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BIOMASS DISTRIBUTION AND HABITAT USE BY FOREST ELEPHANTS (*Loxodonta africana cyclotis*), BONGOS (*Tragelaphus eurycerus eurycerus,*) AND DUIKERS (*Cephalophus spp.*) IN THE KAKUM CONSERVATION AREA

A THESIS

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES,

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI, IN PARTIAL FULFILMENT OF THE

REQUIREMENTS FOR THE

MASTER OF PHILOSOPHY DEGREE

IN

WILDLIFE AND RANGE MANAGEMENT

BY

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(BSC. NATURAL RESOURCES MANAGEMENT)
FEBRUARY 2004

CERTIFICATION

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ABSTRACT

Elephants, bongos and duikers use the same patches of forest but previous studies have focused on elephants with little or no recent information on the status of bongos and duikers in Kakum Conservation Area. The objectives therefore were to estimate the number of elephants, bongos and duikers and identify the factors that underlined the distribution and use of the habitat by elephant and bongo. The size structure and biomass of the elephant population was also examined.

After a reconnaissance, the study area was stratified into three (high, medium and low) density strata. By dung counts in the wet and dry seasons, the population size and biomass of elephants, bongos and duikers (Maxwell, Black and Yellow-backed) were estimated. Camera traps were also used to survey the bongo population.

The elephant population size was estimated as 217 with confidence interval of 136-336. This estimate is close to an estimate obtained from a previous genetic survey of the population, when the dung data was analysed using a model that relates the number of dung piles on the forest floor to rainfall in the two months preceding the survey.

Fewer bongo droppings (< 7) were recorded in each season during the dung count. Bongo photographs were not obtained through the camera traps and an estimate of bongo numbers could not be made. But through inferences from the dung count, the camera traps results and from a predicted camera trapping success, a conservative density estimate of 0.10 bongos/ sq km in the high density zone is presented. The bongo population was discrete and isolated.

Maxwell and black duikers densities were estimated as 9.61 and 2.20 sq /km respectively. No Yellow-backed duiker dropping was seen in the dung count.

All elephants irrespective of age group were potential crop raiders. There was no marked difference when the dung boli circumference data of the elephant population in the park and their crop raiding counterparts were compared. Sub-adult elephants made the highest contribution to the dung boli records and dominated the estimated biomass.

Elephant abundance and distribution was influenced by gaps in the forest canopy and fruiting tree spots. But there was a threshold of fruit abundance (approx. 2.80 fruiting tree spots/km) beyond which elephant dependence declined. A weak relationship exists in the sharing of food resources between elephants and bongos. It is suggested that there is no strong competition between the two species at their current densities.

The park staffs have always said that poachers are less active in the wet season because they would be tending their farms but their assertion was not supported by the study, so anti-poaching efforts must be intensified in the wet season.

Farmers also maintained that killing elephants will keep them off the crop fields but illegally killed elephants in the study area within three months to the dry season survey did not significantly influence the distribution of the elephants.

ACKNOWLEGMENTS

I am grateful to Conservation International Elephant Biology and Management Project (EBM) for providing the funds and logistical support. I wish to acknowledge the source of funding for the EBM project namely, the Centre for applied Biodiversity Science, United States Fish and Wildlife Service (African Elephant Conservation Fund), Smart family Foundation and the Betlach family Foundation.

I thank Dr Brent Bailey for his support for this project. I wish also to thank Okyeame Ampadu-Agyei, Director, Conservation International-Ghana and the administrative staff for their invaluable support. I am indebted to Dr Richard W. F. Barnes for his encouragement, guidance, useful comments on the initial draft and his assistance in the data analysis. I am grateful to my academic supervisor, Dr William Oduro for guiding me through all stages of this project. Dr S.K Oppong's suggestions during the fieldwork and comments on the initial draft were invaluable.

My thanks also goes to the late Mr N.K Ankudey Executive Director, Wildlife Division for the permission to undertake the project and to all members of Kakum management (Mr Cletus Nateg, Sylvester Azika and Joseph Bilinla) for their support and encouragement. I thank the field team (John Nyame, Michael Oppong and Isaac Owusu) for enduring all the hardships and also for their company. My sincere thanks also go to all members of the EBM team and the drivers (Johnson Kemeh and Baba Usman) for their various contributions. Mr Emmanuel Danquah suggestions, field maps and company were remarkable.

I thank Dr Lori S. Eggert and Dr B. Hoppe-Dominik for the scientific materials. I am also grateful to Mr E.O. Agyakwa at the University of Cape-coast Herbarium for

identifying the plant samples and the Central Regional meteorological officer, Mr Emammuel Adu, for releasing the rainfall data. Last but not least, I thank my parents for their sacrifices and patience.

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LIST OF ABBREVIATIONS

CI	Confidence Interval
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CL	Confidence limit
DNA	Deoxyribonucleic acid
DS	Dry season
EBM	Elephant Biology and Management Project
GCFZ	Guinea- congolian forest zone
GPS	Global positioning system
HD	High density
LCL	Lower Confidence limits
LD	Low density
NP	National Park
MD	Medium density
MIKE	Monitoring the Illegal killing of Elephants
PADP	Protected Area Development Programme
HQ	Headquarters
UCL	Upper Confidence limits
USA	United States of America
WD	Wildlife Division
WS	Wet season

CHAPTER ONE

1.0 INTRODUCTION

West Africa elephants account for 5% of the continental total (Barnes *et al.*, 1999). Their forest range constitutes about 0.11% of the Guinea-congolian forest zone (GCFZ). This zone has been humanly influenced more than any forest block in the world (Sayer, 1982; Barnes, 1999) leaving the elephant populations fragmented and isolated.

In Ghana, elephants were widely distributed in the rainforest of the southwest until in the fifties when intensive development started (Roth and Douglas-Hamilton, 1991). Today, remnant forest populations occur in five ranges namely: Kakum, Bia, and Ankasa Conservation Areas, Dadieso and the Goaso complex. The Kakum Conservation Area (KCA) elephants are the easternmost surviving viable population in the Upper Guinean forest.

The new West Africa sub-regional and national strategies (AfESG, 1999; WD, 2000) enlist elephants as species of priority concern and emphasizes the need to get reliable data on population size and trend. Elephants have attracted the attention of most researchers to Ghana's protected areas but the same cannot be said about bongos and duikers. But species do not live in isolation.

In KCA, bongo is second to elephant in terms of individual sizes of the large mammal species. Its range in West Africa is much limited compared to elephants. Whilst alarm has been sounded for the threatened status of elephants and some primates like the western chimp and Miss Waldron's red colobus monkey in the GCFZ (Oates *et al.*, 1997; Oates *et al.*, 2000), little is known about the status of bongos (East, 1990).

