, 1988). Further observations were made that breeding rates of all four anthropoid species were depressed in Tekam, West Malaysia, six years after logging (Johns, 1983). Differences in primate densities exist even between similar forest types. For example, the primate community within the same gross type of undisturbed and mature forest of Kibale can vary appreciably over distances as short as 10km (Struhsaker, 1997). The density of black and white Colobus monkeys in Kibale varied nearly tenfold between areas separated by no more than 1km and within the same broad forest type (Struhsaker, 1978). These differences may be related to availability of nutrients in swamp vegetation and soil that are apparently critical to the diet of black and white colobus (Oates, 1978).

Studies from Kibale clearly indicate that all of the seven common diurnal primates were adversely affected by moderate to heavy logging. This was first noted in the early 1970s, three to six years after logging and shown to persist in parallel with changes in vegetation for at least 18 years post-logging (Skorupa, 1988). To buttress this, a simple comparison of encounter rates with primate groups along the same route in the heavily logged areas showed no significant differences for any species between 25 of censuses made between 1971 and 1975 (Struhsaker, 1975) and 25 of those made in 1980-81 (Skorupa, 1988). But the results from census just prior to logging are consistent with these findings (Struhsaker, 1997).

Timber extraction not only alters the structure of the forest, it also influences the species spectrum by removing economically valuable species. Since practically, commercial timber species are among the tallest trees with trunks of large diameter, the tree species spectrum in the upper canopy is most hard-hit by the extraction procedure. This indicates that it is not by chance that at Bia Conservation Area in Ghana, 43% of the species found in the diet of red colobus were economically valuable timber species and 25% in pied colobus. It has also been documented that 20% of the species found in the diet of Roloway monkey were timber species and they include Mahogany (*Khaya spp*), Iroko (*Milicia excelsa*), Sapele (*Entandrophragma cylindricum*) and Makore (*Tieghemiella hecklii*) (Martin, 1991).

However, assuming that food is a major factor affecting primate populations, when the tree species being harvested or killed in the process of logging are largely or exclusively non-food species for primates, then one expects either no change or increase in primate numbers (Struhsaker, 1997). In support of this Johns (1988) found no reduction in group densities of five diurnal primate species at Tekam, West Malaysia, during the first year after logging, because the tree species harvested were dipterocarps and not primate food species. Over 50% of the unharvested trees were incidentally destroyed during the logging operation, and many of these may have been food species for primates. A subsequent survey in this area six years after logging indicated a decline in birth rates of all these primates (Johns, 1992). In Lope reserve in Gabon, low intensity logging (13% basal area reduction) led to significant changes in density of only one of eight primate species (i.e., chimpanzees declined markedly after logging) (White, 1994).

CHAPTER THREE

MATERIALS AND METHODS

The Study Area

Location, legal setting and historical background

Kakum Conservation Area (KCA) is located on longitude 1°30' W and 1°51' W and latitude 5°20' N and 5°40' N and is made up of the 210 km^2 Kakum National Park (KNP) and its twin 150 km^{2}Assin Attandanso Resource Reserve (AARR). It spans the Twifu Hemang Lower Denkyira, Assin (North and South) and Abura-Asebu-Kwamangkese districts of the Central Region of Ghana (Figure 3). The Kakum forest and Assin Attandanso forests was legally regazetted as a national park and resource reserve respectively in 1991 under the wildlife reserves regulations (L. I 1525) under the administrative jurisdiction of the Wildlife Division of the Forestry Commission (Wildlife Department, 1996).

The area was initially placed under timber production by the Forestry Department until 1989 when its management was transferred to the Wildlife Division because of change in management status. About 52 communities are scattered around the conservation area. Prior to the transfer of administration of the area from the Forestry Department to the Wildlife Department, the communities used to hunt and extract non-timber forest products from the area.

Timber exploitation started in the two reserves in 1936 with mahogany (*Khaya ivorensis*) being the principal species logged. Other timber species were included for exploitation from the 1950s until 1989 when the two reserves were transferred from the Forestry Department to Wildlife Department. As a result of an initial faunal survey the Kakum forest reserve was designated as a national park and Assin Attandanso forest reserve as a resource reserve in 1991 under Wildlife reserves regulations 1971, L.I. 710 as amended by Wildlife Reserves Regulations 1991, L.I 1525.

The Kakum and Assin Attandanso forests were demarcated between 1925 and 1926 and put into reserve and managed as forest reserves in 1931 and 1937 respectively as a source of timber production and protection of the watersheds of the Kakum and other rivers which supply water to Cape Coast and its surrounding areas by the then Governing Council of the Gold Coast. The legal framework was supplied by Section 4(4) of the Colonial Forest Ordinance, Cap 63 and gazetted in the Gold Coast Gazette. The traditional owners of the reserve were the Assin Attandanso, Twifo Heman, Denkyira and Abura States.

The conservation area has gone through a long period of disturbance as a result of commercial and subsistence hunting on the one hand and logging on the other. Prior to timber exploitation, the reserve was more or less a virgin forest since there was no evidence that farming might have taken place in the reserve for any considerable length of time (Paijmans and Jack, 1960). It has however been alleged that the local people mined gold and clay several years before the area was reserved (Agyare, 1995).

The two reserves contained a good stock of economic and other tree species of both local and international importance for timber, which resulted in division of the reserves into concessions. All the traditional states leased portions of their forests to timber concessionaires. Hence at the time of converting the reserves into a conservation area, both reserves were held by the concessionaires as shown in Table 1 and Figure 4.

The Paramount Chief of the Assin Attandanso state leased a portion of the state's share to M. R. Stein and Co. (a Gold Coast Timber company) on 20th September 1948 for a period of 40 years. The Certificate of Validity was signed on 7th September, 1950 and published in the Gold Coast Gazette No. 83 of 1st October 1950. The concession of M. R. Stein and Co. was reassigned to Mr. Batholomew Bayman (Batholomew and Co.) when M. R. Stein and Co. went into liquidation in 1954. The transaction was published under Notice 154 in the Gold Coast Gazette No.8 of 1956. The concession was ultimately passed on to Messrs R. T. Brisco (Ghana) Ltd for a period of 30 years by the Paramount Chief of Assin Attandanso state. The lease was signed on the 26th of March 1957 and the Notice of Concession was published in Gold Coast Gazette Supplement No.9 of 10th April, 1958 (Paijmans and Jack, 1960).

The Jukwa portion of the Kakum Forest Reserve belonging to the Lower Denkyira stool was assigned as a concession to M. R. Stein and Co. Ltd for a period of 25 years from 7th June 1950. The concession was later re-assigned to Batholomew and Co. and subsequently to R. T. Brisco (Agyare, 1995).

The elders of Heman state, Mr. Josiah Otoo and others granted a lease to Associated Hardwood and Co. Ltd. for a period of 50 years. The lease was signed on 24th August, 1954 and the notice of the concession was published in the Gazette Supplement No.1 of 3rd March 1955 (Paijmans and Jack, 1960).

The Abura state granted concession rights to Mr. J. Cole, a timber merchant, on 7th November, 1957 for 50 years. All royalties were paid to the paramount chiefs of the various states (Agyare, 1995). Figure 4 shows the various concession areas occupied by the respective concessionaires as at the time of converting the forest reserves into a conservation area.

A working plan covering the reserve was prepared in 1949 but was amended later in 1955 with a 10-year felling cycle being established. The area was divided into three working circles made up of selection, research and protection. The selection working circle was divided into a north-east felling series and south-east felling series. All felling series were worked with the exception of the south west series, as no working provision was made in the plan for it. The research working circle, which originally covered an area of approximately 259 ha in 1947, was reduced to about 81 ha in 1953. It was designated as then forest district's major research center for purposes of finding out whether regeneration of valuable species could be achieved by the application of the Tropical Shelterwood System (TSS). The regeneration experiment proved profitable as the assessment of the regeneration in 1954 showed 30 % success for class one species, of which 26.7 % was *Heritiera utilis* whilst the remaining class one species accounted for 3.3 %. The silvicultural practice did not end with TSS, though; in 1956 an area of about 47 ha was planted with 777 individuals of *Khaya ivorensis*, 84 individuals of *Entandrophragma cylindricum*, 874 individuals of *Entandrophragma angolense* and 567 individuals of *Tieghemella heckelli*. In 1957, a further 230 individuals of *Khaya ivorensis* and 50 individuals of *Entandrophragma cylindricum* were planted. All did not go well with the management of the reserve and in 1958 eight *Khaya ivorensis*, three *Entandrophragma sp*, three *Tieghemella heckelli*, and three *Triplochiton scleroxylon* were felled by M. R. Stein and Co. (Paijmans and Jack, 1960).

Paijmans and Jack (1960) further stated that "As no exploiter could be found to take the remaining yield, the following trees were poisoned: one *Khaya ivorensis*, 42 *Lophira alata*, 20 *Heritiera utilis*, 19 *Piptadeniastrum africanum*, 11 *Antiaris toxicaria*, three *Nauclea diderrichii*, three *Distemonanthus benthamianus*, two *Milicia excelsa*, two *Terminalia ivorensis*, one *Lovoa trichilioides*, one *Cyanometra ananta*, one *Guarea cedrata* – a total of 106 trees".

The protection working circle was intended to protect watersheds. Under section 16 (7) of the Concessions Act 1962, the Assin Attandanso forest reserve was constituted under the Forest Ordinance Cap 157. A second working plan called the Attandanso-Suppong was prepared and implemented from 1st October 1962 to 31st December, 1972. After this period, both the Kakum and Assin Attandanso Forest Reserves were exploited without any working plan until 1989 when these reserves were converted into wildlife reserves during which time six timber companies were still operating (Agyare, 1995). In 1989, pre-feasibility study towards the conversion of the Kakum and Assin Attandanso Forest Reserves into

Kakum National Park and Assin Attandanso Game Production Reserve respectively were completed (Mensah-Ntiamoah, 1989).

Vegetation, climate, physical features and drainage

Kakum Conservation Area forms part of the Moist Evergreen Forest Zone (Hall and Swaine, 1981). The rainfall pattern is bimodal with a two peak rainy season separated by a short dry period in August. The major season is between April and July peaking in June, and the minor season is between September and November, peaking in October. The wet season is followed by a long dry season from December to April during which most streams dry up and rivers break into pools. The mean annual rainfall is between 1500 mm to 1750 mm. The prevailing wind is south-westerly and is generally light. The average relative humidity is about 85% and the temperature fluctuates between 30°C and 35°C. The terrain is generally undulating, with an elevation between 150 m and 250 m. The soils are mainly forest ochrosols and forest gleisols along rivers and streams. The corresponding classification by FAO is Rhodic ferralsols and dystric gleysols along water bodies. The soils on upper slopes are mainly reddish-clay with angular quart stones and sand increasing down the slope and clay towards the valleys. The pH of the top soil is between 5.5 and 7.0 (Owusu-Bennoah *et al.*, 2000).

The major drainage of the area consists of the Kakum, Nemini and Nchemna rivers which flow out to the south-east towards the sea; Obuo, Sukuma, Panim, Bosumfuo and Afia rivers flow to the west into the Pra river. Others are Ajuasu and Aduasu rivers to the east and Benebe, Aboabo and Ongwa rivers to the north (Figure 3) (Wildlife Department, 1996).

Floral and faunal diversity

Vascular plant species identified total 105 including 57 trees, 10 shrubs, nine, nine climbers, 17 herbs and 12 grasses. Common large mammals inhabiting the area are forest elephant (*Loxodonta cyclotis*), bongo (*Tragelaphus eurycerus*), bushbuck (*Tragelaphus scriptus*), Maxwell's duiker (*Philantomba maxwelli*), and black duiker (*Cephalophus niger*). Six different primates include Geoffroy's pied colobus (*Colobus vellerosus*), Lowe's monkey (*Cercopithecus campbelli lowei*), lesser spot-nosed monkey (*Cercopithecus petaurista petaurista*), olive colobus (*Procolobus verus*), Bosman's potto (*Perodicticus potto*) and Demidoff's galago (*Galagoides demidoff*) have been identified in the area. A total of 266 bird species including the threatened white breasted guineafowl (*Agelastes meleagrides*) and yellow-throated olive bird (*Criniger olivaceus*) inhabit in the area. A wide variety of reptiles, amphibians and 405 species of butterflies have been reported to inhabit the area (Wildlife Department, 1996). At present, the conservation area is considered as the number one eco-tourist attraction in Ghana for its unique ecosystem and a canopy walkway which is a bridge suspended on top of selected emergent trees. Tourists walk on this for entertainment while scientists depend on it for research purposes (Wildlife Department, 1996).

Figure 3: Map of Kakum Conservation Area (Inset: Map of Ghana showing the location of the area)

Table 1: **Areas of timber operation by various concession owners prior to the conversion of forest reserves into Kakum Conservation Area.**

Concessionaire	Area (km^2)	Period of Lease	Name of reserve
S.K. Owusu Timbers	36.06	1/11/1971-31/12/1996	Kakum
Pan Sawmills Ltd.	60.32	24/8/1959-23/8/2004	Kakum
Takoradi Veneer and Lumber Co.	109.43	21/8/1988-20/9/2093	Kakum
Ghana Prime-wood Product Ltd	134. 62	1/7/1969-30/6/1994	Assin Attandanso
Gabrah Brothers Ent. Ltd	6.86	1/2/1986-31/1/1996	Assin Attandanso
R. T. Brisco/T. V. L. C	12.22	20/9/1948-19/9/1988	Assin Attandanso

Source: Mensah-Ntiamoah (1989)

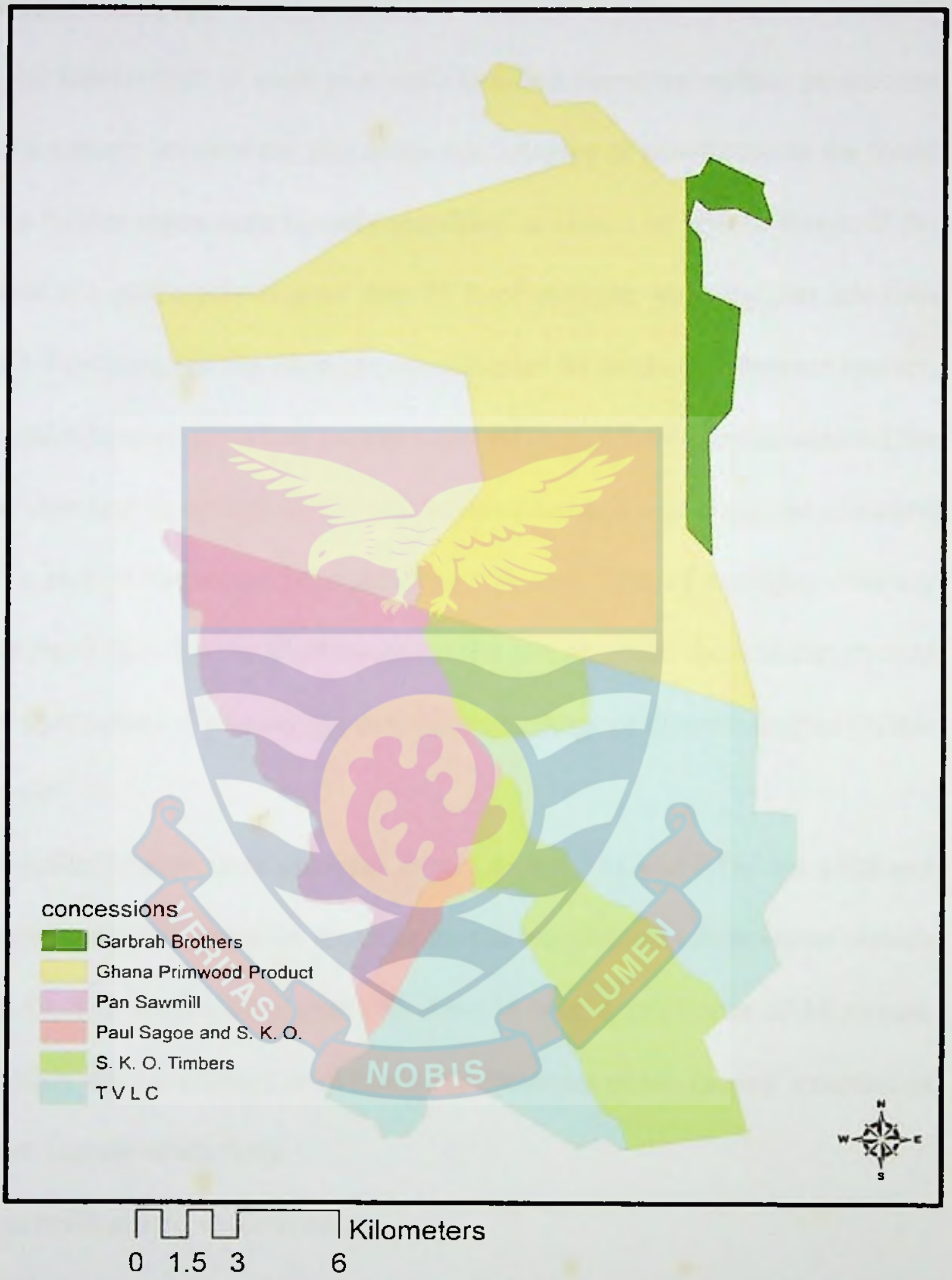

Figure 4: Map of Kakum and Assin Attandanso forest reserves showing areas occupied by the different concession owners before converting into a conservation area.

Methods

Vegetation Assessment

The habitat type in each plot was classified based on various parameters such as the canopy cover of the plot or the sun's degree of penetration to the forest floor. The habitat types were broadly classified as closed or opened forest. If the forest floor of a plot received more than 75 % of sunlight, visibility was less than 10m in all directions and the undergrowth occupied by thickets of pioneer species, herbs, climber tangles as well as invasive species (e.g., *Chromolaena odorata*) the plot was classified as opened forest. On the other hand, it was classified as closed forest if a plot of the forest floor received less than 75% of sunlight, visibility extending more than 10m in all directions and less than 5% of the understorey was occupied by thickets of pioneer species, herbs, saplings or climber tangles (Wiafe *et al*., 2010).

Satellite images were obtained from Landsat TM and ETM for 1986 and 2002 to represent the vegetation structure for the logging and conservation periods respectively. The scenes were path 195 Row 56 with a resolution of 30 meters. These images were processed to evaluate the dynamics of the canopy structure of the Kakum Conservation Area.

Plot demarcation and enumeration

Along each transect, 10 rectangular, 20 m by 10 m plots were demarcated one kilometre apart, in each forest block. Plots were measured using a 20-metre long nylon rope. Red ribbons were tied at the borders of the plot and any border tree with the greater part falling within the plot was enumerated.

The 3-person enumeration team was made up of a recorder, tree spotter and assistant. The main duty of the recorder was to record all information about any the tree including identification and measurements. The tree spotter identified, measured and provided the information to the recorder while the assistant helped in measurements and specimen collection.

Moving in a clock-wise direction within a plot, all trees with girth at breast height (1.30m from the ground) equal to or greater than 31cm ($\geq$31cm, gbh), were identified, measured and recorded. The girth at breast height of each sampled tree was measured over bark with the linear tape. However, there were some reasons to deviate sometimes from this standard "breast height" and execute the girth/diameter measurements at another position on the sample tree. These were as follows:

- Sample trees with buttresses: the stem diameter was measured approximately 30 cm above the buttress.
- Sample trees with aerial or stilt roots: the stem diameter was measured at 1.3m above the beginning of the stem.
- Forked trees were regarded as two sample trees if the fork was below 1.3m.

The girth values (gbh) were converted to diameter at breast height (dbh) values by using the formula:

$$D = \frac{C}{3.142} \quad \text{.......} (1)$$

Where D = diameter

C = girth

Tree height was defined as the total length from the ground up to the tip of the tallest vertical branch of the sample tree. As the measurement of the tree height is very time consuming, mostly not very accurate and also not very important to increase the precision of floral information, it was replaced with estimation of stem height in meters. An assistant stood at the foot of the sample tree and held a 2m-long ranging pole in his hand (when he lifted up the ranging pole while holding it on one end the upper part of the ranging pole shows the length of 4m). Relative to this given length, the total height of the sample was estimated.

The local name or common name of the tree species, girth at breast height, and estimated height were called out by the men who identified and measured trees to the recorder. To ensure that the right information had been recorded, the recorder in turn calls back the same information to the source. All trees were identified to species level. Specimens of unidentified trees were collected and sent to the Resource Management Support Centre's Herbarium in Kumasi for identification. Nomenclature was after Hawthone and Jongkind (2006).