KCA elephant density is high with an estimated juvenile population of 20% (Eggert, 2001). Furthermore, the elephants dietary catholicism may greatly overlap that

of bongos as both prefer secondary patches of forest (Short, 1981; Merz, 1986; Barnes *et al.*, 1991; Hoppe-Dominik, 1992; Struhsaker *et al.*, 1996). Grazing by cattle and sheep has been found to reduce the amount of forage available for tortoise, which in turn may reduce tortoise survival, growth and fecundity (Berry, 1978; NERC, 1990). This illustrates how competitors can depress the densities of other herbivore species. If there is competition between elephants and bongos, then an increasing elephant population may have a detrimental effect on bongos. Since animals are interdependent, it is fundamental to understand the mechanisms that regulate their population size.

Recent duiker surveys in KCA (Fordwoo, 1992; Dickinson, 1996) did not establish their status. But duikers are targets of most hunting expeditions (Ntiamoah-Baidu, 1987; PADP, 1998). It is therefore necessary to determine the abundance and status of duikers within the context of possible competition between duikers and bongos.

1.1 Objectives

The specific objectives of this research were:

- To estimate the numbers of elephants, bongos and duikers.
- To examine the size structure of the elephant population.
- To estimate the biomasses of the elephant, bongo and duiker populations.
- To determine the factors that influence the distribution of elephants and bongos.
- To assess habitat utilization by elephants and bongos.
- To make suggestions that will help to maintain the species diversity at KCA.

1.2 Justification

Even though reliable population estimates of KCA elephants have been provided through different methods namely dung count (EBM, 2000) and genetically-based survey (Eggert, 2001), it is important to monitor the numbers and distribution especially in

situation where crop raiding is rife. It is also a useful exercise to assess the size distribution of the elephant population, which reflects the age structure of the population for strategic decision-making.

KCA is a MIKE site (a continental program to Monitor the Illegal Killing of Elephants). It has been suggested to undertake surveys in all MIKE sites on a bi-annual basis. This study would therefore feed into the MIKE programme.

The bongo is a spectacular species with a relatively high touristic value. But very few studies have been undertaken on wild bongos (Hillman, 1986; Hillman and Gwynne, 1987; Hoppe-Dominik, 1992; Klaus-Hugi *et al.*, 2000) with most information coming from the zoo populations. Against the backdrop of more people hunting and the change in hunting technology from the traditional methods of bow and arrow to guns (PADP, 1998; Lahm 1993 cited in Barnes 2002), it becomes imperative to determine the status of bongos in the face of the hunting culture of some local communities. Through this project, illegal activity data were systematically collected and could serve as guide to the park management in the deployment of patrol teams.

Even though the main focus of this study was on elephants and bongos it was necessary to look at the numerical status of duikers. Previous works on duikers in KCA (Fordwoo, 1992, Dickinson, 1996) were limited in coverage as they acknowledged. It was therefore imperative to set the records on duikers straight.

In order to optimize time and effort during the field data collection phase, the duiker studies were limited to the abundance of the three large-sized duikers in KCA, namely Yellow-backed duiker (*Cephalophus silvicultor*), Black duiker (*Cephalophus niger*) and Maxwell duiker (*Cephalophus maxwelli*).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Biology and Status of Elephants in West African Forest

Forest elephants are relatively smaller, have longer, thinner and straighter tusks, smaller and more rounded ears and a flatter forehead than their savanna counterparts (Martin, 1991). Elephants in the forest have long been referred to as *Loxodonta africana cyclotis*. Eggert (2001) proposed the naming of the West African species as *Loxondonta africana occidentalis* to highlight their geographical and genetic status. According to her, elephants in the forest of West Africa are more closely related to their savanna counterparts than to the forest elephants of Central Africa. Stalmans and Anderson (1992) reported the sightings of forest elephant in a savanna habitat in northern Togo. This supports Eggert's theory that West African elephants are all the same. Sexual dimorphism is marked in elephants. Adult male for instance attain up to 1.5 times females height and about twice the female weight (Laws, 1966).

Within a decade, the status of West Africa elephants has received extensive review (Roth and Douglas-Hamilton, 1991; Barnes, 1999). West Africa holds the smallest elephant population on the African continent (Barnes, 1999; Barnes *et al.*, 1999). Roth and Douglas-Hamilton (1991) estimated the elephant numbers in the sub- region to be about 18000 between 1976-1984 and was reviewed by Said *et al.* (1995). The West African elephants are in 70 small isolated and fragmented populations. With the exception of Togo and Benin, the six countries on the Atlantic coast hold forest elephant populations in the GCFZ (Figure 1).

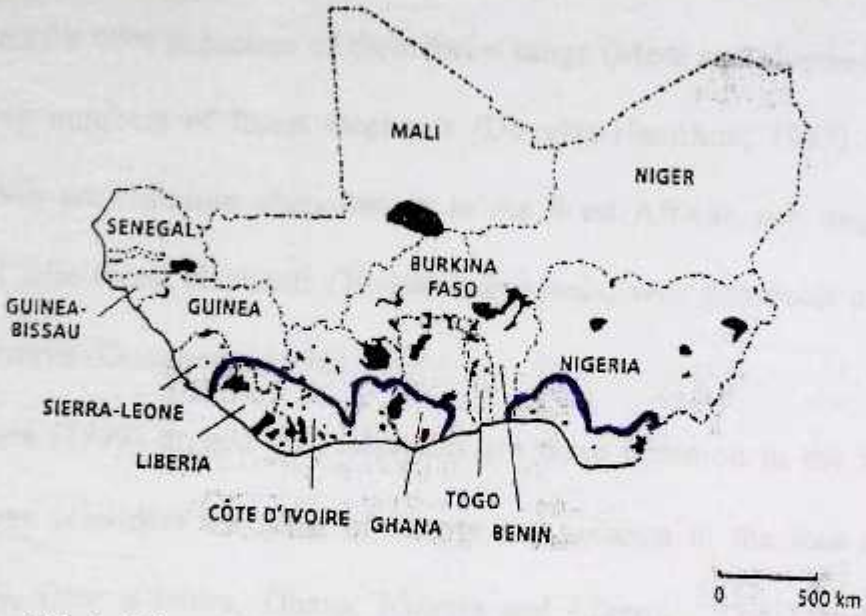


Figure 1: Map of West Africa showing the limits in blue of the GCFZ belt (modified from Barnes, 1999). Elephant ranges are shaded black (Said *et al.*, 1995). The KCA range marks the easternmost surviving viable population (shaded red).

Few surveys (14 out of 75 survey zones) have been carried out on the West African populations (Barnes *et al.*, 1999). The current status of the populations in Liberia and Sierra Leone, for instance, are largely unknown.

In Ghana, the range of elephants constitutes about 13% of the land area of the country. On the other hand, the area of wildlife estates is a little over 5%. The estimated elephant densities in the forest range from 0.04/km^2 in Ankasa to 0.61/km^2 in Kakum Conservation Area (Danquah *et al.*, 2001; Eggert *et al.*, 2003). Recent forest surveys (2001 and 2002) by a combined team from the Wildlife Division, Forestry Division and the Forestry Commission covered most of the forest reserves and off reserve populations in southern Ghana. This also adds to the wealth of information available but data generated only indicates presence and/or absence. Details of the status of elephants in Ghana are in the strategy for the conservation of elephants (WD, 2000).

In Côte d'Ivoire, the estimated forest elephant densities range from 0.02 to 1.25 per sq km (Merz and Hoppe-Dominik, 1991). Elephants found in Tene forest reserve (4/sq km area) have no prospects of survival in the long term but accounts for the density

of 1.25/sqkm. A 50% reduction of the elephant population in Côte d'Ivoire occurred as a consequence of a 40% reduction of their forest range (Merz and Hoppe-Dominik, 1991). The declining numbers of forest elephants (Douglas-Hamilton, 1987) and forest areas (Barnes, 1990) are common phenomenon in the West African sub -region. In Nigeria, only a small relic forest elephants (70-100 individuals) with prospects of survival exists in Okomu reserve (Dougherty, 1996).

Barnes (1999) argued that elephants are more common in the forest zone than savanna if one considers the areas of forests and savanna in the four heavily forested areas namely, Cote d'Ivoire, Ghana, Nigeria and Liberia. The Liberian Sapo forest complex is perceived to be the stronghold and bastion of hope for elephant conservation in the Upper Guinean forest (Waitkuwait, 2001). However, current information about the numbers against the backdrop of the political conflict and logging is not available (Alex Peal, 2000 pers. comm.). In contrast to this general anxiety about the status of the population, Waitkuwait (2001) argued that the civil war impacted positively on wildlife densities and that hunting with firearms decreased because rebels in the course of the conflict confiscated the arms.

Owen (1983) cautioned against the tendency to conclude that a particular species is rare. He argued that some species might have short and sharp seasonal peaks the timing of which differs between species and between years. He used studies on butterflies to illustrate the point. But this concern might not hold for large mammal species like elephants and bongos that might come under intensive study spatially and temporally over a long period in order to understand their ecology.

The 19th century witnessed the greatest scale of elephant destruction in the history of the African continents' elephant population (Barnes, 1999). The elephant has been listed in Appendix 1 of CITES to highlight its endangered status.

2.2 Biology and Status of Bongos in West African Forest

The subspecies of bongo in West Africa is named *Tragelaphus eurycerus eurycerus*. It is a spiral -horned antelope with 10-15 vertical white torso stripes, greatly enlarged ears and sharp senses (Macdonald, 1987; Estes, 1991), see (Plate 1 in Appendix I). Sexual dimorphism is marked in adult bongos. Males, for instance, are darker in colour, have more massive horns than the females whose horns are relatively thinner and more parallel and are sometimes deformed (Katherine, 1978). Besides the horns, other noticeable cocktail features that could be used to distinguish individuals include, the facial spots shape and spacing, number of stripes that run from the torso and torn ears etc.

Bongo is the largest social forest- dwelling antelope and ranges discontinuously in the lowland rainforest in the west coast (Figure 2). Its range outside West Africa extends to the Congo Basin and to southern Sudan with significant isolated population on mountainous forest in Kenya (Estes, 1991).

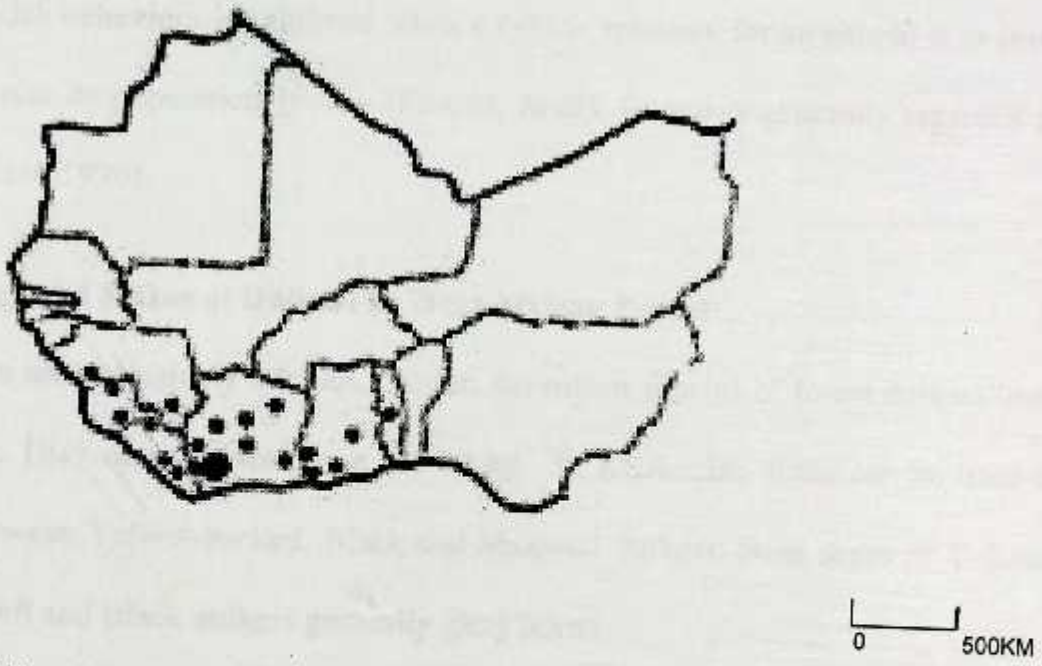


Figure 2: Map of West Africa showing the distribution of bongo in black spots. Most of these wild populations are guessed to be less than 100 individuals.

In Ghana, the northernmost bongo population in the forest has been recorded at Bosam Bepo in the Brong-Ahafo region. In Côte d'Ivoire, bongo in the savanna-forest

mosaic has been recorded in Marahoue National Park. Estes (1991) has reported drastic decline of some isolated populations in Africa.

Bongos' nocturnal activities and cryptic behaviour make their studies extremely difficult hence the general lack of information about their status. They are rarely seen even when at high densities (Hillman, 1986). Bongos are the only forest antelope that form large herds up to 50 (Hillman, 1986). The large bongo groupings were linked to adequate food availability.

Bongos are said to be non- territorial (Estes, 1991). But Klaus-Hugi *et al.* (2000) estimated the home range for group size of 10-20 individuals to be 19-49 sq km. Stamps (1995) in Powell (2000) argued that animals have home ranges because individuals learn site-specific serial motor programmes, which could be regarded as near reflex movements that lead them along well-traveled route. A territorial behaviour refers to an animal that ranges within well defined home within which it has exclusive use or perhaps priority use. Such behaviour is exhibited when a critical resource for an animal is in short supply and limits its population growth (Powell, 2000). Bongo is generally regarded as endangered (East, 1990).