Primate Census

Distribution of transects

To equalize sampling effort, the entire conservation area was divided into eight blocks (Plots A-H) of approximately 45km² each. These were Adiembra (A), Aboabo (B), Ahomaho (C), Afiaso (D), Kruwa (E), Antwikwa (F), Briscoe II (G) and Abrafo (H) protection camps (Danquah, 2007; Wiafe *et al.*, 2010). Each block was identified by the name of the nearest protection camp (Figure 5). In each block, two transects were laid at random at least 4km apart. Each transect was straight and run for a length of 4km long. Wooden beacons were placed at 100 m intervals to indicate the distance covered during the census. Navigation was by compass and a

Geographical Positioning System (GPS) to reach the starting point of each transect. Transects which followed compass lines were measured with a GPS and laid out with minimal cutting and disturbance (Peres, 1999a). A one minute of latitude or longitude grid consisting of cells, each was placed at random over the map of the study site. The intersections of the lines then formed the mid-point of each transect, and two transects chosen at random were laid in each block. Transects were oriented northwards as a rule of the thumb (Danquah, 2007).

Determination of density, group size and distribution of Lowe's monkeys

The 3-person survey team was maintained throughout the survey to ensure consistency in data collection procedures. Primates were counted using the line transect method in accordance with Buckland *et al.* (2001) from November, 2009 to January, 2010 to represent the dry season and May to July, 2010to represent the wet season. During the census, the observers moved along a transect line and stopped every 50m to listen and scan the surrounding area, at optimal walking-pace of about 1 km/h. At the beginning of each transect, the location, habitat type, and date, weather, starting time and participating personnel were recorded as standard items. When a primate group was seen, 10 minutes was spent observing it, and the observer remained on the census route without following the animals away from the line. The following information was recorded following the guidelines of National Research Council (1981) and Peres (1999a):

1. Identification of species and number of individuals. The group size was estimated when conditions prevented a complete count.

2. Mode of detection (Sight, vocalization, or sound produced by animals moving through the vegetation).
3. Time of sighting
4. Observer's location along transect
5. Animal-observer distance: distance from observer's position to the animal when was first detected (sighting distance)
6. Shortest transect-animal distance: (perpendicular distance from the transect line to the animal)
7. Height of first animal sighted
8. Activity of animals at first detection
9. Age and sex of individuals in each group
10. Time encounter ended

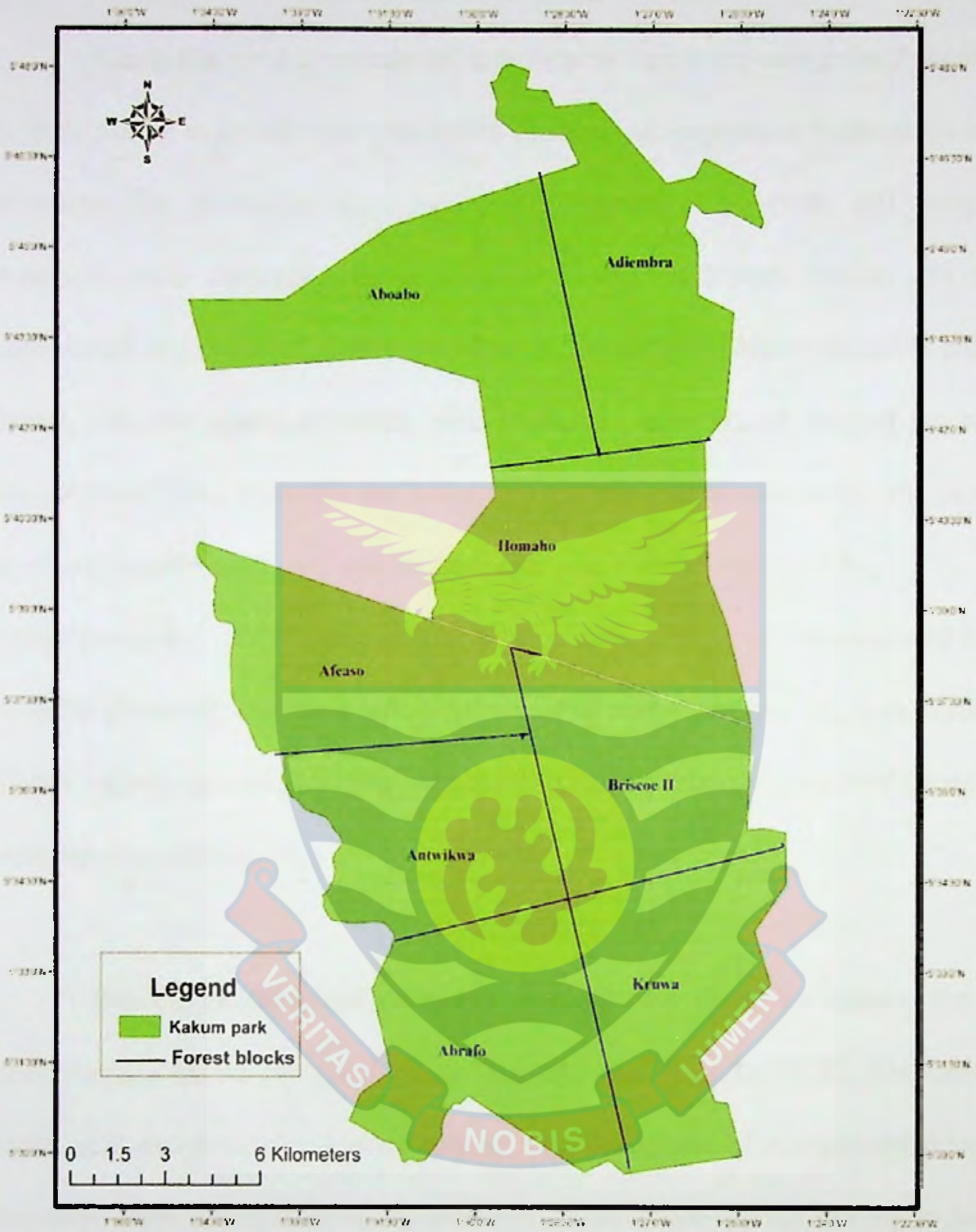

Figure 5: Map of Kakum Conservation Area showing the divisions into forest blocks and the distribution of transects.

Assessment of Hunting Activities

Along the same transects, all human activities were categorized according to their nature especially the possibility for hunting, capture or destruction of the primates. The following were recorded: (i) arrest of poachers, (ii) escape of poachers, (iii) firearms confiscated, (iv) spent cartridges found, (v) skins confiscated, (vi) gunshots heard, (vii) poacher's camps found, (viii) killed animals found, (ix) wire snares removed, and (x) carbide ashes found. Any of the events encountered along transects was identified and the number recorded. The position at which a particular event was encountered was marked with G.P.S.

From November, 2009 to November, 2010, whenever a hunter was arrested by the wildlife protection rangers, some information about the hunting was recorded. These include the animals that had been harvested, hunting methods used and number of poachers.

Bird Census

The fixed-width point counts method was used to assess the bird communities in the primates' range (Bennun and Howell, 2002). The observer stood at a pre-determined point that formed the center of a count cylinder that extended from forest floor to the tree tops. After a two-minute settling in period, the next five minutes were spent recording all the birds seen and heard within a 25 m radius. The species and number of individuals were recorded for all birds within the limits. The bird counts were made from 6.00 am to 11.00am each day.

Foraging Behaviour of Lowe's Monkey

The day's feeding activities were observed by quietly following an observed troop or group throughout the day. Feeding observations were made in 10 consecutive days at anytime certain common and conspicuous species of tree fruit matured. Each feeding observation usually consisted of the identification of the specific food eaten by the monkey and the identification of the plant species. For the purpose of this study, 26 species of trees whose fruits had been observed and reported (Boureliere *et al.*, 1970; Curtin, 2002; Kakum Conservation Area Monthly Reports, 1999-2009) to have been consumed by Lowe's monkeys and other cercopithecines were selected at all the eight blocks and monitored in the reserve. Maize (*Zea mays*) and banana (*Musa sapientum*) were also selected and observed on farms that shared common boundaries with the wildlife reserve. This was carried out over a 12-month period. Data collected included:

- The number of times the Lowe's monkeys visited the fruit trees
- Food types eaten by members of the troop or group
- Type of plant species observed to be eaten (e.g., tree, climber or herb)
- Amount of part seen to be eaten (e.g., whole fruit or half fruit and half seed, etc.)
- Foraging behaviour (how the group searched for their required food)

Measurement of Nutrient Composition of Some Fruits Consumed by Lowe's Monkey

Nutrient contents of three species that were observed to have been consumed most by the Lowe's monkeys were analysed and compared. They were the ripe fruits of banana (*Musa sapientum*) without the peel, fresh matured grains of maize (*Zea mays*) and ripe pulp of Hog plum (*Spondias mombin*).

'Weende system of Analysis' or proximate analysis, the most widely used method for determining the composition of feed stuff was used to partition the fruit parts into six fractions: water, ash, crude protein, ether extract (fat), crude fibre and nitrogen-free extract. This analysis was an attempt to simulate animal digestion. After extracting the fat, the sample was subjected to an acid digestion, simulating the acid present in the stomach, followed by an alkaline digestion, simulating the alkaline environment in the small intestine. The crude fiber remaining after digestion was the portion of the sample assumed not digestible by monogastric animals. In the proximate analysis of feedstuffs, Kjeldahl nitrogen, ether extract, crude fiber and ash were determined chemically. The determination of nitrogen allowed the calculation of the protein content of the sample.

Samples of the fruit parts were obtained from KCA, and were subjected to proximate analysis at the Agroforestry Laboratory of the Institute of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Data Analysis

The line transect method has been widely used and is considered the most accurate method of conducting wildlife surveys to study animal populations and calculate species density (Buckland *et al.*, 1993; Whitesides *et al.*,1988; Plumptre, 2000). The software package DISTANCE (Thomas *et al.*, 2005) is commonly used to analyse data from line transects. However, the use of this method requires certain criteria or assumptions in order for the mathematical model to be applicable to the data (Buckland *et al.*, 2001):

- objects directly on the transect line are never missed;
- objects do not move before being detected;
- objects are not counted twice in a single transect walk;
- distances and angles are measured accurately;
- sightings are independent events;
- sufficient sightings are made for an accurate estimate of the distance;
- detection function (i.e., number of occasions animals were sighted) must usually be greater than 40 sightings.

Unfortunately, several constraints prevented use of this method. Firstly, the animals the monkeys most of the times detect the observer and started moving, before the observer could detect them. Secondly, there was poor visibility in the forest which prevented the clear detection of the objects or animals for accurate distance and angle measurements.

As the mathematical models associated with line transects could not be applied to calculate densities, the Kilometric Indices of Abundance (KIA) which is the ratio of the number of animals encountered to the distance covered was used to analyse the data. This method is based on the ratio of the number of observed animals to the distance traveled by the observer along a set of transects in the study area (Groupe, 1991; Gatti, 2010).

The plant community parameters were calculated as follows:

$$\text{Density} = \frac{\text{Total number of trees in all plots}}{\text{Total Sampled Area}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

$$\text{Relative Density} = \frac{\text{Number of particular species capturedx100}}{\text{Total number of captures of all species}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

$$\text{Relative Dominance} = \frac{\sum \text{Basal area for all trees of a particular species}}{\sum \text{Basal area for all trees pooled}} \text{X100} \ldots\ldots\ldots \text{(4)}$$

The percentage of Lowe's monkey population growth rate was calculated as:

$$\text{Growth rate} = \frac{(N_t - N_0}{N_0} \text{X100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

Where, N_t= Population size at time t,

N_0= Population size at the beginning of the period of interest

The nomenclature of all plants were after Hawthorne and Jongkind (2006) and mammals after Kingdon (1997).

Statistical analysis involved the use of Paleontological Statistics software package for education and data analysis, PAST (Hammer *et al.*, 2001), and Microsoft Excel. The Kruskal-Wallis test was used to evaluate statistical differences in medians of three or more variables while the Mann-Whitney U test was used to test the differences in densities of species between two variables. Spearman's rank analysis was conducted to evaluate the degree of relationship between other biological components on Lowe's monkey's density.

Maps were processed using Arc Map (version 9.3) mapping software developed by Environmental Systems Research Institute (ESRI) (1999-2008). The satellite images after acquisition were processed using IDRISI Kilimanjaro and CHIPS softwares by first presenting a false color composite for visual interpretation. An unsupervised classification was performed using five categories and later reduced to three, closed canopy forest, opened canopy forest and farms. The images were later smoothened with 5x5 filter kernel. Areas covered by the three categories of the canopy structures were calculated.

The diversity indices were calculated using Shannon, Simpson, Menhinick, Margalef, Fisher alpha and Beger-Parker. Kruskal-Wallis test was conducted to test the hypothesis that the tree densities occurring in the various blocks were the same. The satellite image of the canopy of coverage of the Kakum conservation area for 1986, when the timber operation was in progress; and 2002, that is, 13 years after logging were used to evaluate the dynamics of the canopy coverage.

Mann-Whitney test was conducted to evaluate the hypothesis that the Lowe's monkey densities in dry and wet season were the same. In the different blocks Kruskal-Wallis test was conducted to explore the differences in the densities of the Lowe's monkeys that were encountered in both seasons. Spearman's rank correlation was used to evaluate the relationship between the densities of Lowe's monkey and diversity of trees found in the various blocks. Mann-Whitney test was conducted to evaluate the hypothesis that the number of groups of Lowe's monkey and average group sizes encountered in the dry season differ from the wet season.

Spearman's rank correlation was also conducted to evaluate the relationship between the number of groups and average group sizes between the two seasons.

CHAPTER FOUR

RESULTS

Vegetation of the Lowe's Monkeys Range

Among the important determinants of the density and distribution of monkeys in African forests are vegetation characteristics and the distribution of important resources. This section describes the vegetation of Lowe's monkey: structure, composition, diversity and density, relative density and relative dominance of trees encountered in the monkeys' habitat.

Forest structure, tree species composition, relative density, relative dominance and vegetation dynamics of the Lowe's monkey habitat

The general structure of the forest vegetation has three major storeys: (i) lower storey comprising of the undergrowth and trees less than 10 m high, (ii) the canopy layer involving trees from 10 m to 20 m, and (iii) the upper layer ranging from trees of 20m to 40m and the emergent layer of 50 m and above. The study indicated that the number of trees reduced with increasing height classes at an exponential rate of -0.5158, and this explains about 71 % of the relationship as shown in Figure 6 ($y = 651.86^{e-0.5158x}$, $R^2 = 0.7082$).

This represents a forest undergoing regeneration after selective logging about 20 years before (Figure 6). In total 1,064 individual trees comprising 97 different species were enumerated within 62 plots. The results of diversity of trees are presented in Table 2.

The mean density of trees enumerated in all the forest blocks were presented as number of trees per 0.20 ha as follows: Aboabo, 50 (SD=16.74), Abrafo, 51 (SD=17.18), Adiembra, 60 (SD=15.81), Afeaso, 37 (SD=13.51), Antwikwa, 56 (SD=6.25), Briscoe II, 57 (SD=15.67), Homaho, 92 (SD=20.79) and Kruwa, 41 (SD=12.57). The densities of trees in all the eight blocks were found to differ significantly (H=19.28, DoF=7, p=0.007).This could be attributed to a combination of factors such as logging history, past silviculture, edaphic factors, etc. The details of the relative species densities and relative dominance of the enumerated species have been presented in Table 3.

It was found that tree species such as *Carapa procera, Celtis mildbraedii, Diospyros sanza-minika, Aulacocalyx jasminflora, Dacryodes klaineana, Funtumia elastica, Myrianthus arboreus, Diospyros gabunensis, Nesogordonia papaverifera, Cola gigantean*, etc. were dense in the conservation area representing about two to nine percent of the species present in the Lowe's monkeys range. Trees species with higher relative density were not necessarily of higher relative dominance as the latter deals with diameter of the particular species. The following species were among others, examples of trees with higher relative dominance (Table 3): *Celtis mildbraedii* (10 %), *Trichilia prieuriana* (5%), *Tabernaemontana africana* (9%) and *Panda oleosa* (7%).

The result showed that in 1986, out of the total canopy coverage of 295.8 km² the opened canopy area was 80.6 %, closed canopy area was 18.4 % and farms at the peripheries of the conservation area covered1.03 % as shown in Figure 7. On the contrary, in 2002, out of 302.9 km² the open canopy area was found to be58.4 %, while the closed canopy area was 37.4 % and the canopy coverage of the farms around the peripheries of the conservation area was 4.1 % as shown in Figure 8. Comparing the two periods, it could be inferred that the open canopy area had reduced while the closed canopy area had increased in size inside the forest. The peripheries of the farm area had also increased (Figure 7 and 8).

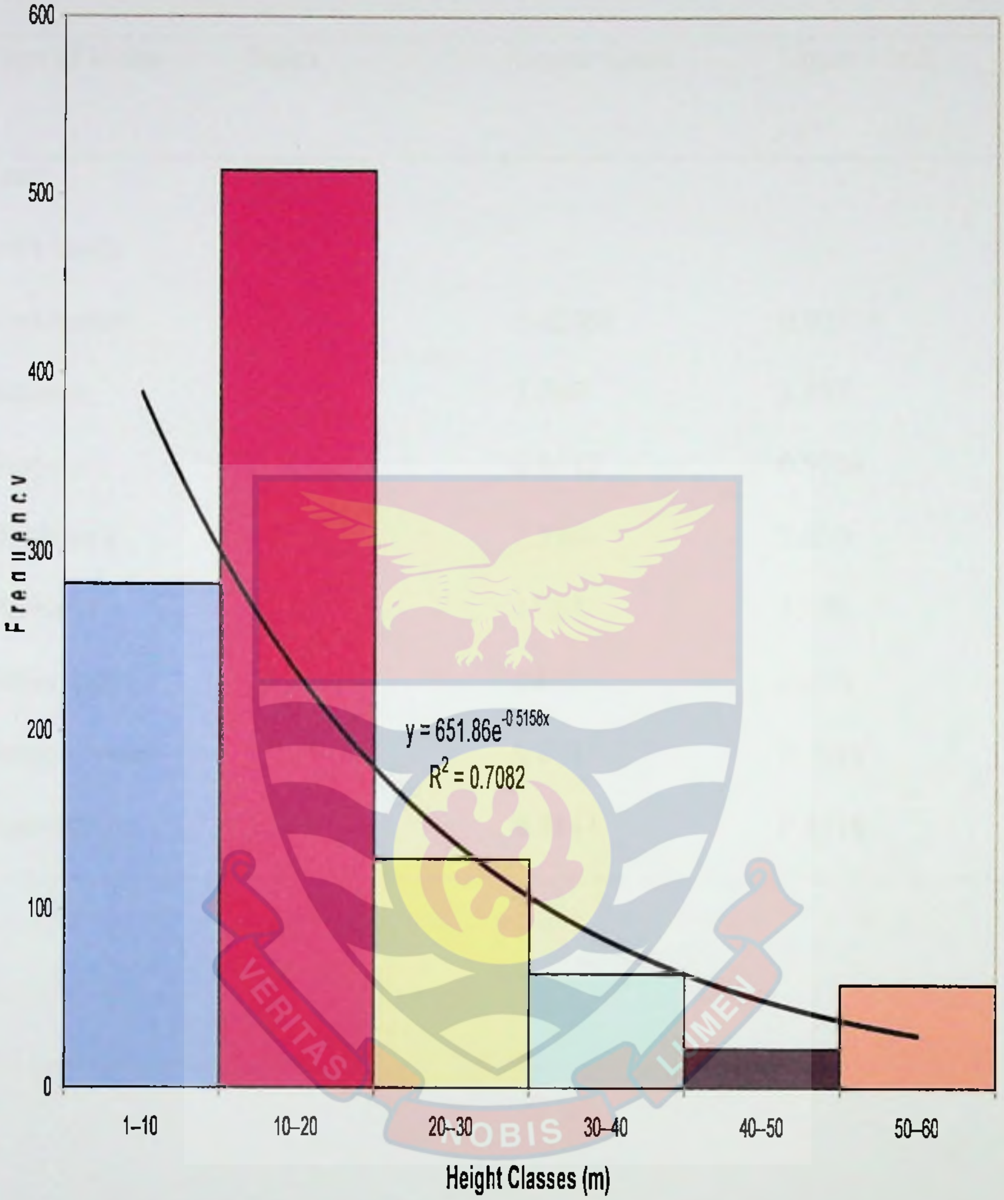

Figure 6: Height of trees found in various blocks of Kakum Conservation Area.

Table 2: Diversity indices of trees enumerated at the Lowe's monkeys' range.