2.3 Biology and Status of Duikers in West African Forest

Duikers are exclusively African. So far, seventeen species of forest duikers have been recorded. They range in size from 3.5-80 kg. In KCA, size alone can be used to distinguish between Yellow-backed, Black and Maxwell duikers. Both sexes of Yellow-backed, Maxwell and Black duikers generally carry horns.

Most duikers are territorial. With the exception of some endemic species, most duikers are ubiquitous in the savanna, transitional and forested protected areas in West Africa (East, 1990). Details of the range and distribution of the three duikers are described in Kingdon (1997).

Generally, the conservation status of Maxwell and Black duikers in West Africa is satisfactory (not threatened) unlike Yellow- backed duiker which is rare (Kingdon, 1997; East, 1990). Maxwell duiker has been observed to be the most abundant followed by Black duiker (Wilson, 1994; East, 1990). However, the future of duikers depends on the effective management of protected areas (PAs) since like other plant and animal resources outside PAs, they are considered "free for all". Recent surveys by Fordwoo (1992) and Dickinson (1996) in KCA were less extensive in coverage hence the current status of duikers is uncertain.

Most of the factors that limit the distribution, status and viability of the duiker populations in West Africa are not peculiar to a country in the sub- region. In Côte d'Ivoire, for instance, commercial hunting is widespread inside and outside PAs (East, 1990) even though, hunting has been banned since 1974.

2.4 Size distribution, Age and Biomass Estimations

Age structure of a population expresses the distribution of the number of individuals in each age group. Age class structure reflects demographic and physiological changes and trends and could be used as basis for comparing different populations (Caughley, 1977; Sukumar, 1989). Age structure estimation for elephants has generated much interest and attention by many authors (Western *et al.*, 1983; Jachmann and Bell, 1984; Pilgram and Western, 1986; Lindeque, 1991; Lee and Moss, 1995) but the same cannot be said for bongos and duikers. Since estimations of the age structure for bongos and duikers were not objectives of this project they have not been given prominence in this section.

2.4.1 Elephant Size distribution, Age and Biomass estimations

Age estimates and population age structures for elephants have been derived from ground and aerial surveys. Body parameters like shoulder height and hind footprint length (Western *et al.*, 1983; Lee and Moss, 1995), back length (Lindeque, 1991), dung bolus circumference (Jachmann and Bell, 1984), tusk circumference (Pilgram and Western, 1986), tooth eruption and wear sequence (Laws, 1966) are indices of body size and age.

Age group classification based on ground counts is biased as calves are undercounted, underrepresented and the adult group could be over estimated (Lindeque, 1991). Besides, Caughley (1977) observed that the age structure of a population does not necessarily indicate population trends. For instance, the number of calves (<1year old) per unit time only gives attributes of the demographic and physical condition and trend of the population if sex differences in mortality and fertility rates are discounted. This not withstanding, the comparative value of age structures are not invalidated if one could reasonably assume a stationary standing population between seasons and years. In the case of KCA, crop raiding is a problem and size structure of crop raiders compared with the sample of the overall population could give useful insights for strategic planning and decision-making.

Information about the structure of forest elephant populations in the forests of West and Central Africa is very scanty because of the poor visibility in the rainforests. Most of the studies have been undertaken on their savanna counterparts (Laws, 1966; Western *et al.*, 1983; Lee and Moss, 1995; Moss, 2001) and in some cases on an Asian population (Sukumar, 1989). Morgan and Lee (2003) attempted to correlate shoulder height or hind print measurement with age for the forest elephants at Petit Loango in Gabon. Eggert (2001) estimated shoulder height of forest elephant calves (one year old)

and juveniles (at age 10) as 0.9 and 0.85 times that of the savanna ones at the same ages. She also estimated bolus circumference of male and female forest elephant at age 10 and ≤ 10 years old as 32cm and ≤ 32cm. But all the estimations were based on Morrisson-Scott's (1947) scanty data on forest elephants and largely on Jachmann and Bell's (1984) savanna work.

Morgan and Lee (2003) found that sexual dimorphism in shoulder heights is less pronounced in adult forest elephants compared to the savanna ones. Forest elephants are also said to be smaller than the savanna ones at the same age (Morgan and Lee, 2003). At Petit Loango, they recorded the minimum and maximum boli width for forest elephant as 4cm and 16cm respectively and the mean as 10cm and emphasized the possibility of population- specific differences. Jachmann and Bell (1984) observed that at certain age, the bolus sizes of male and female elephants in the wild differ considerably (Figure 3).

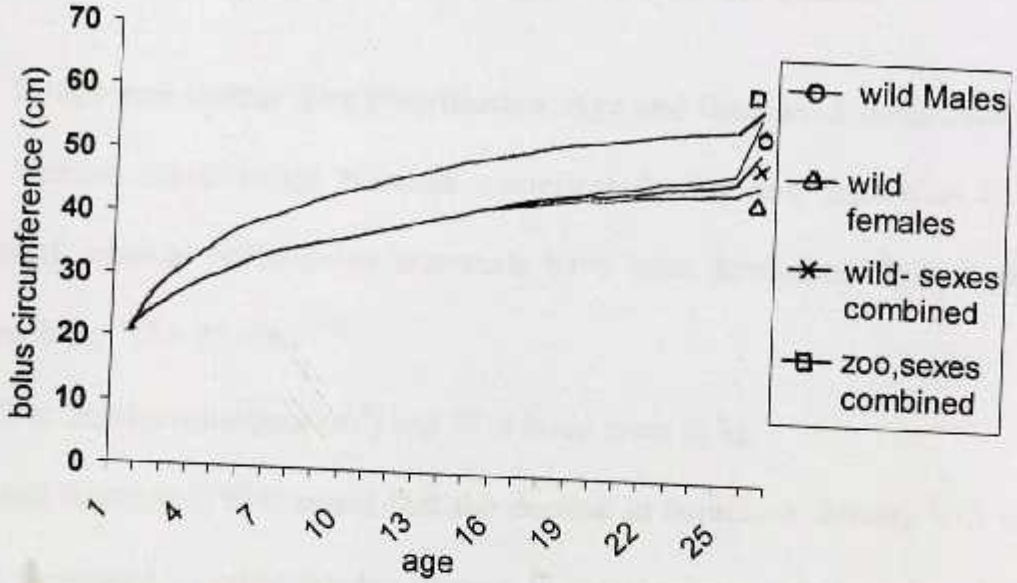


Figure 3: Dung bolus circumference by age for elephants in the Kasungu NP (wild) and zoo elephants (data from Jachmann and Bell, 1984).

There was size dimorphism at age 15 for the elephant population in the wild. One therefore needs to know the sex of the elephant that defecated to be able to assign age to

the bolus. It is thus possible to construct a reasonable age structure without recourse to the sex distinction at the sub- adult stage of growth but not for the older age classes.

There is a general conception that forest supports a higher biomass than savanna but Barnes and Lahm (1997) tried to correct this erroneous idea. The misconception is supported by high elephant densities recorded in some Guinea-Congolian forests (Barnes *et al.*, 1991). White (1994) attributed the high percentage of large-bodied animals in African forest than the savannas to their ability to adapt and digest coarse forage. Mammalian biomass has been estimated directly by multiplying the mean population size for the year by the average mass of each species (Drent and Prins, 1987; Plumptre and Harris, 1995). Thus the accuracy of biomass estimations depends on two variables:

(i) the completeness and accuracy of the census method used to estimate densities.

(ii) the accuracy of the unit live weight used for each species.

2.4.2 Bongo and Duiker Size Distribution, Age and Biomass Estimations

Various relationships between numerical density and individual body size of some small tropical herbivorous mammals have been developed (Peters and Raelson, 1984) such as, $D = 22.4W^{-0.493}$

where D is density (numbers/km^2) and W is body mass in kg.

Peters and Raelson (1984) noted that the decline in herbivore density with size is very gradual compared to other trophic classes like carnivores and that size alone explains 53% of the variation in numerical density of smaller tropical species. The residual variation was accounted for by weather, food, predators and habitat quality (Peters and Raelson, 1984). But such relationships remain hypotheses since in some cases specific taxonomic, ecological and other site specific differences though recognized, are not included in the development of the size- density relationship due to lack of data. Pellet

weights have been used to get an insight into the size of some small mammals (Peters and Raelson, 1984).

The population parameter needed in the estimation of bongo and duiker biomasses is the same as aforementioned (i.e. population size). At Tano Nimri Forest in Ghana, a biomass of 72kg/km^2 was estimated for ten species including 3 ungulates and 6 primates (Owen, 1983).

2.5 Habitat Requirements, Choice and Preference by Forest Elephants, Bongos and Duikers

The spectrum of resources to be partitioned and shared by co-existing species in a particular habitat include amongst others; food (defined by the size and quality), space (defined as horizontal and vertical "spectra" of the vegetation), physico-chemical characters (eg. climate, substrate type) and time. Food preference is the extent to which a food item is consumed in relation to its availability in the habitat (Babaasa, 2000).

2.5.1 Elephants

Elephants do not use different habitat types in proportion to the areas of the habitat (Babaasa, 2000). Secondary forest supports higher densities of elephants than primary forest (Short 1981; Merz, 1986; Barnes *et al.*, 1991; Struhsaker *et al.*, 1996). Prins and Reitsma (1989) however observed that logging which has the potential to create secondary forest patches had a negative impact on some mammal densities in Borneo rain forest.

The bulk of elephant diet comes from fruits, leaves, bark and roots. Short (1981) recorded 138 plant species browsed by elephants in the Bia wildlife reserve. Thirty-six species were fruits eaten. Herbs were absent in the diet and grass was rare (Short, 1981). Seasonal differences in the quantity and diversity of the fruits eaten have been noted

(Short 1981; White *et al.*, 1993). Fruits of *Strychnos aculeata* are available all year round in the Bia forest and features in elephants diet throughout the year (Short, 1981).

Elephant food in the secondary forest could be 2.6 times greater than in the primary forest (Olivier 1978 cited in Merz, 1986) and that elephants are attracted to gaps (Wing and Buss, 1970; Hoppe-Dominik, 1992; Dudley *et al.*, 1992). The opening of the tree canopy through logging activities and by wind thrown trees enhances the dominance of the herbaceous understorey vegetation (Struhsaker *et al.*, 1996). The heliophytes that colonize gaps are attractive and more palatable to elephants because they contain less toxic compounds and tannins than the ombrophile species under forest canopy

At Bossematie forest reserve, in Côte d'Ivoire, many small clearings have been taken over by *Chromolaena odorata* making gaps unattractive to elephants (Theuerkauf *et al.*, 2001). *Chromolaena* is common at KCA and Dudley *et al.* (1992) reported its occasional use as cover for some ungulates. However, elephants have not been found to feed on *Chromolaena* (Dudley *et al.*, 1992; Schulenberg *et al.*, 1999).

In the Budongo forest in Uganda, elephant preference for plants in the forest openings inhibited growth of seedlings in such gaps. On the whole, elephant-browsing intensity depends on species selectivity, perhaps density, landscape and plant community composition and/ or digestibility (Struhsaker *et al.*, 1996).

2.5.2 Bongos

It is estimated that over 80% of the total area of KCA has been logged. Bongos, like elephants, prefer secondary forest (Hoppe-Dominik, 1992). They are not obligate browsers but their diet varies considerably. In Sudan and Kenya, 20 and 30% grass respectively has been found in their rumen. They feed more on dicots and herbs (Hillman and Gwynne, 1987; Klaus-Hugi *et al.*, 2000). Generally, bongos and other forest animals

are geophagous. They frequent natural saline areas to consume the soil (Hillman, 1986; Hillman and Gwynne, 1987; Klaus-Hugi *et al.*, 2000) to supplement their mineral intake.

2.5.3 Duikers

Duikers feed on fruits that fall directly to the ground. To some extent they depend on monkeys, birds and fruit bats to dislodge fruits, flowers etc. that might not otherwise be available (Kingdon, 1997). Like elephants and bongos, duikers use gaps and are sensitive to what happens in the forest canopy (Kingdon, 1997). Prins and Reistma (1989) attributed the low biomass of small duikers in the equatorial forest of Gabon to sparse undergrowth in an area where hunting was on a lower scale.

2.6 Factors influencing Numbers, Distribution and Habitat Use by Elephants, Bongos and Duikers.

For the purpose of clarity and explanation in this section, the variables identified by some authors which strongly influenced densities and movement patterns of elephants, bongos and duikers are broadly grouped into two; human- related (logging and deforestation, hunting for bush meat and ivory) and natural (raphia swamps, water sources, fruiting tree spots etc) factors. Most of the factors affect elephants, bongos and duikers alike.

2.6.1 Human-related factors in and around Forested Protected Areas

2.6.1.1 Elephants

The Guinea forest block has been influenced by humans to a greater extent than any forest block in the world (Sayer, 1982). Only about 10% of the original forest cover in West Africa remains (Sayer *et al.*, 1992). This makes the conservation of forest dwelling species ever more challenging. Besides, West Africa currently has the highest rural population density compared to the other sub-regional blocks (Central, East, and

Southern) and are mainly subsistent farmers practising shifting cultivation and slash and burn agriculture. The shifting cultivation farming pattern creates a mosaic of secondary forest patches that entice elephants (Nchanji, 1994).

Both people and elephants seek the same resources, for example, fertile soil and water (Parker and Graham, 1989) and are bound to come into frequent contacts. The decrease in the forest cover combined with increasing human population has caused a rapid decline in per capita forest resources (Barnes, 1990). Mayr (1963) noted that competition for any essential resources such as food, a place to live/hide or breed would be sufficient to knock a population into extinction.