Type of Index	Index	Lower Limit	Upper Limit
Taxa	97	-	-
Individuals	1064	-	-
Dominance	0.03152	0.02962	0.03574
Shannon	3.884	3.766	3.897
Simpson	0.9685	0.9642	0.9704
Menhinick	2.974	2.514	2.820
Margalef	13.77	11.62	13.06
Fisher alpha	25.95	20.72	24.16
Berger-Parker	0.08553	0.0731	0.1034
Equitability	0.8491	0.8444	0.8716

Table 3: Tree species composition, relative density and relative dominance enumerated in the Lowe's monkey range

Family	Scientific Name	Local Name	Relative Density	Relative Dominance
Meliaceae	*Carapa procera*	Kwakuobese	8.6	1.90
Ulmaceae	*Celtis mildbraedii*	Esa	7.4	10.36
Ebenaceae	*Diospyros sanza-minika*	Osonoafe	4.8	0.38
Rubiaceae	*Aulacocalyx jasminflora*	Asabine	4.5	0.44
Burseraceae	*Dacryodes klaineana*	Adwea	4.0	0.03
Apocynaceae	*Funtumia elastica*	Fruntum	3.7	0.01
Cecropiaceae	*Myrianthus arboreus*	Nyankomabere	3.5	0.05
Ebenaceae	*Diospyros gabunensis*	Kusibire	3.4	0.82
Sterculiaceae	*Nesogordonia papaverifera*	Danta	3.0	0.05
Sterculiaceae	*Cola gigantea*	Watapuo	2.9	0.15
Sterculiaceae	*Triplochiton scleroxylon*	Wawa	2.9	0.14
Sterculiaceae	*Sterculia rhionpetala*	Wawabima	2.8	0.36
Meliaceae	*Trichilia prieuriana*	Kakadikro	2.8	5.03
Apocynaceae	*Tabernaemontana*	Oboonawa	2.5	9.17

Table 3 (continued

Family	Scientific Name	Local Name	Relative Density	Relative Dominance
	africana			
Olacaceae	*Strombosia pustulata*	Afena	2.3	0.02
Meliaceae	*Trichila monadelpha*	Tanro	1.9	0.01
Sterculiaceae	*Cola chlamydantha*	Tananfre	1.8	0.05
Chrysobalanaceae	*Parinari excelsa*	Afam	1.7	1.28
Combretaceae	*Terminalia superba*	Ofram	1.6	0.36
Malvaceae	*Desplatsia chrysochlamys*	Osonowesamfe	1.5	0.17
Meliaceae	*Entandrophragma angolense*	Edinam	1.5	0.63
Euphorbiaceae	*Drypetes aubrevillei*	Duamako	1.3	0.14
Leguminosae	*Parkia bicolor*	Asoma	1.2	0.04
Pandaceae	*Panda oleosa*	Kokroboba	1.1	7.29
Leguminosae	*Piptadeniastrum africanum*	Dahoma	1.1	0.20
Meliaceae	*Guarea cedrata*	Kwabohoro	1.0	0.01
Leguminosae	*Baphia pubescens*	Odwenkobire	0.9	0.14

Table 3 (continued)

Family	Scientific Name	Local Name	Relative Density	Relative Dominance
Malvaceae	*Mansonia ultissima*	Oprono	0.9	0.02
Caesalpiniaceae	*Afzelia africana*	Papao	0.8	0.31
Euphorbiaceae	*Discoglypremna caloneura*	Fetefre	0.8	0.56
Apocynaceae	*Funtumia africana*	Okae	0.8	0.60
Sapotaceae	*Gluema ivorensis*	Nsudua	0.8	0.08
Lecythidaceae	*Petersianthus macrocarpus*	Esia	0.8	7.30
Violaceae	*Rinorea oblongifolia*	Mpawoutuntum	0.8	0.06
Violaceae	*Rinorea welwitschii*	Apose	0.8	1.85
Leguminosae	*Daniellia ogea*	Hyedua	0.7	4.71
Euphorbiaceae	*Uapaca guineensis*	Kuntan	0.7	0.03
Rutacee	*Zanthoxylum gilletii*	Okuo	0.7	0.69
Moraceae	*Antiaris toxicaria*	Kyenkyen	0.6	2.91
Euphorbiaceae	*Bridelia atroviridis*	Opamkotokrodu	0.6	0.51
Moraceae	*Milicia excelsa*	Odum	0.6	4.49
Sterculiaceae	*Sterculia oblonga*	Ohaa	0.6	0.98
Sapindaceae	*Blighia sapida*	Akye	0.5	0.19

Table 3 (continued)

Family	Scientific Name	Local Name	Relative Density	Relative Dominance
Leguminosae	*Bussea occidentalis*	Kotoprepre	0.5	0.07
Malvaceae	*Celba pentandra*	Onyina	0.5	0.96
Sterculiaceae	*Cola caricifolia*	Ananseaya	0.5	0.10
Sterculiaceae	*Cola nitida*	Bese	0.5	0.45
Leguminosae	*Crudia gebonensis*	Samantaa	0.5	0.02
Moraceae	*Ficus sur*	Nwadua	0.5	0.15
Simaroubaceae	*Hannoa klaineana*	Fotie	0.5	0.03
Guttiferae	*Pentadesma butyracea*	Abotoasabie	0.5	0.91
Moraceae	*Treculia africana*	Ototim	0.5	0.20
Annonaceae	*Xylopia quintasii*	Obaa	0.5	0.20
Sapotaceae	*Aningeria robusta*	Asanfina	0.4	2.43
Leguminosae	*Dialium guineense*	Asenaa	0.4	0.15
Euphorbiaceae	*Uapaca corbisieri*	Kuntanmiri	0.4	0.09
Verbenaceae	*Vitex microntha*	Otwentrowa nini	0.4	0.06
Capparaceae	*Buchholzia coriacea*	Konini	0.3	0.04
Ulmaceae	*Celtis philippensis*	Premprensa	0.3	0.03
Sapotaceae	*Chrysophyllum africanum*	Sutabene	0.3	1.36

Table 3 (continued)

Family	Scientific Name	Local Name	Relative Density	Relative Dominance
Leguminosae	*Distemonanthus benthamianus*	Bonsamdua	0.3	0.09
Irvingiaceae	*Irvingia gabonensis*	Abesebuo	0.3	0.02
Pandaceae	*Microdesmis keayana*	Ofema	0.3	6.79
Cecropiaceae	*Myrianthus libericus*	Nyankomanini	0.3	0.00
Rubiaceae	*Nauclea diderrichii*	Kusia	0.3	5.48
Rubiaceae	*Oxyanthus unilocularis*	Kwaetawa	0.3	0.18
Sapotaceae	*Tieghemella heckelii*	Baku	0.3	0.18
Mimosaceae	*Albizia zygia*	Awienfoosamina	0.2	0.98
Annonaceae	*Annickia polycarpa*	Duasika	0.2	0.02
Olacaceae	*Coula edulis*	Bodwue	0.2	0.25
Meliaceae	*Entandrophragma cylindricum*	Penkwa	0.2	2.32
Meliaceae	*Entandrophragma utile*	Efobrodedwo	0.2	0.03
Bignoniaceae	*Kigelia africana*	Nufuten	0.2	0.16

Table 3 (continued)

Family	Scientific Name	Local Name	Relative Density	Relative Dominance
Irvingiaceae	*Klainedoxa gabonensis*	Kroma	0.2	0.02
Anacardiaceae	*Lannea welwitschii*	Kumanini	0.2	0.02
Euphorbiaceae	*Macaranga barteri*	Opam	0.2	0.01
Myristicaceae	*Pycnanthus angolensis*	Otie	0.2	0.18
Mimosaceae	*Albizia adainthifolia*	Pampena	0.1	0.01
Apocynaceae	*Alstonia boonei*	Nyamedua	0.1	0.00
Anacardiaceae	*Antrocaryon micraster*	Aprokuma	0.1	0.27
Leguminosae	*Baphia nitida*	Odwen	0.1	0.01
Leguminosae	*Cylicodiscus gabunensis*	Danya	0.1	0.16
Leguminosae	*Cynometra ananta*	Ananta	0.1	0.11
Meliaceae	*Entandrophragma candolai*	Penkwa-akoa	0.1	3.05
Guttiferae	*Garcinia kola*	Tweapeakoa	0.1	0.52
Sapotaceae	*Chrysophyllum albidum*	Akasa	0.1	0.57

Table 3 (continued)

Family	Scientific Name	Local Name	Relative Density	Relative Dominance
Ulmaceae	*Holoptelea grandis*	Nakwa	0.1	0.04
Leguminosae	*Hymenostegia afzelii*	Takrowa	0.1	0.29
Sapindaceae	*Lecaniodiscus cupanioides*	Dwindwira	0.1	0.22
Guttiferae	*Mammea africana*	Bompagya	0.1	2.44
Lecythidaceae	*Napoleonaea vogelii*	Obua	0.1	0.70
Olacaceae	*Ongokea gore*	Bodwe	0.1	0.03
Euphorbiaceae	*Ricinodendron heudelotii*	Wama	0.1	0.09
Sapotaceae	*Synsepalum msolo*	Asaba	0.1	0.18
Combretaceae	*Terminalia ivorensis*	Emire	0.1	2.40
Meliaceae	*Trichilia tessmannii*	Tanronini	0.1	0.24
Leguminosae	*Xylia evansii*	Samantaa	0.1	0.20

Figure 7: Satellite image of Kakum conservation area in 1986 during the period of logging.

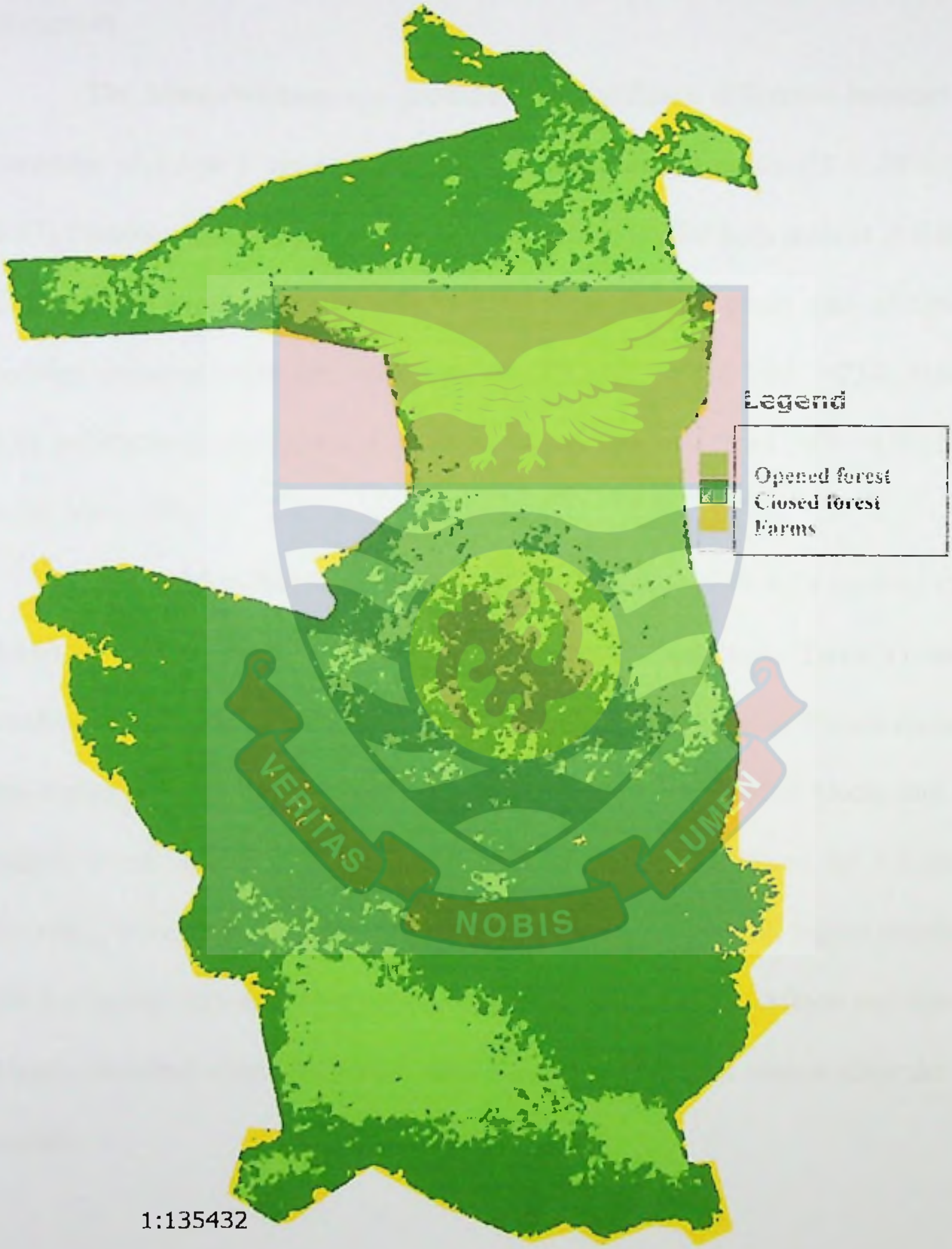

Figure 8: Satellite image of Kakum conservation area in 2002, thirteen years after logging.

Lowe's Monkey Population Density in KCA

The mean kilometric index of abundance of Lowe's monkey per kilometre per forest block in the wet season was 0.99 ± 0.70 and 1.07 ± 0.66 in the dry season (Figure 9).

The Mann-Whitney test indicated no significant difference between the densities of Lowe's monkey encountered in the two seasons (U = 29.5, p = 0.83).Therefore the average density of Lowe's monkey for both seasons at Kakum Conservation Area was 1.03 (SD = 0.03). The average group size of Lowe's monkey encountered in the wet season was 10.2 (SD = 5.2, Max. =23.0, Mini. = 1.0) and the in the dry season the average group size was 11.80 (SD = 4.90, Max. = 26, Mini. = 4).

The Kruskal-Wallis test indicated that densities of Lowe's monkey in all forest blocks in the dry season did not differ from the densities of Lowe's monkey in all blocks in wet season (H=12.74, p=0.08) (Figure 10). Briscoe II block recorded the highest average number of Lowe's monkeys than all the other blocks and was higher in the dry season than the wet season. It was followed by Adiembra, Homaho, Abrafo and Antwikwa blocks in that order again with higher density in the dry season than the wet season. On the other hand, Kruwa, Afeaso and Aboabo blocks recorded relatively higher densities during the wet season than the dry season.

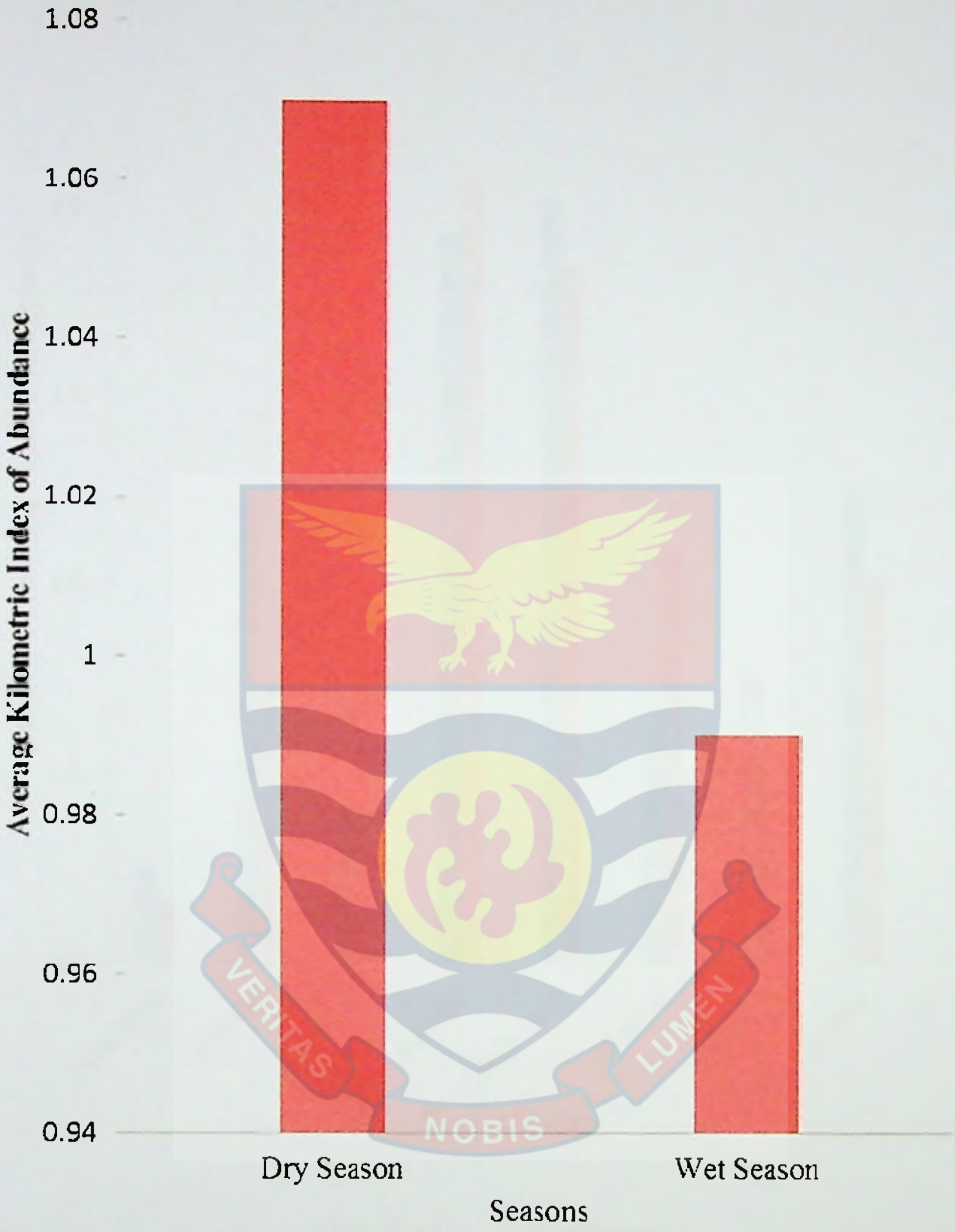

Figure 9: Density of Lowe's Monkeys in dry and wet seasons at KCA.

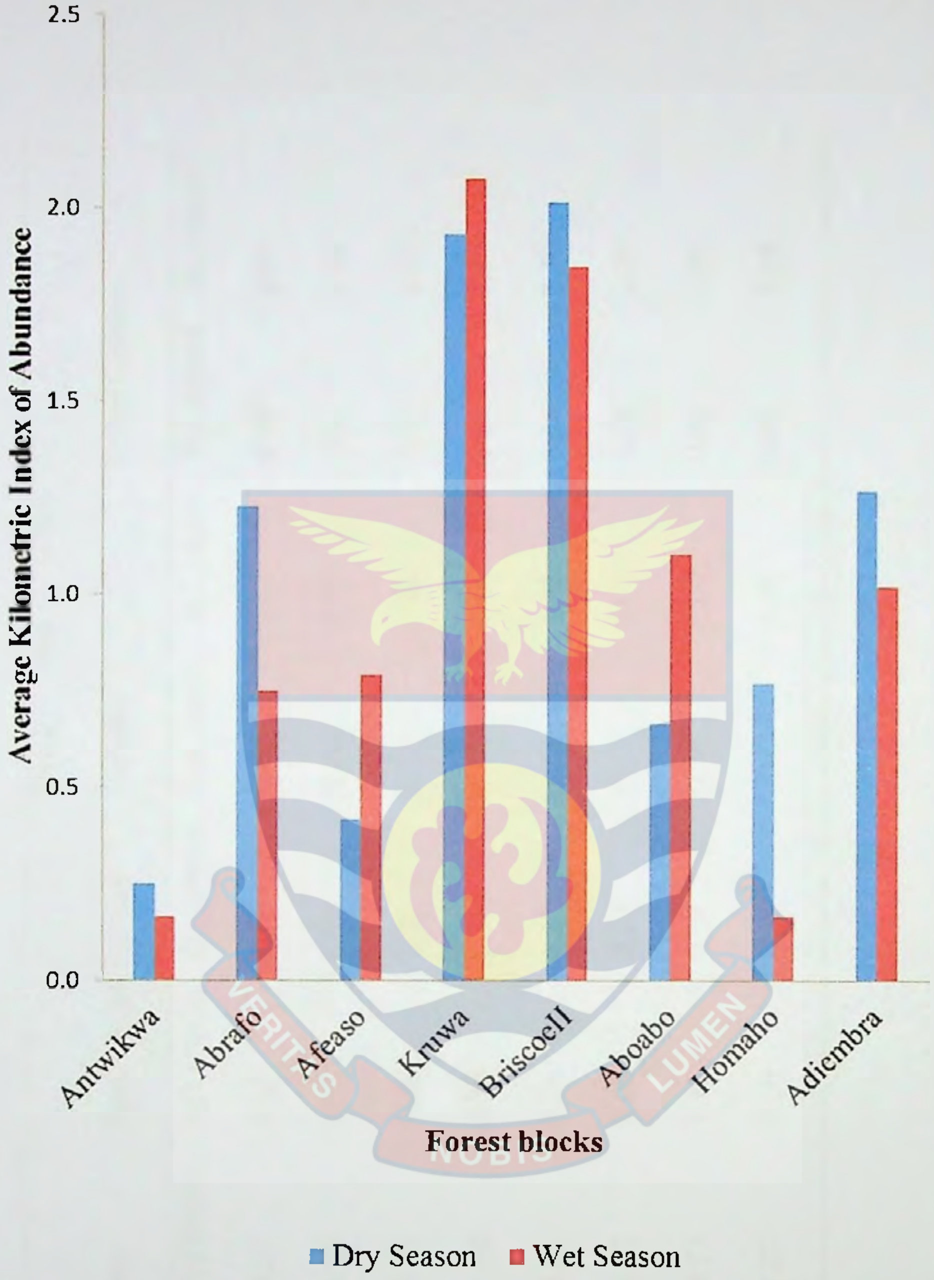

Figure 10: Density of Lowe's Monkeys in the various forest blocks

Table 4: Encounter rates per km of anthropoid primates in Kakum Conservation Area during the 2009-2010 survey

Site name	Lowe's Monkey		Spot Nosed Monkey		Black and White Colobus		Olive Colobus	
	wet season	dry season	wet season	dry season	wet season	dry season	wet season	dry season
Antwikwa	0.17	0.25	0.15	0.13	0.00	0.00	0.00	0.04
Abrafo	0.75	1.23	0.15	0.21	0.40	0.10	0.04	0.08
Afeaso	0.79	0.42	0.00	0.27	0.13	0.00	0.04	0.00
Kruwa	2.08	1.94	0.33	0.33	0.85	0.44	0.00	0.00
Briscoe II	1.85	2.02	0.35	0.27	0.77	1.15	0.06	0.10
Aboabo	1.10	0.67	0.00	0.29	0.13	0.00	0.00	0.00
Homaho	0.17	0.77	1.13	0.29	0.00	0.00	0.00	0.00
Adiembra	1.02	1.27	0.00	0.21	0.00	0.00	0.00	0.00

Table 5: Encounter rates per km with anthropoid primates in Kakum Conservation Area, Bia Conservation Area and Nini-Suhien National Park during a survey conducted in 1993 in Ghana after Oates *et al.* (2000)

Site name	Lowe's monkey	Spot Nose Monkey	*Cercopithecus* (unidentified)	Pied Colobus	Olive Colobus
Kakum (Antwikwaa)[1]	0.50	0.42	0.17	0.00	0.17
Kakum (Obuo)[2]	0.25	0.31	0.25	0.00	0.19
Kakum (Obuo)[3]	0.19	0.50	0.00	0.00	0.06
Bia C.A	0.07	0.14	0.05	0.00	0.00
Nini-Suhien N.P	0.00	0.00	0.00	0.00	0.00
Average	0.20	0.27	0.09	0.00	0.08

[1] Struhsaker and Oates; [2] Oates; [3] Struhsaker

Relationship between Lowe's Monkey, Density and Diversity of Trees

The density of Lowe's monkeys and the diversity of trees at Kakum Conservation Area followed almost the same parabolic trend (Figure 11). The result of Spearman's rank correlation was positive but not significant (ρ = 0.383, p = 0.348). The hypothesis that the higher the diversity of trees the higher the density of Lowe's monkeys was rejected.

Similarly, the correlation between the density of Lowe's monkeys and density of trees (Figure 12) was not significant ($\rho=0.167$, $p=0.695$). This therefore rejected the hypothesis that the higher the density of trees the higher the density of Lowe's monkeys. This suggests that though the relationship between density and diversity of trees in the forest and the Lowe's monkey numbers was not significant, there might be other factors as well which contribute to the density of Lowe's monkeys in the KCA. These include intrinsic factors such as birth, death and growth rate and extrinsic factors such as hunting pressure and changes in food availability.

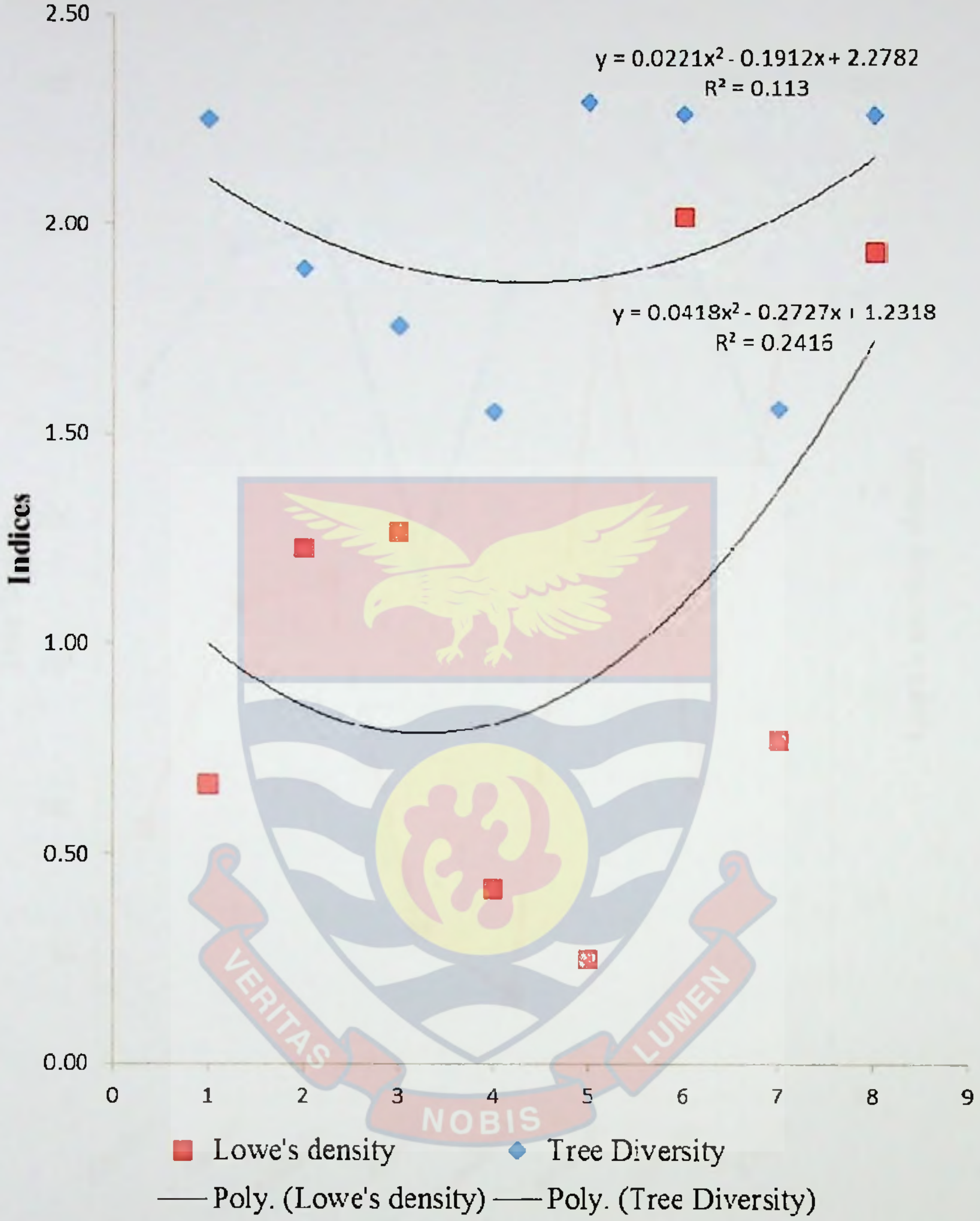

Figure 11: Relationship between trends of density of Lowe's monkeys and tree diversity.

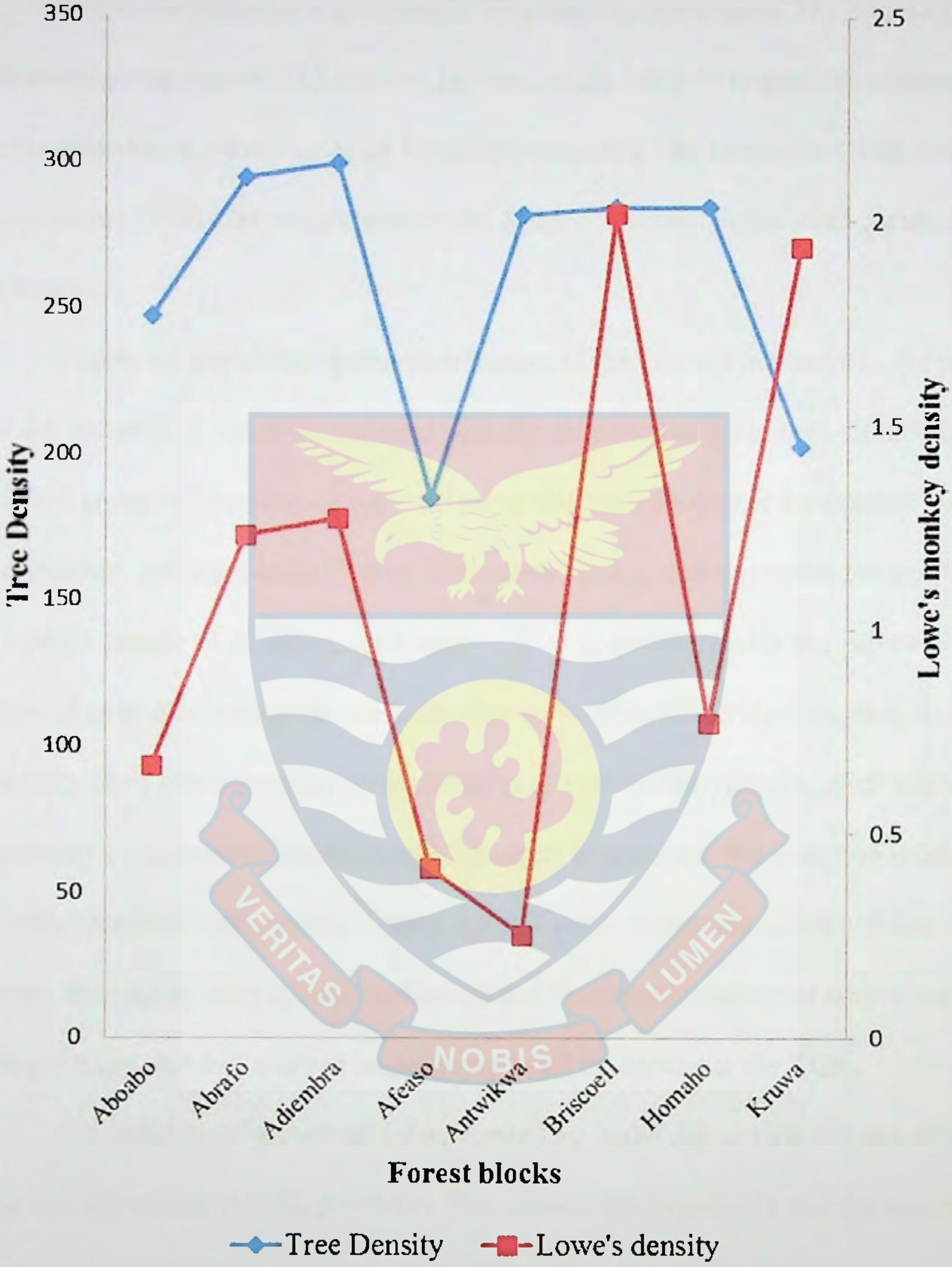

Figure 12: The distribution of Lowe's monkey density over the densities of trees found in the various forest blocks.

Distribution Pattern and Group Size of Lowe's Monkey

In the wet season, a total count of 35 groups comprising of 357 individuals with mean group size of 10.2 (SD= 5.14, Max. = 23, Mini. = 1) were encountered. On the other hand, a total count of 41 groups involving 484 individuals with mean group size of 11.80 (SD = 4.90, Max. = 26, Mini. = 4) were encountered during the dry season.

Figure 13 shows the spatial distribution of the Lowe's monkeys in the wet and dry seasons. It could be deduced that the distribution is random. Sometimes different groups of monkeys meet each other and forage together for reasons such as protection. An experienced hunter interviewed speculated that when the number of Lowe's monkeys is large, the hunter is then confronted with the problem of choice of prey (the hunter becomes confuse as to which individual monkey to be selected). The Lowe's monkeys were found in all the habitat types (i.e., both opened and closed canopy forest habitat types). Numbers in groups differ from one another including isolated male groups. Tables 6 and 7 show the details of the numbers of groups, their mean sizes and the minimum and maximum number of counts made during the dry and wet seasons respectively in all the blocks at the KCA.

The number of groups of Lowe's monkey in the dry season did not differ from the wet season (U=30, $p = 0.88$). This rejects the hypothesis that the number of groups encountered in the wet season differs from that of the dry season. Similarly, no difference was found in average group sizes between the two seasons (U=28, $p = 0.71$). The hypothesis that the average group sizes differs from dry to wet season was also rejected.

Spearman's rank correlation indicated that though the number of groups positively correlate with average group sizes the relationship in not significant in both dry ($\rho = 0.57$, $p = 0.14$) and wet seasons ($\rho = 0.57$, $p = 0.15$). The hypothesis was rejected.

Furthermore, in the dry season, the minimum group size (three) was recorded at Aboabo and the maximum group size (26) was recorded at Briscoe II (Table 6). In the wet season the minimum number (one) was recorded at Aboabo, Briscoe II and Kruwa while the maximum number recorded (17) was at Adiembra (Table 7).

Table 6: Number of groups and average group sizes encountered in the forest blocks of the Kakum conservation area during the dry season

Forest Block	Number of Groups	Mean group size	Standard Deviation	Minimum	Maximum
Aboabo	4	5.2	1.3	3	10
Abrafo	6	9.8	2.8	6	12
Adiembra	9	12.3	3.3	5	15
Afeaso	2	10.0	0	10	10
Antwikwa	2	6.0	1.4	5	7
Briscoe II	13	15.9	5.4	7	26
Homaho	4	9.3	1.5	8	11
Kruwa	8	8.3	3.5	4	14

Table 7: Number of groups and average group sizes encountered in the forest blocks of the Kakum conservation area during the wet season

Forest Block	Number of Groups	Mean group size	Standard Deviation	Minimum	Maximum
Aboabo	4	4.3	3.3	1	6
Abrafo	5	11.8	7.8	2	8
Adiembra	7	15.1	2.5	10	17
Afeaso	4	9.3	5.1	5	15
Antwikwa	1	8.0	-	-	-
Briscoe II	13	9.3	4.2	1	15
Homaho	2	8	4.9	6	10
Kruwa	9	9.4	5.6	1	16

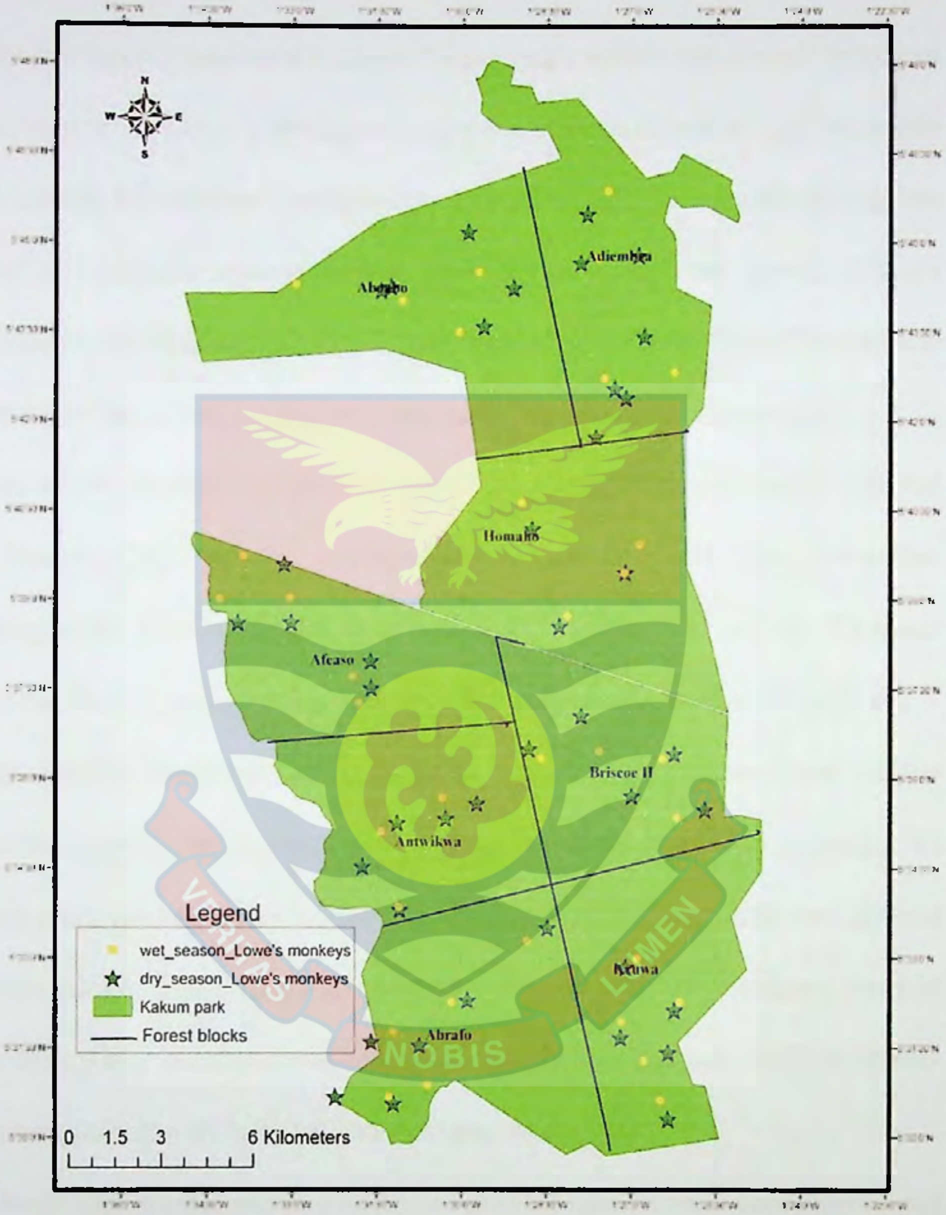

Figure 13: Spatial distribution of Lowe's monkeys in Kakum conservation Area during the wet and dry seasons.

Relationship between Lowe's Monkeys and other Mammals of Kakum Conservation Area

Some observations were made on the interactions between Lowe's monkeys and other mammals. Lowe's monkeys occupy one or more niches and guilds, which can be defined by various combinations of habits such as (i) arboreal against terrestrial, (ii) arboreal against diurnal, and (iii) diet frugivore against folivore against insectivore (Bourliere, 1985). Other mammals that were sighted in transects were therefore considered to elaborate the niche sharing of the mammals.

In all, 19 species were encountered in the conservation area which differed in the blocks. These species belonged to 11 families with Cercopithecidae dominating with 51% in the dry season, and 48% in the wet season. This was followed by Bovidae comprising 18% both dry wet seasons. Appendices IV and V show the details of the mammalian diversity indices at the various blocks of the conservation area in the dry and wet seasons respectively, while Appendix VI shows the checklist and kilometric indices of abundance of mammals encountered during this survey. These mammals normally interact with the monkeys either in space or time. Only one carnivore, *Civettictis civetta* was encountered in relatively low numbers 0.01/km in both dry and wet seasons.

In all four diurnal and two nocturnal primate species were encountered and confirmed to be currently present. Arranging them into eco-taxonomic categories, the KCA's primates arranged into four structures (Chapman *et al.* 1999) as follows:

(i) Pottos: *Perodicticus potto*;

(ii) Galago: *Galagoides demidoff*;

(iii) Arboreal cercopithecines: *Cercopithecus campbelli lowei* and *Cercopithecus petaurista petaurista*;

(iv) Colobines: *Procolobus verus* and *Colobus vellerosus*.