As forest estates diminish in size, the perimeter to area ratio will increase thereby making accessibility easier. Thus most of the forests delimited and designated as protected in West Africa can be crossed in a day's walk (Barnes, 2002). On the other hand, very large parks are not adequately protected because most of them are poorly funded and usually exist by name. Elephant densities depend on the level of protection of a protected area (Jachmann and Billiouw, 1997).

Human population growth and activities have left most of the protected ranges for elephants fragmented (Barnes, 1999). The human-elephant interface keeps widening through agriculture, logging, mining and hunting. Thus competition and conflict keeps escalating with a dire consequence for biodiversity conservation (Dudley, 1995; Hoare, 1995). Undoubtedly, logging and hunting are linked. Park accessibility increases due to logging and consequently hunting. Even though, habitat loss is seen as the greatest threat to forest elephant populations, ivory poaching is still a serious problem in some West African states (Merz, 1986). But Wilkie *et al.* (1998) cited in Bowen-Jones and Pendry (1999) opined that defaunation and not habitat loss has been the major threat to animal conservation in the West and Central African forests.

Hunting in Liberia has driven most of the elephant populations to extinction (Waitkuwait, 2001). In Cote d'Ivoire, income from poaching exceeded that from commercial logging (Fisher and Linsenmair, 2001). Even though, there has not been recent large- scale elephant poaching in the West African sub- region, Nigeria is still hub of the illegal ivory trade whilst Cote d'Ivoire's ivory carving industry is one of the largest in the sub- region (Dublin *et al.*, 1995). In Central Africa, ivory poaching alone reduced forest elephant numbers by 40% (Barnes *et al.*, 1995) and has distorted the age structure in East Africa elephant populations (Barnes and Kapela, 1991). However, Dublin *et al.* (1995) and Jachmann and Billiouw (1997), observed that poaching was not only fuelled by ivory prices but also inadequate resources committed to law enforcement. Hunting for ivory between 1890 and the First World War reduced the elephant population in West Africa to the level it has not been able to recover.

Armed conflicts, political instability, swelling refugee numbers, dwindling Wildlife authority budgets (in real terms) and increased human-elephant conflicts have had a multiplier effect individually and collectively on the numbers and distribution of elephants (Douglas-Hamilton, 1987; Dublin *et al.*, 1995; Barnes, 1999; Hoare, 2000).

2.6.1.2 Bongos

About 7% of Ghana's total land area is forest under reservation (FD, 1998) and there is a common misconception that the African forests are fertile and productive. Against the background of this natural limitation, the influence of human –driven factors becomes more pronounce. It is noteworthy that factors such as habitat loss and illegal hunting similarly affect the abundance and distribution of bongos and duikers, as they do to elephants. However, Ottow *et al.* (1996) reported that bongo population in a predominantely secondary forest in Bangassou in Central African Republic was stable even though it was hunted. Bongos are crop raiders as they get increasingly confined to

confined to protected areas. Their future thus lies in the adequate protection of the protected areas (East, 1990).

2.6.1.3 Duikers

In the centre of Kakum and Bia Conservation Areas where hunting was less, duiker numbers were high compared to areas close to the reserve boundaries (Struhsaker and Oates, 1993). In the east of Marahoue NP, duikers distribution was consistent with primates but low numbers were recorded in the west which was attributed to high hunting pressure.

Within 7km around Ankasa and Bia reserves, 5000-6000 and about 5000 hunters, respectively, were estimated to ply their trade (PADP, 1998). Hunting in and around these two forest reserves affected 82 species (42 mammals, 35 birds and 5 reptiles, excluding small rodents and birds) (PADP, 1998). Oates *et al.* (1997) observed more hunting in Ankasa than KCA and attributed the low hunting in KCA to a well-motivated staff through the Conservation International/USAID funded project.

In Ghana, generally, almost all species of mammals in the forest are hunted and eaten including elephants. Generally, village hunting is based on snaring and accounts for 84% of all kills (Bowen-Jones and Pendry, 1999). Snaring is not directed at specific species and is reported to have caused the local extinction of some species.

In Liberia, duikers make up 75% of all bush meat harvest (Waitkuwait, 2001). The resilience and persistence of species faced with a hunting culture differs. The large-bodied animals with their low reproductive rates easily succumb to sustained hunting pressure (Barnes, 2002). Even though, duikers are good indicators of snare trapping and are said to be relatively resilient to hunting pressure, they could be over exploited (Waitkuwait, 2001). All animals over 1kg are equally at risk (Bowen-Jones and Pendry, 1999).

2.6.2 Natural Factors

Forests are found in West Africa where rainfall exceeds about 1300mm per annum (Hall and Swaine, 1981). Rainfall strongly dictates the flowering and fruiting of plant species with high number of fruit species recorded in the dry season (Taylor, 1960). Elephant densities also fluctuate locally in response to fruits availability (Short, 1981). Rainfall also influences water availability and bongo, for example, is water dependent.

Underground geology also dictates the soil types as some soils support poor plant diversity. Bongos and elephants alike are reported to visit natural saltlicks to eat the soil (Hillman and Gwynne, 1987). Natural predators such as leopards and diseases like anthrax, limit animal population densities.

2.7 Some Techniques used to Survey Forest Animal Populations

2.7.1 Dung counts by Line Transects

Dung counts are the only practical, reliable (Barnes *et al.*, 1995; Barnes, 2001) simple and cost effective (Eggert, 2002 pers comm.) way of estimating ground-based mammalian herbivore populations in the forest. They produce estimates that are precise for a wide range of species (Barnes, 2001) and are comparable to estimates from genetic surveys (Eggert *et al.*, 2003).

The standard line transect technique (Buckland *et al.*, 1993) has proven to be reliable both in aerial counts (Jachmann, 1991) and ground (both in the forest and savanna habitats) surveys. The principle underlying the technique is outlined in Barnes (1996). The forest poor visibility precludes the use of direct counts hence the use of standing crop dropping/pellets group counts (Barnes and Jensen, 1987). Line transects have widely been used to survey many animal populations ranging from lizards to large mammals (Koster and Hart, 1988; Fay, 1991; Barnes *et al.*, 1995; Barnes, 2001).

Dung count has been used as a good measure of habitat occupancy (Jachmann and Bell, 1984). Pellet size, shape and odour are unique for a species particularly the bovids and a model which shows a predictive positive correlation between body weight and pellets weight has been developed by Coe and Carr (1983), i.e.

$y = 6.4387x^{1.1223}$

where y is body weight (kg) and x is the mean of twenty oven- dried weight (g) of randomly selected pellet group samples.

The technique of pellet group counts to determine animal numbers or level of occurrence was first developed by Bennet, English and McCain (1940) cited in Coe and Carr (1983). It underwent considerable review by Neff (1968) and used in the study of deer.

2.7.2 Using Camera- Traps to Survey Animal Populations

Camera-traps provide a new method of surveying animal abundance and have proven to be reliable. Amongst other studies, the method has been used to survey low density secretive tigers (Karanth, 1995; Karanth and Nichols, 1998), Mediterranean monk seal (Forcada and Aguilar, 2000) and salamanders (Doody, 1995). For the first time in the African rainforest, the method was used here in an attempt to census the cryptic bongos in KCA.