The densities of the diurnal anthropoid primates are shown in Table 4.The same primate species were recorded in the 1993 survey (Oates *et al*., 2000).

The Lowe's monkeys were observed to be associated with other mammals in most of the forest blocks. In Abrafo and Briscoe II, they were observed associated with black-and-white colobus monkeys at one location. Of the average of seven observations recorded, neither intimate nor antagonistic interactions were observed between the two species. The black-and-white colobus monkeys were observed in the emergent layer while the Lowe's monkeys were observed in the middle to lower canopy layer.

In all the blocks, 80% of the observations recorded associations between Lowe's monkeys and spot-nosed monkeys during the afternoon. These two species were found to move together and feed from the same food source. The Lowe's monkeys were normally found at lower layers than the spot nosed monkeys.

In the Abrafo block, Olive Colobus, spot-nosed monkey and Lowe's monkeys usually came together from mid-morning (around 10.00 hours GMT) and foraged along the Cape Coast-Twifo Praso main road. This observation was also madein the Briscoe II block near the satellite camp.

In all the forest blocks, between 70-100% of the observations recorded the presence of duikers (Maxwell's, black, bay or yellow-backed) foraging below the fruit trees where the Lowe's monkeys were found foraging. These antelopes appear to take advantage of the opportunity of the monkeys dropping fruits from the canopy which would have been difficult to reach.

Activity Patterns of Lowe's Monkeys

The average observed time for Lowe's monkeys to wake up in the morning was 06.15GMT (SD=30 minutes, N=30, Range 05.45 -06.45GMT) and the average sleeping time was 17.46 GMT (SD=17 minutes, N=30, Range 17.09-18.15GMT). When the Lowe's monkeys wake up, the dominant male always gives out an alarm call before the group moves out of their sleeping tree. The group starts searching for food right from the sleeping place. Sometimes the sleeping tree was the last tree the group foraged on before sleeping within their territory. The morning food choice was done opportunistically by picking any edible item they came across especially the early morning insects which flew away as the monkeys disturbed the vegetation.

The group then moved from one tree to another in search of their preferred food, stopping to eat together when the food is found but with caution to avoid predators. Feeding on the preferred food would continue until the group members had filled their stomachs and cheek pouches, the food becomes exhausted, or the group detects an intruder. After feeding, the group moves to the top of a tall tree covered with lianas and leaves and members start playing, grooming and resting according to the choice of individual members of the group. The staple food was fruits of many kinds of trees, insects and sometimes succulent leaves. Insects were captured with the palm and carefully removed (Plate 2). Nectar was sometimes consumed when the group came across some flowers with nectar. When a group meets another group, a territorial alarm call would first be made by the male of one group which would be responded to by the other group. The members of the group would then mixed up and either they merged and move together as a troop or disperse again for each group to move on its own way. The group then retired to sleep after 17 hours GMT on one of the large diameter trees in their territory. The choice of sleeping place was found to be influenced by safety and food availability.

Indicators of Hunting Activities

Indications of hunting, capture or destruction of Lowe's monkeys were recorded. These were categorized as follows: (i) pile/deposits of carbide powder found, (ii) empty cartridges found, (iii) fire arms confiscated, (iv) human foot prints other than patrol staff, (v) gunshots heard, (vi) poachers arrested, (vii) poachers who escaped arrest, (viii) poachers' camp found, (ix) wire snares, (x) saplings and climber cutting found (Table 8). Mann-Whitney test indicated no significant difference between the indicators recorded in dry and wet seasons (U = 37.5, p = 0.36). In addition, when all indicators of hunting, capture, or destruction of primates from the various forest blocks in both dry and wet season (Figure 11) no difference was found between the two seasons in all the forest blocks (U=30, p=0.87). Furthermore, the various indicators recorded in the various blocks (Figures 15 and 16) while Figure 17 shows the totals of the indicators recorded in both dry and wet seasons in the eight forest blocks. The hypothesis that human activities encountered in all blocks are the same was accepted (Kruskal-Wallis: H =10.38, p = 0.26). Similarly, during the wet season, human hunting activities in the forest blocks were not significantly different (H = 2.6, p = 0.95).

The presence of carbide powder gave an indication of night hunting. Calcium carbide is used to power a device to generate light which blinds the targeted animal. Currently, this method of hunting is not common as flush lights have replaced the carbide powdered lights.

Empty cartridges from shotguns are also indicators of hunting activity. The pellets are embedded in a shell, which is discarded after shooting the target animal and replaced with a new one. The sound of gunshots was also an indication of hunting activity. The use of shotguns was in evidence in all blocks of the conservation area in both dry and wet seasons (Figures 15 and 16) (Plate 3).

Trapping was the commonest hunting method during both dry and wet seasons (Table 8; Figures 15 and 16). Trapping tends to be dangerous because they are elusive and non-selective of species, sex or age. The predominant type of trap used is the cable snare (Plate 4), a noose set along an animal's trail. When an animal steps on a pressure pad, it releases a curved pole, which springs up to tighten the noose around the animal's leg. Neck snares capture animals as they try to pass through a cable noose that is perpendicular to the ground. A variation of the neck snare method is to build drift fence, a fence of branches and leaves (often palm) to direct animals to paths through the fence where several snares are set 2 to 5m apart (usually off-reserve areas or farmlands). In some cases where primates are the main target (Plate 5) a mirror is placed beneath the set-snare to reflect the image of curious species which are attracted to the trap (personal observation).

Permanent and temporary poaching camps were identified during the field survey (Plate 6). A temporary camp has no shelter with the hunters surrounding a fire with wooden poles. The hunters use the fire to smoke the meat for preservation and also to warm themselves. A permanent camp (Plate 7) has a thatched roof made from the fronds of the raffia palm. The hunters use it for several months or years until detection by the park guards or abandonment by the poachers themselves. At a permanent camp, the hunters prepare and smoke the meat and occasionally (normally on market days) send them to the traders and middlemen in the nearby villages. They cook their meals and mend their hunting gears at this camp.

Sapling and climber cuttings were indications of either the presence cable snares or a hunting camp. These were also recorded in almost all the blocks. Poacher's footprints were differentiated from park patrol staff and the survey team by the sole prints of the boot (though not very reliable). The park patrol staff and the survey team were given a special boot for forest work and were not allowed to use any other.

Table 8: Indicators of hunting, capture or destruction of primates recorded during the wet and dry seasons survey.

Activity	Mean Encounter (wet season)	Standard Deviation (wet season)	KIA (wet season)	Mean Encounter(dry season)	Standard Deviation (dry season)	KIA (dry season)
Carbide powder	2.0	2.9	0.02	2.2	3.2	0.03
Empty Cartridges	21.8	30.2	0.26	17.3	23.8	0.20
Fire arms	0.2	0.4	0.00	0.7	1.3	0.01
Foot Prints	9.3	13.5	0.11	7.3	10.5	0.09
Gunshot heard	6.0	8.2	0.07	9.1	12.6	0.11
Poachers arrested	0.4	0.7	0.01	1.3	2.2	0.02
Poachers camps	0.9	1.4	0.01	3.3	5.4	0.04
Poachers escaped	0.0	0.0	0.00	0.4	0.9	0.01
Sapling & climber cutting	0.2	0.4	0.00	10.4	20.4	0.12
Snares	24.4	37.1	0.29	12.4	19.5	0.15

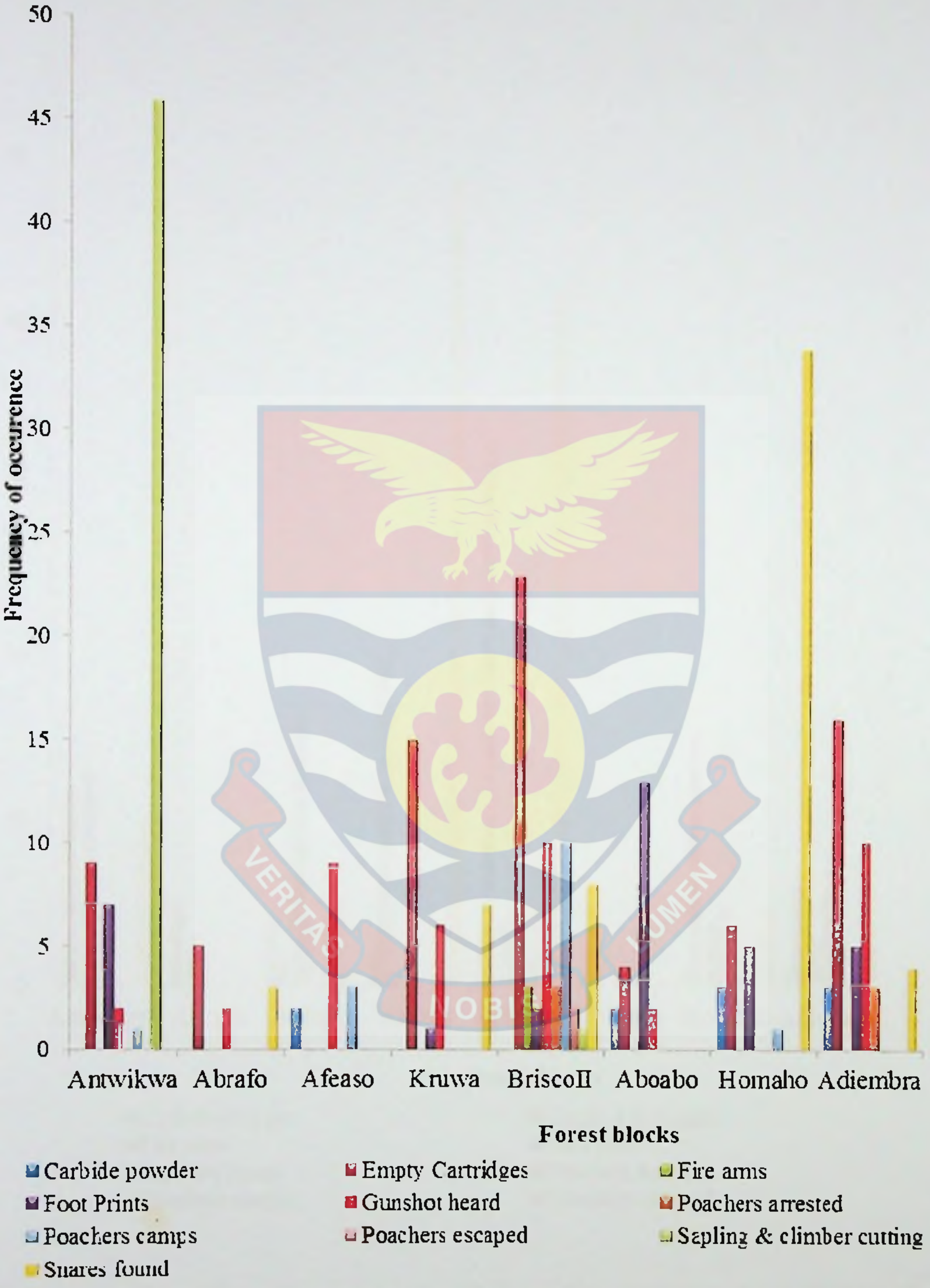

Figure 14: Hunting indicators in the Kakum Conservation Area during the dry season.

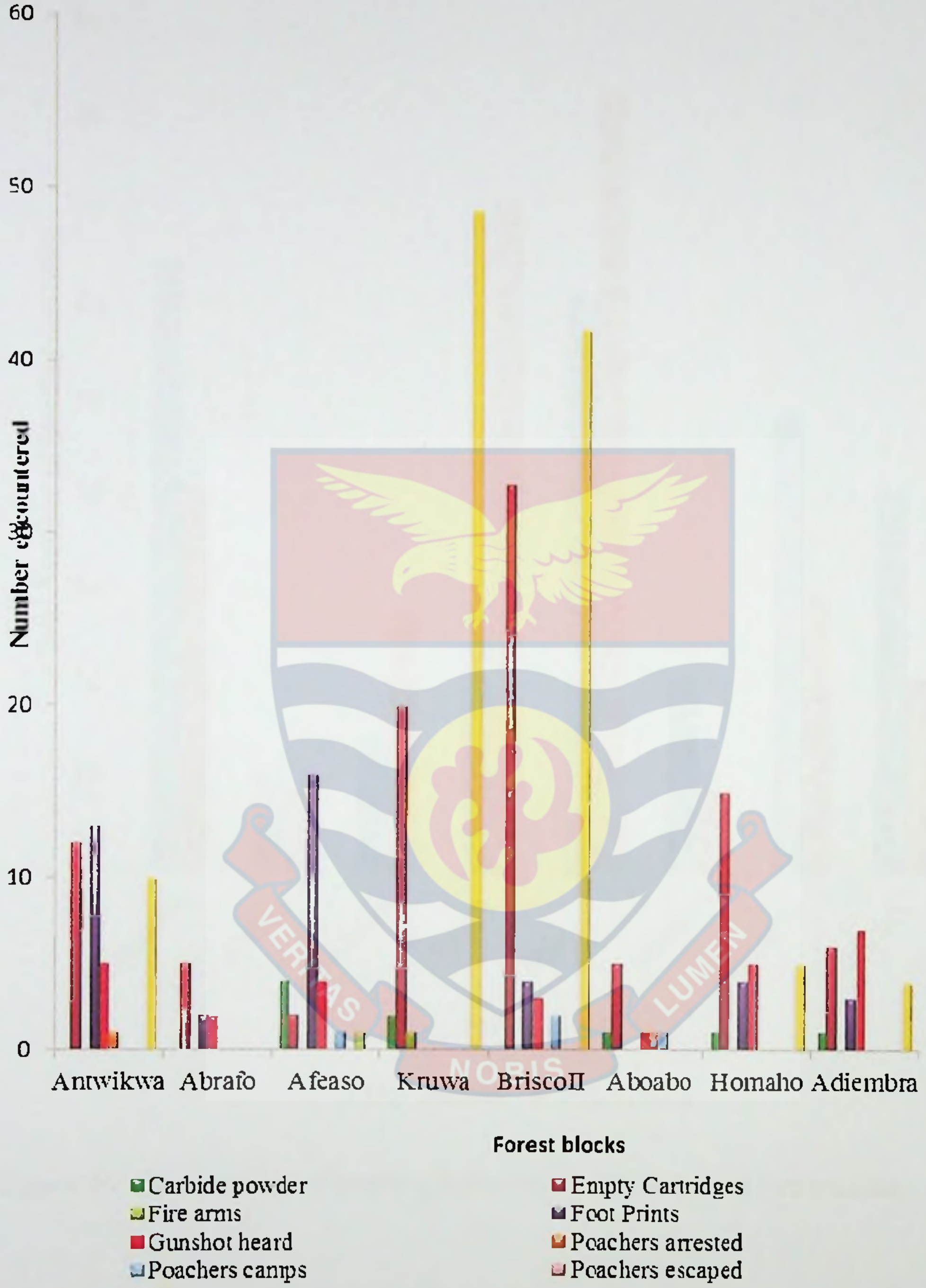

Figure 15: Hunting indicators in the Kakum Conservation Area during the wet season.

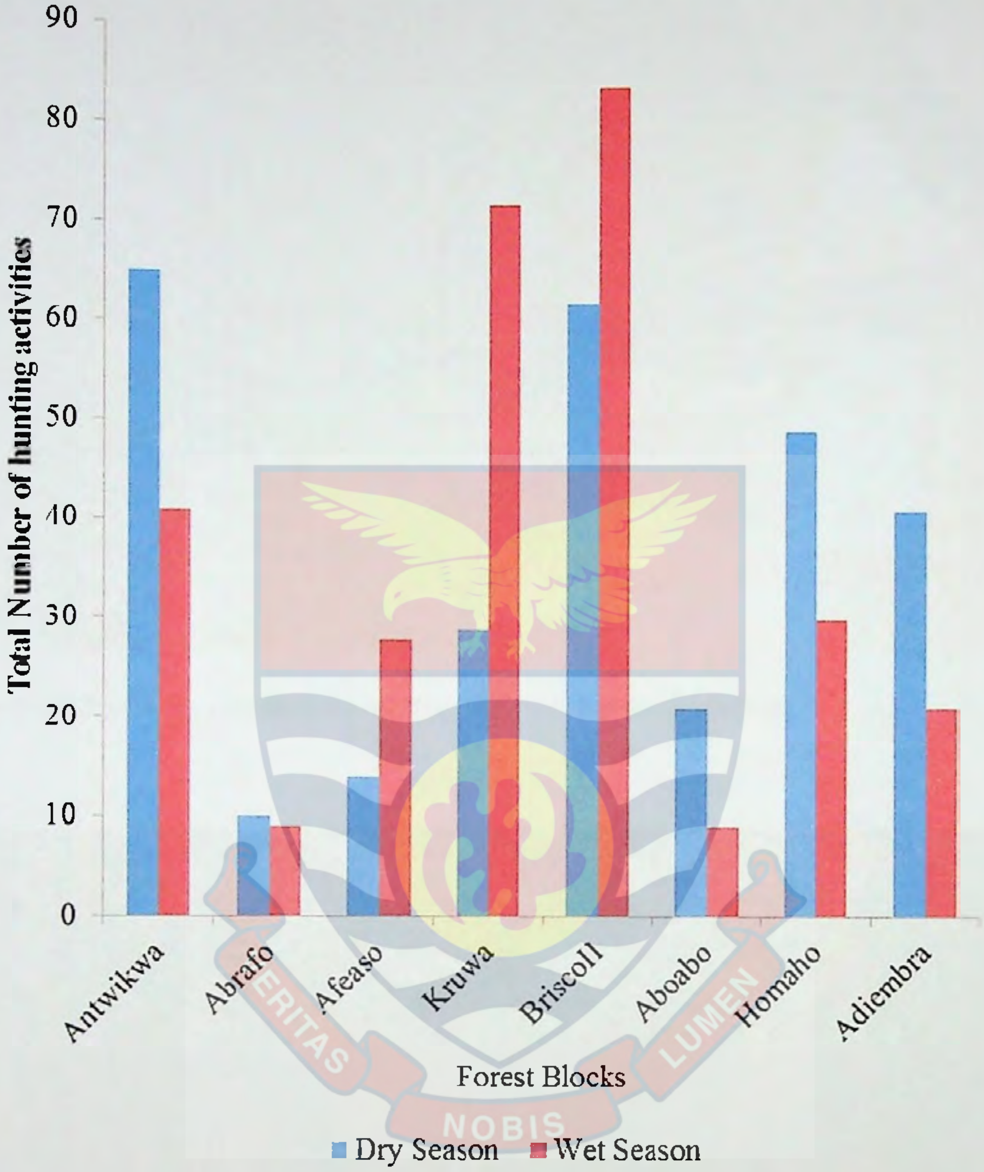

Figure 16: Comparison of hunting indicators in the dry and wet seasons.

Plate 2: Firearms confiscated during the primate field studies.

Plate 3: Wire snares found in Kakum Conservation Area.

Plate 4: Spot nosed-monkey (*Cercopithecus petaurista petaurista*) found killed by poachers.

Plate 5: Temporary Poachers' camps

Plate 6: Permanent Poacher's camps

Relationship between Incidence of Hunting Activities and Lowe's Monkey Density

To investigate the degree of relationship between the incidence of hunting and Lowe's monkey, a non-linear regression indicated the following: In the dry season, the density of the Lowe's monkey was negatively influenced by the hunting incidence accounting for about 18% ($y=-000x^2+0.068x-0.085$, $R^2=0.182$). Spearman's rank correlation indicated that this relationship was not significant ($\rho = 0.05$, $p = 0.91$) which may imply that other factors contributed, to the Lowe's numbers apart from hunting during the dry season (Figure 17). Conversely, during the wet season a positive relationship emerged ($y = 0.000x^2 + 0.046x-1.328$, $R^2 = 0.699$) (i.e., the number of hunting activities increased with the density of Lowe's monkey, accounting for about 70 %). The Spearman's rank correlation however was not significant ($\rho = 0.27$, $p = 0.53$). Similarly, there were other contributory factors that influenced the density of the Lowe's monkeys in the wet season (Figure 18). This rejects hypothesis that incidence of hunting activities alone affect the density of Lowe's monkeys. The variation in the relationships occurring in different seasons reflects the effects of seasonal changes on the users of the ecosystem as well as on the components of the whole system.

Composition of Hunted Species

Within a period of 12 months 17 hunters were arrested by the wildlife protection rangers on 13 different occasions. Arrests were not made in all the blocks or all the months within the period and the number of poachers arrested per operation ranged from one to three (Table 9). The total number of animals found harvested was 69 individuals out of 12 assorted species, with an average off-take of 5.8 (N = 12, SD =19.6) animals per month. The Shannon index indicated that the diversity of the species affected by poaching was 1.9 (evenness = 0.77). The mean number of all animals found to have been harvested by the arrested poachers were 5.3 (N =13, SD = 7.3) per arrest while the mean number of primates killed per arrest was 1.1 (N =13, SD = 0.95).The ratio of primates hunted to all other animals was 1:4.9. The common primates found to have been hunted were Lowe's monkeys (eight), spot-nosed monkey (two), pottos (two) and olive colobus (one) (Table 9). The species and individuals of animals harvested at KCA by poachers were compared to Martin (1991) who found different species caught by inhabitants of Kwamebikrom, a forest village near Bia National Park, from May to August, 1978. It was indicated that 19 different species were affected by the killings with Shannon diversity index of 2.12 (evenness = 0.72). The diversity t test was conducted to evaluate the differences between the diversity of game catch of KCA and Kwamebikrom hunters. The result indicated no significant difference between them (t=0.72, p=0.47).

Table 9: Information on poachers arrested from November, 2009 to November, 2010 at KCA.

Month of arrest	Block	Poachers arrested	No. of animals killed	No. of primates killed	Method of hunting	Species identified killed by arrested poacher's
October, 2010	Aboabo	3	3	0	Shotgun	1 Maxwel's duiker, 2 Pangolins
July, 2010	Aboabo	1	29	0	Snare	2 Live tortoise, 27 rat
November, 2009	Abrafo	1	1	0	Shotgun	1 Maxwel's duiker
July, 2010	Adiembra	2	1	0	Shotgun	1 Elephant
March, 2010	Antwikwa	1	2	1	Shotgun	1 Maxwell's duiker, 1Lowe's monkey
December, 2009	Antwikwa	1	5	2	Shotgun	1Maxwel's duiker, 2 Lowe's monkey, 2 pangolin
May, 2010	Antwikwa	1	2	1	Shotgun	1Maxwel's duiker, 1spot nose
January, 2010	Brisco 2	1	4	3	Shotgun	1Maxwel's duiker, 1 Lowe's monkey, 2 spot nose,

Table 9 continued

May, 2010	Brisco 2	1	3	1	Shotgun	1Maxwel's duiker, 1Lowe's monkey, 1 Royal antelope
May, 2010	Brisco 2	2	5	1	Shotgun	2 Maxwel's duiker,1 Lowe's monkey, 1Royal antelope,
August, 2010	Brisco 2	1	5	2	Shotgun/ Snare	1flying squirrel, 2 Maxwell's duiker, 1Lowe's monkey, 1Olive colobus, 1live tortoise
July, 2010	Homaho	1	3	1	Shotgun	1Maxwel's duiker, 1Lowe's monkey, 1 Royal antelope
February, 2010	Kruwa	1	6	2	Snare	2Maxwel's duiker, 2tree squirrels, 2 potto
Total			69	14		

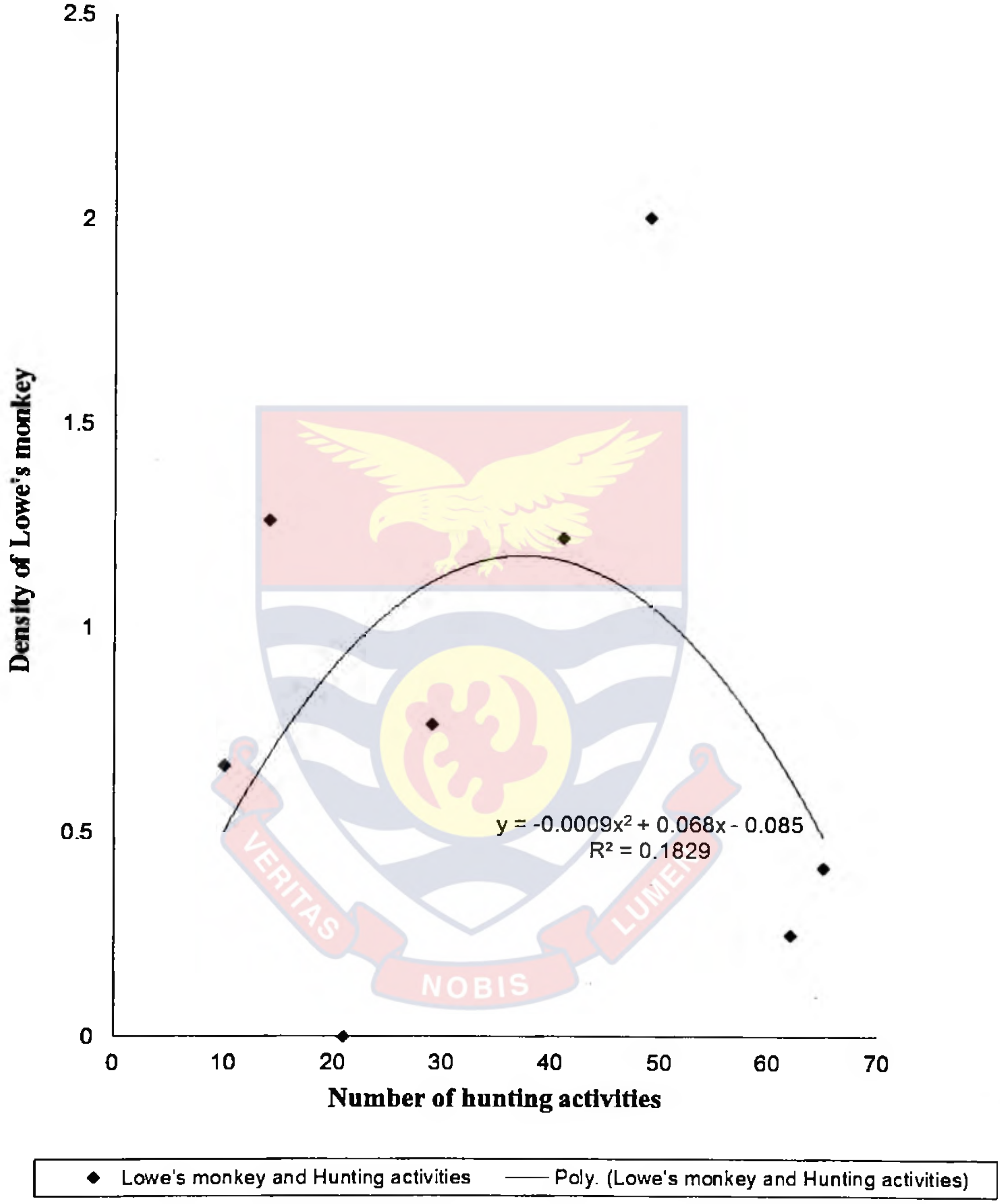

Figure 17: Relationship between the number of hunting activities and density of Lowe's monkey during the dry season.

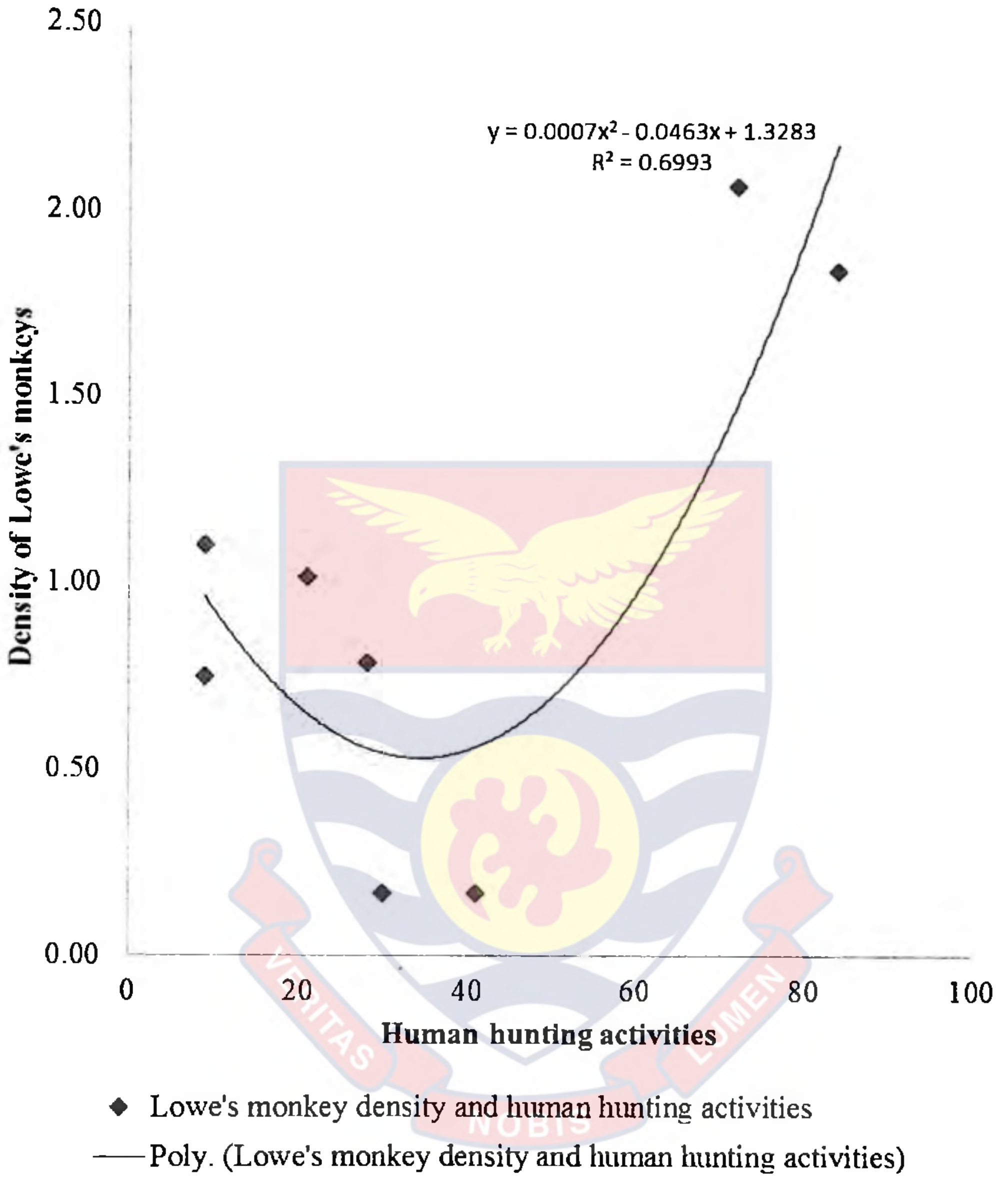

Figure 18: Relationship between the number of hunting activities and density of Lowe's monkey during the wet season.

Bird Community Assemblages and their Relationship with Lowe's Monkeys in the Forest

A total of 3,641 individual birds belonging to 31families were encountered in all the eight forest blocks of the conservation area. Abrafo forest block recorded 126 species, followed by Antwikwa (124), Afiaso (121), Aboabo (119), Adiembra (115), Homaho (114) and Kruwa (113). The differences in bird abundance in all eight blocks were not significant (Kruskal-Wallis test: H =13.04, $p = 0.08$). This supports the hypothesis that the densities of avian communities occurring in all forest block the same.

Regression analysis was conducted to establish relationship between the density of Lowe's monkey in both dry and wet seasons and bird densities occurring in the various blocks of the conservation area. The results indicated a polynomial relationship between the densities of Lowe's monkey and birds in both dry and wet seasons. In the dry season, there was a positive relationship between bird abundance and Lowe's monkey density accounting for about 52% ($y = 0.0716x^2 - 0.5108x + 1.5443$, $R^2=0.522$)and Spearman's rank correlation indicated no significant relationship ($\rho=0.06$, $p=0.89$).Similarly, during the wet season, the relationship between the densities of the two taxa was also positive ($y = 0.0497x^2 – 0.2593x + 0.891$, $R^2 = 0.559$) explaining about 56% of the relationship with no significant relationship ($\rho = 0.07$, $p = 0.88$).

Lowe's monkeys were observed to have been involved in mixed flock foraging birds in 60% of feeding observation records. Both monkeys and fruigivorous birds, insectivorous birds and raptors were discovered to visit trees with ripe fruits. The birds included yellow - billed Turaco (*Tauraco macrorhynchus*), Klaas's cuckoo (*Chrysococcyx klaas*), little bee-eater (*Merops pusillus*), African pied hornbill (*Tockus fasciatus*) and black-casqued hornbill (*Ceratogymna atrata*). There was no evidence of a raptor preying on Lowe's monkey, but on three occasions at Antwikwaa and Briscoe II, Lowe's monkeys were observed to have dismantled the nests of some unidentified birds probably looking for eggs. Two groups of Lowe's monkeys at Adiembra, Antwikwa and Briscoe II forest blocks and one group at Aboabo were always found in association (i.e., foraging together or within the same vicinity) with a group of black-casqued hornbills (*Ceratogymna atrata*).

The study could not confirm whether the birds and monkeys slept together on the same tree or just came together from different sleeping places. Furthermore, the study failed to confirm that the black-casqued hornbill group always contained the same individuals that moved with the same monkey group or any group of hornbills could meet any monkey group and follow them. However, it was conspicuously noted that the black-casqued hornbill would call loudly whenever they spotted the research team and immediately the activities of the Lowe's monkey would come to a halt and subsequently the monkeys take cover in the canopy. Whenever, the Lowe's monkey group stopped feeding the hornbills also stopped feeding.

Lowe's Monkey Food Trees

Table11 provides the details of the mean frequency of visits when 26 selected plants fruited during the study period. The fruiting period of most of the plants varied among species. Lowe's monkeys consumed 81 % of fruits and 19% of unripe fruits visited. The result of Kruskal-Wallis test indicated significant differences among various plants (H=16.52, *p*=0.02).

It was observed that Lowe's monkeys monitored their food plants from when they started bearing fruits till maturity according to the phenological pattern of the plant. For example, some banana (*Musa sapientum*) stands still growing at the former logging stations were frequently checked by the Lowe's monkeys to see whether the fruited ones had matured. They sometimes moved outside the protected area boundary to consume cultivated banana on farmlands. This is because banana has no regular fruiting pattern. On the other hand, the fruits of the majority of hog plum (*Spondias mombin*) trees ripened between 17th June to 15th July, 2010 and follow a regular pattern of fruiting once a year. When maize farms that were closer to the forest boundary matured the Lowe's monkeys plucked the cob, removed the cover and consumed the fresh grains. Maize consumption stopped when the grains matured toward dryness.

Table 10: Selected wild fruit trees observed to be fed on frequently by Lowe's monkeys

Scientific name	Parts consumed	Total number of times visited	Mean number of times visited	Standard Deviation
Parkia bicolor	RF	56	7.0	2.1
Chrisophyllum albidum	RF	48	5.8	0.5
Chrysophyllum pruniforme	RF	46	5.6	2.1
Trichilia monadelpha	RF	43	5.4	1.2
Celtis mildbraedii	RF	41	5.1	1.1
Carapa procera	RF	35	4.4	1.6
Pycnanthus angolensis	RF	35	4.4	0.9
Diospyros sanza-minika	RF	35	4.4	1.4
Buchholzia coriacea	RF	35	4.4	1.6
Cola gigantean	URF	35	4.4	1.4
Entandrophragma angolense	URF	33	4.1	1.6
Blighia sapida	RF	32	4.0	1.3
Ongokea gore	RF	30	3.8	0.5

Table 10(continued)

Scientific name	Parts consumed	Total number of times visited	Mean number of times visited	Standard Deviation
Panda oleosa	RF	29	3.6	0.7
Dacryodes klaineana	RF	29	3.6	1.2
Myrianthus arboreus	RF	24	3.0	1.1
Cola chlamydantha	RF	22	2.8	0.9
Bussea occidentalis	URF	16	2.0	0.8
Aningeria robusta	RF	15	1.9	1.1
Musanga cecropoides	RF	15	1.9	1.5
Zea mays	RF	62	7.8	2.2
Musa sapientum	RF	49	6.1	1.9
Ficus sur	RF	47	5.9	1.6
Ficus exasperata	RF	36	4.5	1.7
Elaeis guineensis	RF	27	3.4	1.1
Spondias mombin	RF	27	3.4	2.8

RF: ripe fruit

URF: unripe fruit

Nutrient Content of Lowe's Monkey Food

Table 11 provides the details of the means of three replicates of nutrient content of Hog plum, banana and maize being only three of the fruits observed to be consumed by the Lowe's monkey. Kruskal-Wallis test indicated no significant difference between the nutrient contents of the three fruits (H=0.17, *p*=0.92). The result of the proximate analysis of fruits of three food plants of Lowe's monkey indicated that the mean moisture contents of fresh samples of maize was 58% (SD=3.46, N=3), banana (68%) (SD=3.46, N=3) and hog plum (85.33%) (SD=1.15, N=3). Kruskal-Wallis test indicated significant differences among the moisture contents of the fresh samples of the three fruits (H=7.39, *p*=0.03).On dry matter basis the study showed that Hog plum contained moisture of 16.03% (SD=0.29), banana 14.0% (SD=0.17) and maize 8.0% (SD=0).Mann-Whitney test indicated a significant difference between moisture content of dried samples of maize and banana (U=1, *p*=0.033), maize and hog plum (U=1, *p*=0.03) and no difference between hog plum and banana (U=1, *p*=0.32).

Nitrogen-free extract (NFE), being an estimate of crude starch and sugar content of a feed, in the three fruits of Lowe's monkey were as follows: banana contained 75.43% (SD=0.38), maize 67.04% (SD=0.00) and hog plum 66.08% (SD=0.06). The differences in the NFE were significant (H=7.39, *p*=0.02) according to Kruskal-Wallis test.

Protein and fat were respectively higher in maize 11.13% (SD=0.04) and 10.00% (SD=1.10), relatively more than hog plum of 7.88 % (SD=0.01) and 5.01% (SD=0.00); and banana of 3.52 % (SD=0.02) and 1.05 % (SD=0.00).

Whereas ash was relatively higher in hog plum 4.00% (SD=0.01) than maize 2.00% (SD=0.01) and banana 2.00% (SD=0.00); fibre was higher in banana 4.00% (SD=0.17) than maize of 1.58% (SD=0.02) and hog plum of 1.02 % (SD=0.02). Table 11 presents the summary of the means of the result of proximate analysis of maize, banana and hog plum.

Table 11: Nutrient content of fruits of three food plants commonly consumed by Lowe's monkeys in KCA

Type of Nutrient	Maize (%)		Banana (%)		Hog plum (%)	
	Mean	SD	Mean	SD	Mean	SD
MOISTURE	8.00	0.00	14.00	0.17	16.03	0.29
ASH	2.00	0.10	2.00	0.00	4.01	0.01
FAT	10.00	0.10	1.05	0.00	5.01	0.00
PROTEIN	11.13	0.04	3.52	0.02	7.88	0.01
FIBRE	1.58	0.02	4.00	0.17	1.02	0.02
NFE	67.04	0.00	75.43	0.38	66.08	0.06

CHAPTER FIVE

DISCUSSION

Lowe's Monkey Habitat Structure and Species Composition

The structure of the forest vegetation in KCA conforms to the structure of a normal old-growth rainforest as stated by Ghazoul and Sheil (2001) that in almost every old-growth rain forest free of major external disturbances, small trees greatly outnumber large ones. The overall spatial pattern of tree stems in most rainforests differs little from random (Lieberman and Lieberman, 1994; Sheil and Ducey, 2002). However, the structure of the forest of Kakum could have resembled young re-growth forest as the last logging activities ended only about 20 years ago (1989) rendered it to lack large diameter trees for the total stem densities of relatively small diameter class to be higher. Therefore, the structure of this could be attributed to the fact that the logging operations were done through systematic selective exploitation. The loggers removed trees within 70cm diameter classes and above at reference height. The systematic selective exploitation was based on the preference by international and national buyer for certain species. It was only the best grade timber trees which were taken. The largest trees were first taken, going progressively down in size until the allowable yield was obtained. The stock was then distributed over each compartment of 65ha or 1.3 square km (Parren and de Graaf, 1995). The idea was that an even distribution would ensure sufficient seed regeneration and this might have favoured animals that depend on such trees for survival. Past logging operations have a great influence on the variations in structure and composition of the forest as indicated by Ghazoul and Sheil (2010) who stated that differences in forest structure occur at all scales both in the physical environment and in the biological communities. Densities of many canopy species were relatively unaffected by logging, and this could be largely due to the relatively moderate logging levels (i.e., one to two trees per hectare in western Ghana) (Holbech, 1996).