The technique is based on the capture –recapture model. A capture history is constructed for every animal caught by the camera. A capture history simply means array of 1s and 0s where 1 denotes capture and 0 connotes no capture. For example, an animal with this history 10011 implies it was photographed in the first sampling occasion, recaptured in the 4^{th} and 5^{th} occasions but not photographed in the 2^{nd} and 3^{rd}. A probability model is developed to describe the sequence of events that produced each capture history (Nicols, 1992) and built into a computer program like CAPTURE (Otis *et*

al., 1978; Rexstad and Burnham, 1991) to generate the estimate of numbers. The program has been developed for a closed population and takes into account variations in capture probabilities that might result from time, behavioural response to capture between the young and adults, trap happiness or shyness (Otis *et al.*, 1978; Rexstad and Burnham, 1991). With tigers, for instance, Karanth and Nichols (1998) observed that cubs (<1year old) actively avoided the traps and were therefore underestimated. In such instances, personal observations and knowledge about the population structure and dynamics in the area or elsewhere could be advantageous. With such knowledge, simulation models could be developed to estimate the cub proportions to correct the underestimation.

It is also important to be able to distinguish between individuals of the population. Thus the species must have distinct natural markings that can be used to identify individuals (Karanth, 1995) from the photographs taken. Both elephants and bongos can be individually identified. However, to avoid the complications likely to be associated with identifying individuals, Carbone *et al.* (2001) developed an approach that makes the data collected analyzable without recourse to identification of individuals.

The basic assumptions of capture-recapture model on which Eggert (2001) based her KCA elephant genetic study were:

(i) the population was a closed one.

(ii) that individuals mixed randomly between samples and that each had an equal chance of being captured. The bongo population is closed at KCA, so it satisfies the first requirement.

In most camera trapping programmes, the target species might be in high densities but the captured individuals usually represent a small fraction of the capture successes (Karanth, 1995, Carbone *et al.*, 2001). In other words, other species dominate the total number of photographs taken. This causes a lot of films to be spent.

2.7.3 Genetic Surveys

DNA extraction from dung (or hormones in dung) and genotyping is so far one of the most accurate methods for estimating animal populations. It also gives an idea about the sex ratio (Eggert *et al.*, 2003). But the method is an expensive undertaking and the standard capacity has not been developed in West Africa. Eggert *et al.* (2003) applied this method to survey the KCA elephant population. Genetic surveys have also been used extensively in the developed world. For instance, coyote population has been estimated using the non-invasive faecal genotyping (Kohn *et al.*, 1999). DNA was extracted from faeces (Eggert *et al.*, 2003) and individuals were identified and sexed through amplification of specific DNA sequence.

2.7.4 Other Potential Methods

The discovery of infrasound communication in elephant populations and other mammals has opened the panorama and prospects to explore the possibility to estimate abundance through acoustic surveys. Elephant Biology and Management Project carried out a pilot study in KCA in conjunction with the Cornell University in USA. A similar study was undertaken in Dzangha-sangha reserve in Central African Republic. Both studies recorded remarkable number of infra sound calls by elephants.

2.8 The Biology of Small Populations

The precision of dung and aerial sample surveys is inversely proportional to abundance (Barnes, 2002). As a small population (< 200) declines, the precision of the estimate sharply decreases and the power to detect changes in the population also diminishes steeply (Barnes, 2002). A small population runs a greater risk of going extinct (Shaffer, 1987) and is more prone to stochastic events like epidemic and poaching. With low densities, it is likely that reproductive rate will decrease, for example, if females in

oestrous cannot find mates. Thus, the collapse of a heavily hunted population will be hastened.

The chance for a population to survive over a period of time, say 100 years, is mostly dependent on female population size and on changes in the vital rates of mortality and proportion of female at age of first reproduction, interval between births, litter size, cubs sex ratio, and senescence. The magnitude of random individual variations in the vital rates is inversely proportional to population size (Shaffer, 1981; Caughley, 1994; Lande, 1998). In a large population, the independent random events among individuals tend to cancel out and thus give a positive outlook to the growth of the population (Lande, 1998). There is therefore a minimum viable population size below which a population may not be able to bounce back and recover.

For a population to remain fit (i.e. prevent inbreeding depression, loss of genetic heterogeneity and their deleterious effects) in the long term (about 100 years), the effective number should be about 50 (Franklin, 1980; Caughley, 1994). It could be said that this is not a magic number but depends on a whole range of factors including the species life history. Sukumar (1993) estimated that about 200 elephants are needed in an Asian population to be able to survive and avoid events of demographic and environmental shocks and distortions. The demographic events refer to chance variations in individual birth and death. Stochastic environment, on the other hand, is the series of random changes associated principally with habitat quality and quantity. The genetically effective population size of 50 is needed to keep inbreeding below tolerable level of 1% per generation. It depends largely on the number of the less common sex (Caughley, 1994). It is, however, noteworthy that inbreeding depression is less likely to occur in natural populations because individuals actively avoid mating with close relatives. Many of the extinctions are the results of deterministic events such as habitat destruction and

over harvesting which thins the population to a range that the stochastic events then take over to knock the population beyond recovery.

According to Lande (1998), the risk from demographic stochasticity is greater than from environmental fluctuations in a small population. The demographic distortions are likely to come from hunting where it is possible to lose the male members of the population to poachers and the effect of the distortions is much felt in a small population (<100 individuals). Nevertheless, the genetic determinants of any minimum viable population size are still unclear. It's fine resolution depends largely on the availability of reliable and sufficient data on the demographic, environmental, natural and genetic variations that would throw more light on the critical role each stochastic event severally and synergistically plays to affect the growth and regulation of any small population (Shaffer, 1981).

Ecological processes are inherently non-linear. This fact, along with the destabilizing effects of environmental perturbations and trophic level interactions means that complex dynamics, including chaos, are expected in many biological populations. For animals like bongo that exhibit some cooperative social interactions (Hillman, 1986; Estes, 1991), extreme reduction in the population size may impact negatively on the fitness of the overall population since per capita efficiency of group foraging for resources may be adversely affected (Lande, 1998).