The vegetation classification used in this study (according to structural complexity) proved to be adequate for a general description of the overall status of the vegetation. After the logging operations during the last decades, the vegetation of the Kakum conservation area appeared as a mosaic of patches of variable structure. Repeated logging created frequent gaps. At the time this study was carried out, the frequency of occurrence of gaps was high, but not higher than in undisturbed forests where natural gaps constitute 9 % of the forest area (Schemske and Brokaw, 1981). What differed most from mature forest, was the high proportion of patches which were in an early phase of successional development of the forest. Patches where the foliage was more evenly distributed along a vertical profile only made up 24% of the surface. This clearly shows that the overall forest condition is critical. Hawthorne and Abu-Juam (1995) defined characteristics for the evaluation of Ghanaian forests based on the vegetation structure. According to their scale ranging from one to six (one - excellent, six – no significant forest left), the score two has to be assigned to the forest of Kakum Conservation Area.

With the 97 species belonging to 32 families, the most common families were Leguminosae, Meliaceae, Sterculiaceae, and Euphorbiaceae which contributed 13.2%, 9.3%, 8.2%, 7.2%, and 6.2% respectively to the species composition of the vegetation of the Lowe's monkey range. The remaining families contributed from 4.0% to 1.0% species to the ecosystem. This is a clear indication of the potential of the vegetation of the KCA to support Lowe's monkey as well as other wildlife that shared the same ecosystem in space and time. Moreover, this high diversity of trees provided food and shelter for the monkeys. There is therefore higher diversity in the phenology of the plants (Ewusie, 1992), which could imply that at any time there would be fruit available for the frugivorous monkeys.

Population of Lowe's Monkeys

Primate density estimates require that sighting distances are measured accurately, but this requirement is difficult to achieve in rainforest environments. In areas with thick undergrowth, this would require cutting access trails which is not only time consuming but also environmentally inappropriate. Furthermore, going off the transect line introduces other biases, such as seeing undetected groups from transect (Brugiere and Fleury, 2000). As a result, several studies that have attempted to estimate primate densities in tropical rainforest (Skorupa, 1986; Struhsaker 1997; Brugiere and Fleury, 2000; Chapman *et al.*, 2000) have relied on estimated distances. Inter-observer differences in ability to estimate distances can seriously affect density estimates (Mitani *et al.*, 2000).

Even with a single trained observer, as was the case in this study, uneven topography (Brugiere and Fleury, 2000) and differences in vegetation can introduce biases in distance estimates. Distribution of sighting distances differed among transects, suggesting that sighting distances were probably biased by topographic and vegetation attributes. For this reason, this study did not attempt to estimate densities using DISTANCE software since most of the assumptions were not met, but relied on kilometric index of abundance which is widely being used in France and has a precision of over 80 % when compared with DISTANCE density estimate (Groupe, 1991, Gatti, 2010).

Contrary to the findings of Oates (2006) and other previous surveys (Abedi-Lartey, 1999; Magnuson, 2003; Oates *et al*., 1996; Oates *et al*., 2000; Struhsaker and Oates, 1995; Struhsaker, 1993; Whitesides and Oates, 1995), the Lowe's monkey population in the Kakum Conservation Area was found to be relatively high. Comparing the present mean density of 1.03 (± 0.03) per km to the 1993 Lowe's monkey density of 0.31 (± 0.16) it could be deduced that the average population growth rate of 13.6 % per annum is quite encouraging. The population of Lowe's monkeys in the Kakum Conservation Area could probably be higher than the densities reported from census of other forest protected areas conducted during the same period in Ghana (Gatti, 2010). Contrary to Kakum Conservation Area, in Ankasa Resource Reserve, primate signs are concentrated around the core of the conservation area, where the Nkwanta camp is situated. The kilometric index of abundance (KIA) was the highest in a band going from this camp to the Ankasa Gate Camp. This is likely due to the intense activity of Wildlife Division staff and visitors to that area. However, in Kakum and Bia Conservation Areas (though at lower rates) primate signs are found scattered over the whole conservation area.

The average group size of 10.2 (SD = 5.2, mini. =1, max. = 23) could be said to be quite low as compared to primates of different species in other areas such as red Colobus in Kibale living in groups of between eight to 80 (Strusaker, 1997) and banded langurs (Johns, 1983). As stated by Struhsaker (1997) however, the problem of group spread and temporary fragmentation is potentially an important source of sample variance in estimating group densities. Moreover, intra-specific group size and social system can vary between forests of different management histories. Sometimes primate species in logged forests have fusion-fission groups and differences in foraging party size may also be recorded whilst hunting by people may also reduce group size as in Bia Conservation Area, Ghana (Martin and Asibey, 1979; Struhsaker, 1997).

The Influence of Forest Structure on the Density of Lowe's Monkey

The density of trees could not influence much of the density of Lowe's monkeys due to the heterogeneous nature of the forest. Neither the density of trees nor diversity of trees in the Kakum Conservation Area could influence the density of Lowe's monkeys. The difference of density of trees and density of Lowe's monkeys was found to be not significant and this rejected the hypothesis that the higher the number of trees per hectare the higher the number of Lowe's monkeys to be encountered. The tree density was found to influence 38.3% of the Lowe's monkey density which therefore suggests that the density of the Lowe's monkeys did not totally depend on the density of trees in an area. Similarly, diversity of trees was found to influence 16.7% of the densities of the Lowe's monkeys in the KCA. This can be compared to the responses of rainforest primates to selective logging in Kibale forest in Uganda. The conclusion was that selective timber harvesting can be compatible with primate conservation in particular and biological conservation in general (Skorupa, 1986). This is because selective logging target only certain selected species and primates are able to move from one tree stand to another. Skorupa (1986) further suggested that the capital-intensive, mechanized selective logging that is destroying 50 % of the pre-logging forest stand in Kibale seriously compromises the primate conservation value. Furthermore, in their studies of tree-fall dynamics in Kibale National Forest in Uganda, Skorupa and Kasenene (1984) reported that primate conservation would be possible and compatible with logging in forests if the levels of damage are strictly limited.

The differences of density of Lowe's monkeys occurring at all the forest blocks were not significant as $p>0.05$. This was inconsistent with Struhsaker's (1997) report that differences in primate densities exist even between similar forest types. He further elaborated that the primate community within the same gross type of undisturbed and matured forest of Kibale can vary appreciably over distances as short as 10 km. For instance, the density of black and white Colobus monkeys varied nearly tenfold between areas separated by no more than 1 km and within the same broad forest type (Struhsaker, 1978) but the variations might be related to availability of nutrients in swamp vegetation and soils that are apparently critical to the diet of black and white colobus (Oates, 1974). Since the tree densities of various forest blocks does not vary with the densities of Lowe's monkeys, it follows that the conditions occurring at various sites necessary to determine the densities of the Lowe's monkey could be similar.

Effect of Seasonal Changes on Density, Group Size and Distribution of Lowe's Monkey in Rainforest Ecosystem

Seasonal fluctuations were found to have no influence on the Lowe's monkey population densities as the difference of densities between the two seasons was not significant ($p > 0.05$). The variation in the weather conditions during dry and wet periods at the rainforest ecosystem was not significant enough to seriously affect the Lowe's monkey population. This was supported by Janson and Chapman (1999) who stated that of all the descriptions about the tropical forests, the most enduring is that they lack definite seasonal variations. Though the difference in density was not significant statistically, the density variations observed in Figure 9 show some difference in densities occurring in the two seasons. This may be due to some detection errors that may arise as a result of the changes in visibility due to plant phenology. Moreover, it drizzles more frequently during the wet season than the dry season with foggy weather during the period. It was observed that the Lowe's monkey would never move from their place of hiding even with the little showers. The result of the study revealed density variations within the same site and seasons, Briscoe II, Adiembra, Homaho, Abrafo and Antwikwa blocks recorded higher densities of Lowe's monkey in the dry season than the wet season, whereas Kruwa, Afeaso and Aboabo recorded higher densities in wet season. This was supported by Cowlishaw and Dunbar (2000) who reported that differences in abundance can occur even at the same site, owing to variation in local habitat type, season, time of the day and weather conditions. In addition, most primates feel reluctant to move out of their hiding places even with the slightest rain as suggested by Cowlishaw and Dunbar (2000). Therefore, the tendency of Lowe's monkey numbers to be lower in the wet season than the dry season is very high but few hours after rains the monkeys resume their normal activities.

Furthermore, some evidence that the timing of births in seasonally-reproducing species may be related to the availability of food resources in seasonal habitats (Cowlishaw and Dunbar, 2000), would have suggested a wide variation in density. However, food availability through out the year and the dependence of Lowe's monkeys to so many food plants for survival may explain why the difference in density between seasons was not significant. The study found a lot of variations in the group sizes encountered at different blocks and also at different seasons. It was observed that the distribution of the Lowe's monkey did not follow any particular pattern at all sites and this indicates that the distribution is random (Figure 13), and that no particular resource can be assumed to be responsible for the distribution of the species. Tutin and White (1998) stated that the extent of the short and long term impact of climate change on primates in the tropics will depend on factors such as their mobility and dietary flexibility. However, since Lowe's monkeys can survive by shifting to other diets or supplement their diet with other food components, they are likely to survive in different habitat types. The occurrence of Lowe's monkeys and their random distribution throughout its range was supported by Struhsaker (1997), who concluded that *Cercopithecus campbelli lowei* and *Cercopithecus petaurista petaurista* were known to be most abundant in secondary bush throughout their range. On the contrary, a study on impact of logging on primates concluded that in the Bia Conservation Area, four diurnal species of primates were reduced in social groups in logged forest area (Martin and Asibey, 1979). Similarly, a primate study at Tiwai of Sierra Leone comparing old forest (>20 years old) with young secondary forest (<20years old) that developed after farming, it was found that *Cercopithecus campbelli*, *Cercopithecus petaurista* and *Cercopithecus atys* selectively used secondary forest more than the old growth forest (Oates, 1999).

Effect of Conservation Intervention of Lowe's Monkey in KCA

In 1993, Conservation International sponsored a 32-day survey in Kakum Conservation Area and other areas in Bia Conservation Area and Nini-Suhien National Park in the months of March, April, August, and November Oates *et al.*, 2000). The detailed result presented in Table 5 was compared with the present study result in (Table 4). Though the main focus of the 1993 survey was on Miss Waldron's red colobus (*Procolobus badius waldroni*), Roloway monkey (*Cercopithecus diana roloway*), and white-naped mangabey (*Cercocerbus atys lunulatus*) which they could not find in Kakum, they reported on other primates species including Lowe's monkey. The average density of Lowe's monkeys in Kakum Conservation Area was 0.31 (SD=0.16) as at 1993 (Oates *et al.*, 2000) representing the early days of the conservation of wildlife in the conservation area, after several years of logging. Comparing with the present (2010) average density, the population growth is 232 % over 17years at an average rate of 13.6% per annum. Moreover, a similar primate population study conducted in two wildlife reserves and two forest reserves indicated the following kilometric indices of abundances:

Ankara (0.0427), Bia (0.0092) Cape Three Points Forest Reserve (0.0598) and Krokosua Hills forest reserve (0.0290) (Gatti, 2010).

Comparison of Primate Community Structure in KCA to other African Forest Areas

Primate community structure in Kakum Conservation Area has been consistent since the early 1990s when the management of the park was converted from timber production to wildlife conservation. Comparing the number of species in the structure to other primate ranges in Africa, it could be deduced that the number of species encountered at Kakum was too small. For instance, Tai National Park in Côte d'Ivoire and Tiwai in Sierra Leone recorded 11 species (Chapman *et al*., 1999). Though Douala-Edea forest (Cameroon) and Salonga forest (Democratic Republic of Congo) lack a terrestrial cercopithecine (i.e., species of cercopithecine that spend more time on forest floor than on tree tops) similar to Kakum Conservation Area, the number of species were 14 and nine (Chapman *et al*., 1999) respectively. These were both higher than six found in Kakum Conservation Area. However, many primate communities show considerable variations in their number of species. For example, 17 species were found in Makokou forest (Gabon) and Ituri forest (Democratic Republic of Congo), 15 at Lope forest in Gabon, 11-13 and eight at Kibale and Budongo forests in Uganda. The numbers in these communities were distributed across the various eco-taxonomic categories. For example, communities in western-central Africa (Cameroon and Gabon) are relatively much richer in nocturnal prosimians (pottos and galagos) than other areas. Communities in central Africa (Cameroon to the Democratic Republic of Congo) are relatively rich in arboreal cercopithecines whilst West Africa (Sierra Leone and Côte d'Ivoire) was found to be richer in colobines (Chapman *et al.*, 1999) and Kakum recorded two prosimians, two arboreal cercopithecines and two colobines with neither terrestrial cercopithecines nor apes. The reasons for the production of these patterns of variation in forest primate community structure could be the ecological variations occurring at different areas. Vegetation structure may play a significant role in producing the high species-richness at Ituri and Makokou (Gabon) as argued by Oates *et al.* (1990) that habitat heterogeneity tends to increase both the species richness and biomass of primate communities.

The moist and wet forests of tropical Africa have been greatly affected by climatic vicissitudes of the last few million years. During the arid phases of the glacial cycle which began in the Pliocene, these forests would have greatly contracted, becoming restricted to distinct 'refuges'. During interglacial warming, the area of moist forest would have expanded and between peaks and troughs of the cycle, climate has changed erratically so that forest vegetation rarely would have been stable for long periods. Such a pattern of environmental change might have led to a variety of evolutionary forces operating on primates living in African forests. Such historical events and adaptive features of these kinds would have played major roles in producing the patterns of variation seen in present day primate communities (Chapman *et al.*, 1999). The effect of historical events on the primate community in Kakum Conservation Area could be attributed to the its past management history. As logging was in progress, hunting was also in progress and unrestricted because the later was used as incentives for tree spotters (Mensah-Ntiamoah, 1989).

Interactions of Lowe's Monkeys with other Vertebrates

The relationship between Lowe's monkeys and other vertebrates could be classified into four categories as (i) interspecific associations with other monkeys and other mammals, (ii) intraspecific association with other group members of the same species, (iii) predation and (iv) commensalism. Kakum Lowe's monkeys were observed in all the forest blocks associated with spot-nosed monkeys. This observation was similar to Bourliere *et al.* (1970) who also observed a mixed troop of Lowe's and spot-nosed monkeys spending the night in a tall tree in the forest gallery along the river Bandama (Côte d'Ivoire) in 1967. They further observed in the Tai forest in Côte d'Ivoire that Lowe's monkeys were associated with black colobus (*Colobus polykomos*) and red colobus (*Colobus badius*) as was observed in this study at Abrafo and Briscoe II forest blocks of the Kakum Conservation Area.

At Kakum conservation area, when Lowe's monkeys encountered other groups of the same species individuals interact with them first, and either they mixed up and move together or each group disperse again. This is because the relationship between groups overlap and competition in resource utilization is one of the most intractable issues in community ecology. It indicates either strong or weak competition, and large overlap may exist despite substantial competition between species. This may be attributed to the shared resources being abundant or other factors such as predation to reduce populations before competition can act (Tokeshi, 1999).

Commensalism behaviour can be said to occur between the Lowe's monkeys and duikers as was observed in all the forest blocks of Kakum Conservation Area. As the monkeys fed from one tree to another, the duikers followed them and made use of the fruit drops from the arboreal species. In Ivory Coast, Bourliere *et al.* (1970) recorded a commensal association between Lowe's monkeys and white-crested hornbill (*Tropicranus albocristatus*) and suggested that the hornbills follow the monkeys in order to catch the air borne insects disturbed by the monkeys.

The main predators of Lowe's monkeys were human beings who always used several methods and strategies to reduce or eradicate the monkey populations. Other predators include raptors and carnivorous mammals which occur in small densities. Birds are the most diverse and conspicuous components of the tree canopy vertebrate community, playing roles like pollination, seed dispersal, seed predation, animal predation and herbivory. Examination of the relationship between density of Lowe's monkey and abundance of birds showed that the positive relationship was not significant. This may mean that as bird numbers increased, Lowe's monkey number also increased. It could be concluded that the birds have evolved to live harmoniously with Lowe's monkeys as manifested in the observation of the formation of feeding guilds.

Activity Patterns of Lowe's Monkey in KCA

Major activities of Lowe's monkeys at KCA could be loosely categorized as foraging, feeding, meeting, playing and grooming. Light and rain were found to be two components of the weather which tended to influence the Lowe's monkey activities during the day. The waking-up time depended on the time of appearance of the first light of the day, which on average was 6.15 GMT (SD=30mins, N=30). Movement, foraging and feeding followed just after the adult male has emitted a loud call either to signal the beginning of the day or to protect their territory. The movement was found to be associated with the manipulation of the substrate in search of food (i.e., foraging) and when plenty of food (edible fruit) is discovered the individual will call the rest of the group to feed. Similarly, when an edible insect is encountered, the Lowe's monkey will grab it with its palm together with the leaves and carefully remove it for consumption (Plate 2). This was similar to observations made in Côte d'Ivoire by Bourliere *et al.* (1970), who reported that insect hunting was selective as certain species were discarded or ignored. For example, winged individuals of driver ants (Dorylinae), Stink-bugs (Pentatomidae), Danaid butterfly (Danaidae) and millipedes (*Spirobolus sp*) were never touched by the Lowe's monkey. This is because all these arthropods have either repulsive odours and secretions or powerful mandibles.

Simultaneous movement, foraging and feeding were the major activities carried out throughout the day. Movement includes leaping from one tree to another. The type of leap depended on whether movement was to a particular tree or to escape predation. In Côte d'Ivoire, Bourliere *et al.* (1970) also identified three types of leaps as aimed leap, free fall and sideway leap.

Illegal Wildlife Use and Lowe's Monkey Conservation

Over-hunting of tropical forest vertebrates is now a rampant, nearly universal phenomenon (Robinson and Bennett, 2000), rendering primates particularly susceptible to widespread and profound shifts in population and community structure (Peres, 1999b). This is no different in Ghana where poaching is common inside wildlife reserves, which are ostensibly under permanent guard, is the most serious threat to biodiversity. Hunting and sale of bushmeat are controlled by legislation but there is wide disregard for the laws which are largely not enforced.

Both subsistence and commercial hunting occur in the conservation area. Subsistence hunting is practiced by the local people living around the reserves, who are mainly farmers who hunt as a hobby in the farms and short distances inside the wildlife reserve. Such hunters normally erect the temporary hunting camps (Plate 6). Hill *et al.* (1997) also found that the probability of encountering hunters or signs of their presence in the Mbaracayu Reserve in Paraguay declined with increasing distance from the access point. Subsistence hunting is normally practised during the night and late in the afternoons, after the farmers had finished working on their farms (Mensah-Ntiamoah, 1989). A large part of the animals killed is consumed by hunters' families, with the rest being sold to local people to defray the cost of ammunition used. Commercial hunting is practised by hunters from big towns which are often very far from the reserve. The hunters normally build relatively-permanent hunting camps (Plate 7) inside the reserve and spend two to three months on one expedition. Their target species were mostly medium-sized mammals like red river hog, bush buck, duikers and monkeys. Hunting of primates may not be for personal consumption alone but for sale at market outlets which provide a direct source of income and play an important role in determining hunting pressure (Cowlishaw and Dunbar, 2000).

At Kakum Conservation Area, as in Ivory Coast, the major predators of Lowe's monkey have been identified as humans and all monkeys are considered a delicacy by the villagers who actively hunt them all-year-round, and this may explain why there was no significant difference in incidence of hunting indicators in dry and wet seasons. A few other vertebrates may occasionally kill infant and juvenile monkeys (Bourliere *et al.*, 1970).

The hunting methods identified were mainly the use of firearms, mainly shotguns and wire snares as also reported by Freese *et al.* (1982), who stated that the spread of firearms has further accentuated the trend of hunting of monkeys in the forest. Comparing primate densities in 14 Peruvian and Bolivian sites, Freese *et al.* (1982) showed that hunting significantly reduced the average densities of black-capped squirrel monkey (*Saimiri boliviensis*) below the densities found in protected areas. On the contrary, the small callitrichids show no evidence of having depressed densities in unprotected areas because of less hunting pressure on them.

According to Bourliere (1985), the present day populations of monkeys have been so much affected by human activities that they cannot be considered as representative of those existing even a century ago. This is because monkeys have been hunted for food by most forest hunter-gathers down the ages, both in the paleo-tropics and in the neo-tropics. Moreover, hunting canopy species in logged areas is much easier because visibility in higher strata is facilitated (Holbech, 1996).

Animals Normally Hunted and Implications for Conservation of Lowe's Monkeys

A variety of methods have been found to be used to slaughter wild animals depending on many factors such as characteristics and behaviour of the species, habitat requirements of the species, traditional background of the hunters as well as the security of the hunting locality.

During the 12-month period, poachers were arrested mostly in the months of July (three arrests at Aboabo, Adiembra and Homaho) and May (two arrests at Antwikwa and Briscoe II). As the area is protected against hunting, this suggests that illegal hunting is a clandestine activity, as a large number of people hunting could create disturbances. According to a former poacher, a hunting team of more than three people is likely to attract wildlife officers who would cause an arrest. Moreover, some of the hunters in group may hide themselves and sneak to inform the family members at home about the arrest.

The number of animals found killed within the 12 month period was 69 at an average monthly off-take of 5.8 (N =12, SD =19.6) animals. This is below the estimate of Martin (1991) that 50 animals were killed each month in Kwamebikrom near Bia National Park, even this estimate included hunters operating outside the protected area where fear of arrest was less. The number of hunters involved was also not known in Martin (1991).

The species of animals found to have been killed by poachers in KCA did not vary much from Martin (1991), even though no reptiles were recorded at KCA within the period. The difference between the diversity of game of the hunters of KCA and that of Kwamebikrom was not significant ($p>0.05$). This might be due to the similarities in the approaches to hunting by the hunters of the rainforest in Ghana. The ratio of primates hunted to other animals in KCA was 1:4.9, meaning that for approximately every five wild animals killed by poachers one is probably a primate. Among the primates killed, the highest number was the Lowe's monkey. Conversely, Martin (1991) found that for approximately every three animals killed at Kwamebikrom, one was a primate (ratio of 2.7:1). Similar to KCA, Lowe's monkeys were found to be the most hunted species (Martin, 1991). This indicates that Lowe's monkey meat is preferred by rainforest hunters in Ghana and this has a devastating effect on their populations.

The major hunting equipment used by the arrested poachers in KCA were shotguns and wire snare. This was similar to the results of Infield (1988) who examined the hunting habits of hunters in Korup National Park area in Cameroon and found that 38% of the hunters used shotguns while the remainder depended on trapping for their catch. The use of a shotgun is very effective and efficient, especially for arboreal species (e.g., monkeys) which are sometimes located higher than 50 m on some emergent tree layers (Cowlishaw and Dunbar, 2000). Shotguns could be the preferred hunting equipment by ecologists because it is selective, but an illegal hunter may not use it because it makes a lot of noise which may result in arrests by wildlife guards. To avoid being arrested, hunters of KCA sometimes depended on the use of wire snares, which are silent and non-selective. The choice of hunting method depends on the security situation at the place of hunting and the target species. At Korup National Park the choice was based on the season of the year, as thousands of traps could be laid during the wet season (Infield, 1988).

Nutritional Characteristics of the Diet of Lowe's Monkey

Primates are notably consumers of plants and to a lesser extent animal materials. At the ecosystem level, they also exert a very important feedback control on the vegetation itself and are essential for maintenance of homeostasis of the forest ecosystem (Bourliere, 1985). Lowe's monkeys at Kakum were observed to have visited fruiting trees whenever those plants bore fruits. Irrespective of the locations of these trees (i.e., both inside and peripheries of the protected area) the monkeys managed to feed on the fruits. The Kruskal-Wallis test of nutrient contents of fruits of three food plants consumed by Lowe's monkey indicated no statistical difference between them, suggesting that nutrient contents of these three species may be the same. According to Booth (1956) who examined the stomach contents of a few wild specimens, Lowe's guenons are almost entirely frugivorous. Curtin (2002) also found that the greater part of *Cercopithecus diana roloway's* food is made up of fruits (31%). The pulp of mature fruits was found to be the most important food category in both dry and wet seasons. This was consistent with Bourliere (1985) that forest monkeys consumed the fleshy part of the fruit rather than the harder stones except the *Chiropotes* spp. This fruit eating habit should not suggest that Lowe's monkeys are exclusively frugivorous because Bourliere *et al.* (1970) found in Côte d'Ivoire that Lowe's monkeys eat many flowers, leaves as well as insects, though fruits form greater part of plants observed to have been consumed.

In examining resources and primate community structure, Janson and Chapman (1999) suggested that because fruit pulp serves the apparent evolutionary purpose of attracting seed dispersers, it generally presents far fewer problems for primates to find and the pulp is easier to ingest and digest than the leaves. However, plants also have been selected to provide fruits that cause dispersers to leave the tree, otherwise dispersal would not be effected (Herrera, 1981). Janzen (1983) suggested that one mechanism to guarantee that dispersers eventually leave a tree crown is to make the fruit pulp an unbalanced diet (i.e., it will not contain all the nutrients required by the animal).

The results of proximate analysis of hog plum, banana and maize (Table12) indicated that all the fruit pulps consumed by the Lowe's monkey were high in sugars but low in lipids (fats) and proteins. Although some fruits may be high in a particular mineral, Janson and Chapman (1999) stated that, it seems unlikely that primates would actively seek out such fruits as there is little evidence for taste receptors for minerals other than sodium (Hladik and Simmen, 1997; O'Brien *et al.*, 1998). Because of the nutritional deficiencies of fruits as a diet, every predominantly fruit-eating primate must complement its diet with either insects or leaves or both (Janson and Chapman (1999).

Cowlishaw and Dunbar (2000) stated that even though most primates are vegetarians, most eat small amounts of animal matter, which is highly nutritious and contains vitamin B12 which primates cannot synthesize or obtain from non-animal sources. Curtin (2002) found out that the *Cercopithecus diana roloway* spent more time on *Piptadeniastrum africanum* feeding primarily on small immobile insects in the terminal branches; since insect foraging sessions may last more than one hour, and on the same day monkeys may move from one *Piptadeniastrum africanum* to another throughout the day. Bourliere *et al*. (1970) concluded that though the staple food of Lowe's monkeys is predominantly fruits or vegetables, insects constitute an important part of their diet, probably providing the monkeys with the amino acids essential for growth and reproduction.

Moisture content of nutrients were high in all the three fruits examined in the laboratory (Table 11), which suggests that Lowe's monkeys obtain a lot of water from their food. This was supported by Bourliere *et al*. (1970) who observed that Lowe's monkeys seem to drink only sparingly and infrequently and concluded that they obtain sufficient water from their food. This explains why arboreal drinking patterns have been classified as follows: (i) after a shower the monkeys often lick the under part of branches where drops have collected; (ii) monkeys visit certain tree holes where rain water has accumulated, dip in one or the other hand and lick them dry (Bourliere *et al*.,1970).

Furthermore, fruit eating primates have other problems. Firstly, fruits are often chemically defended against insects or mammalian herbivores before the pulp and seed mature, and some continue to be defended even when the pulp is ripe. Secondly, plants have evolved a variety of ways to restrict dispersal of their fruits to a fraction of all of the potential fruit-eating animals in the forest. This include (i) particular fruit presentations (Denslow and Moermond, 1982), (ii) morphologies

(Janson, 1998), (iii) ripening schedules (McKey, 1975) and/or (iv) taste of defensive chemicals (Janzen, 1974). This may explain why Lowe's monkeys use only a fraction of fruit species in the forest, as they are confronted with combination of fruit size, protection, taste, toxicity, inaccessibility, or slow ripening rate. The fruit-eating primates therefore, have to solve the challenge of locating ripe fruit crops that are often sparsely distributed in the tropical forest both in space and time. Moreover, searching for rare fruit trees is likely to be insufficient because detection distances for fruit crops are probably short. Instead, many primates tend to remember the locations of fruit crops over periods of days or weeks, returning at relatively predictable intervals to the same tree crown and moving in relatively straight lines from one resource to the next (Garber, 1989; Janson, 1998). Janson (1998) concluded that spatial memory can increase foraging efficiency up to 300 % relative to random searching. Lowe's guenons in the Kakum Conservation Area invest a lot of energy in jumping from one tree to another. These primates need to develop a strategy each time they wish in reaching the fruits which are held several meters above and or associated insects (personal observation).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

From the result of the study it could be concluded that the habitat of Lowe's monkeys is made up of high diverse species of tree composition with diverse dimensional classes. Trees with short height and sizes outnumber the trees with tall heights and large size, which follows the normal structure of a typical healthy rainforest. In other words, the number of trees reduces with increasing height and size (like an invented 'J' shape) which indicates the good health of the forest. The structure of the forest can be classified as the nature of a forest under natural regeneration 20 years after logging. The logging was selective and the target was on few trees classified as 'economic trees' at that time. Trees that were not economic at the time are still growing in the reserve hence a relatively large number of emergent layer trees were enumerated. Today, logging of economic trees is not allowed in the conservation area and they continue to contribute to the food production of the Lowe's monkey; examples are *Aningeria robusta*, *Chrysophyllum albidum*, *Parkia bicolor* etc.

The density of the Lowe's monkeys in the various forest blocks did not differ significantly in both dry and wet seasons, indicating that seasonality has little or no effect on the densities of the Lowe's monkey. The major effect of the seasonality could be on the vegetation but the Lowe's monkey has, by nature, the ability to switch from one food to another. Therefore, the seasonality may not have lethal effects on individual members of a group since the seasonal impact is not so harsh. However, the densities of Lowe's monkeys differed from one forest block to another which suggests that there are some variations in local conditions at various blocks, probably as a result of different officers conducting the protection operations.

Neither mammal nor bird density and diversity were identified to influence the density of the Lowe's monkeys in the Kakum Conservation Area. It could be deduced that by specialization, many animals can coexist in the same forest, because of the large variety of food available. Time and space partitioning has been a typical phenomenon for distribution of animals in the rainforest. Ultimately, the Lowe's monkeys have evolved to coexist with other taxa within the conservation area and their numbers have been limited by the amount of food available.

The population of Lowe's monkeys has changed from an average encounter rate of 0.31 (SD=0.16) in 1993 when the conservation area was formally gazzeted, to 1.03 (SD=0.03) in 2010. This has increased at an average annual rate of 13.6 % over 17 years. This can be attributed to the consistency of the protection measures operating at the conservation area. Moreover, since the past logging activities were purely selective, there was little impact on the food trees of a forest generalist like the Lowe's monkey.

The Lowe's monkeys were found to be randomly distributed in all the forest blocks suggesting that their habitat resources were also randomly distributed. The numbers in a group also ranged from one to 26 also suggesting that some of the groups were isolated males and others occasionally formed fusion-fission groups. The number of groups in wet season was 35 whilst the number of groups in the dry season was 41. This may be because Lowe's monkeys did not appear to move even with little rain showers. Since the social structure allows only one dominant male in a group, the growing males mostly disperse out of the group to initiate their own groups.

The primate community structure was different from other communities in African rainforests such us Tai National Park. The number of species in the community was also lower than all other communities in Africa. This might be attributed to the vegetation homogeneity that occurs in Kakum Conservation Area as opposed to other areas like Tai National Park where different kinds of vegetation could be found.

The frequency of hunting activities fluctuated from one area to another in the park and also changed according to the season of the year. The major hunting methods identified were the use of shot gun and cable snares. Two types of hunting were identified as commercial and subsistence and these erect permanent and temporary hunting camps respectively. Indicators of hunting activities include carbide powder, empty cartridges, firearms and footprints, gunshots heard, poachers arrested, poachers escaped, sapling cutting and snares found. As rainforest primates have evolved to withstand hunting pressure, they often sleep in the thickets of the canopy to prevent detection by hunters. Primates constitute a major mammal species commonly encountered in the field and they normally congregate at particular sites for foraging and other routine activities while the hunters in the area take advantage of this behaviour and hunt them.

Primates in general and Lowe's monkeys in particular, were found to feature prominently in the catches of the hunters in KCA, one being present for every five animals hunted. The choice of hunting method was found to depend on the security situation and the animals to be hunted.

The variations in the nutrient contents of fruits of Lowe's monkeys were found to be statistically not significant. The proximate analysis of the three fruits of Lowe's monkey showed that the fruits were rich in carbohydrate and moisture more than protein, fat and fibre (Table 11) and would therefore need to supplement the diet with insects which contains high protein and fat contents. This may explain why the Lowe's monkeys depend on other food items such as insects and leaves etc. as supplement to balance the deficiency in the fruits. It may also be taken as an adaptation to withstand lean seasons when particular fruits become scarce in the ecosystem.

Since Lowe's monkeys can thrive well in both closed and open habitat types, this species is presumed to occur in most forest reserves. This has resulted in less attention being paid to the species, which has still been categorized as Least Concern by the International Conservation Union (IUCN). This 'generalistic' attitude has also exposed the species to a lot of predation especially hunting outside the protected areas.

Recommendations

Based on the results certain recommendations have been made to forest authorities, the managers of the conservation area and researchers.

Recommendations to the Forestry Commission, Ghana

Since management focus shifted from timber logging to conservation of biodiversity, the area has witnessed an increase population of Lowe's monkeys. Therefore, many other forest reserves which have been logged and undergoing convalescence could be protected to conserve wildlife species in general and Lowe's monkey in particular.

Moreover, conservation of animal species could even be incorporated in the timber harvesting operations in the timber production forest reserves, so that active hunting in these forest reserves could be reduced to minimum or be regulated. This could be done by enforcing wildlife laws in the forest reserves.

Incentives or an award system could be introduced to award wildlife staff in the protected area to encourage them to continue to reduce the rate of hunting activities in the wildlife reserves.

Since the Lowe's monkey appears not to be vulnerable to habitat modification, it will appear that their population can be maintained all the time. However, the population cannot withstand hunting and bushmeat consumption which is rampant and also non-selective of species in Ghana. Therefore the status of the Lowe's monkey should be reassessed nationwide to help formulate comprehensive conservation measures to maintain their populations.

Recommendations to the Park Management

Home ranges of all the groups of Lowe's monkey in the Kakum Conservation Area must be mapped and marked on the ground. This is necessary for the regular monitoring of the groups, particularly group size and behaviour. Special attention must be paid to the protection of the populations of Lowe's monkeys in all areas of the park. Satellite protection camps could be mounted at some strategic areas of the park to facilitate the protection of the species.

Primate watching tours could be incorporated in the park's tourism activities to promote the importance of the primates to the general public. Since the monkeys have evolved to live with hunting and other human disturbances, group habituation would be a difficult task but possible with time.

Moreover, farmers working around the conservation area should be involved in the conservation of the Lowe's monkeys. They should be educated to develop enough interest in the monkeys so that their hunting would be reduced or ceased. Sometimes, these monkeys are hunted because of crop raiding activities, so an environmental services scheme could be adopted where farmers who forfeit their farms because of crop raiding monkeys are compensated.

Recommendation to Researchers

Lowe's monkey is one of the least researched primates. This might be due to the erroneous impression created by the IUCN categorization as "Least Concern" and their occurrence in all habitat types. Future research should therefore, investigate home range sizes, ranging behaviour, hierarchism and territorialism.

Data on breeding periods, reproduction rates and infant survival are vital for in-situ conservation of the species.

Populations of Lowe's monkey and other primates in forest reserves sharing common boundaries with the Kakum Conservation Area (such as Pra-Suhien, Bimpong and Adjousu Forest Reserves to the west, north and east respectively of the conservation area) should be studied. These reserves are still experiencing logging operation and it will be worth comparing data from these areas to show the effects on the species in KCA had the logging continued. The perception of the inhabitants of the fringe communities around the KCA on Lowe's monkey conservation is unknown and research in this field is also recommended.

Another area worth researching into is the genetic variability among the different groups in all the blocks in the conservation area. This is necessary for the species to withstand any outbreaks of epidemic and to save the population from collapse.

Research is also required to investigate the success of captive breeding and reproductive success which is critical to the maintenance, increase and productivity of every wildlife population. Monitoring of reproductive success is thus an important management function. This is required to monitor Lowe's monkey population, and to embark on successful reintroduction of the Lowe's monkeys into wild areas they used to occupy.

Further laboratory analysis should be conducted to ascertain the chemical contents of Lowe's monkey fruits to determine the levels of anti-nutritional chemicals secreted by the plant. This would help explain the reasons why the monkeys eat the fruits at certain stages and not another.

A nationwide survey should be embarked upon to map the forest reserves which still contain some individuals of Lowe's monkeys. The conservation status should either be changed or the species must be promoted as an icon species so as to gain the attention of policymakers as well as animal lovers in general.

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Appendix A: Pictures of Lowe's monkeys (*Cercopithecus campbelli lowei*)

Appendix B: Diversity indices of mammals encountered in the various forest block during the 2009-2010 survey in Kakum conservation area during the dry season

	Antwikwa	Abrafo	Afeaso	Kruwa	Briscoe II	Aboabo	Homaho	Adiembra
No. of Species	13	9	10	14	11	12	12	11
Individuals	102	105	137	214	376	86	103	227
Dominance	0.1638	0.3451	0.1786	0.23	0.3497	0.2006	0.2129	0.2775
Shannon index	2.105	1.549	1.92	1.959	1.478	1.955	1.86	1.738
Simpson index	0.8362	0.6549	0.8214	0.77	0.6503	0.7994	0.7871	0.7225
Menhinick	1.287	0.8783	0.8544	0.957	0.5673	1.294	1.182	0.7301
Margalef	2.595	1.719	1.829	2.423	1.686	2.469	2.373	1.843
Equitability	0.8206	0.7052	0.8337	0.7424	0.6166	0.7868	0.7485	0.7246
Fisher alpha	3.953	2.357	2.482	3.357	2.122	3.792	3.519	2.416
Berger-Parker	0.3137	0.5619	0.2628	0.4346	0.5505	0.3721	0.3592	0.489

Appendix C: Diversity indices of mammals encountered in the various forest blocks during the 2009-2010 survey in Kakum conservation area during the wet season

	Antwikwa	Abrafo	Afeaso	Kruwa	Briscoe II	Aboabo	Homaho	Adiembra
No. of Species	13	9	12	16	11	10	9	8
Individuals	104	100	153	236	270	109	146	136
Dominance	0.1722	0.271	0.2212	0.2368	0.3477	0.2757	0.2156	0.3712
Shannon index	2.138	1.669	1.833	1.882	1.493	1.731	1.794	1.428
Simpson index	0.8278	0.729	0.7788	0.7632	0.6523	0.7243	0.7844	0.6288
Menhinick	1.275	0.9	0.9701	1.042	0.6694	0.9578	0.7448	0.686
Margalef	2.584	1.737	2.187	2.745	1.786	1.918	1.605	1.425
Equitability	0.8334	0.7595	0.7375	0.6788	0.6226	0.7517	0.8164	0.6869
Fisher alpha	3.922	2.397	3.049	3.879	2.305	2.681	2.119	1.857
Berger-Parker	0.3558	0.46	0.3791	0.4237	0.5519	0.4862	0.3699	0.5809

Appendix D: Checklist of mammalian species encountered on the same transects where the Lowe's monkeys were encountered

FAMILY	Scientific name	Common name	KIA (Dry season)	KIA (Wet season)
Antelopinae	*Cephalophus dorsalis*	Bay Duiker	0.11	0.13
Antelopinae	*Cephalophus niger*	Black Duiker	0.05	0.10
Antelopinae	*Cephalophus maxwelli*	Maxwell Duiker	0.29	0.29
Antelopinae	*Neotragus pygmaeus*	Royal Antelope	0.03	0.02
Antelopinae	*Cephalophus silvicultor*	Yellow-backed Duiker	0.01	0.03
Cercopithecinae	*Cercopithecus campbelli lowei*	Lowe's Monkey	1.49	1.28
Cercopithecinae	*Cercopithecus petaurista petaurista*	Spot Nose Monkey	0.25	0.26

Appendix D *continued*

FAMILY	Scientific name	Common name	KIA (Dry season)	KIA (Wet season)
Colobidae	*Colobus polykomos*	Black and White Colobus	0.21	0.28
Colobidae	*Procolobus verus*	Olive Colobus	0.03	0.02
Elephantidae	*Loxodonta cyclotis*	Elephant	0.10	0.17
Galagonidae	*Galagoides demidoff*	Bushbaby	0.15	0.04
Herpestidae	*Herpestes sanguinea*	Mongoose	0.32	0.37
Hystricidae	*Atherurus africanus*	Porcupine	0.02	0.01
Loridae	*Perodictus potto*	Potto	0.09	0.03
Nandininae	*Civettictis civetta*	Civet	0.01	0.01
Procavidae	*Dendrohyrax dorsalis*	Tree Hyrax	0.08	0.05
Suidae	*Potamochoerus porcus*	Red River Hog	0.17	0.12

Appendix D *continued*

FAMILY	Scientific name	Common name	KIA (Dry season)	KIA (Wet season)
Tragelaphini	*Tragelaphus euryceros*	Bongo	0.01	0.01
Tragelaphini	*Tragelaphus scriptus*	Bushbuck	0.09	0.03