For an isolated independent population where no movement effectively takes place and there is little or no links in the fates of the populations in case of any extreme environmental risk, protecting multiple populations is extremely advantageous (Morris *et al.*, 1999). Where there exists refugia and the habitat is spatially heterogeneous, local populations can be buffered against extinction (Boyce, 1992).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

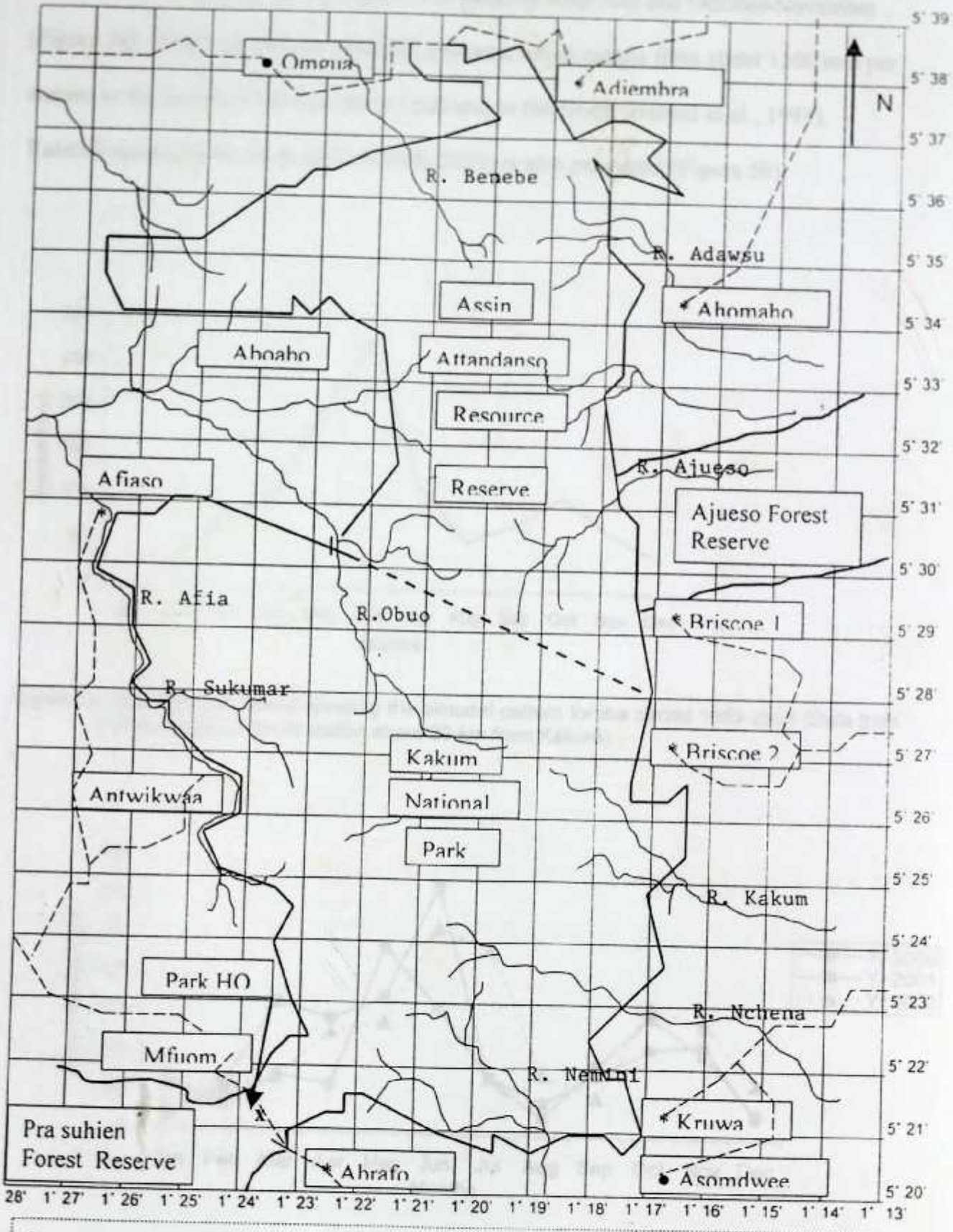
The study site was Kakum Conservation Area (KCA). It comprises Kakum National Park and the adjacent Assin-Attandaso Resource Reserve. The two reserves are separated by a footpath and together they cover an area of 366 sq km (Figure 3). The two forest blocks are managed as one unit.

KCA forms part of a fragment of the Upper Guinean forest block. It thus lies mainly in the moist evergreen zone (Hall and Swaine, 1981). It falls approx. within latitudes 5^0 20' and 5^0 40'N and longitudes 1^0 20' and 1^0 30'W.

The Kakum Park and Assin Attandaso have suffered various degrees of logging in the past, which only ceased in 1989 when the forest block was declared a wildlife reserve. The forest condition of Kakum and Attandaso are described by Hawthone and Musah (1993) as "good" and "slightly degraded" respectively.

KCA is separated from Pra-suhien Forest Reserve to the southwest by an all weather road. On the eastern side, it shares common boundary with Ajueso Forest Reserve (Figure 4).

Faunal surveys of the KCA have so far recorded ten of the sixteen mammals listed as species of conservation concern in Ghana (IUCN, 1988).



Legend

* WD camps/ villages — Rivers — scale= 1unit: 1.84km

--- Roads — – – Path

Conservation area boundary

Drawn by E. Danquah Sept

Figure 4: Map of Kakum Conservation Area made up of Kakum National Park and Assin Attandaso Resource Reserve to the north. It shows location of Pra-suhien and Ajueso Forests.

The rainfall pattern is bimodal with peaks in May-July and October-November (Figure 5a). However, there is a rainfall gradient, which ranges from about 1300 mm per annum in the South of KCA to about 1500 mm in the North (Barnes et al., 1994). Rainfall spanning the study period (2000-2002) is also presented (Figure 5b).

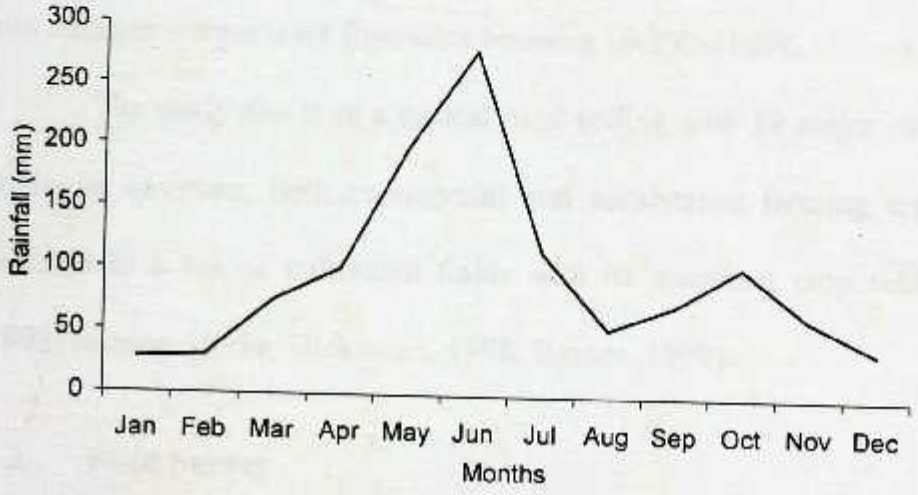


Figure 5a: Mean annual rainfall showing the bimodal pattern for the period 1953-2000 (Data from Brimsu meteorological station about 20 km from Kakum).

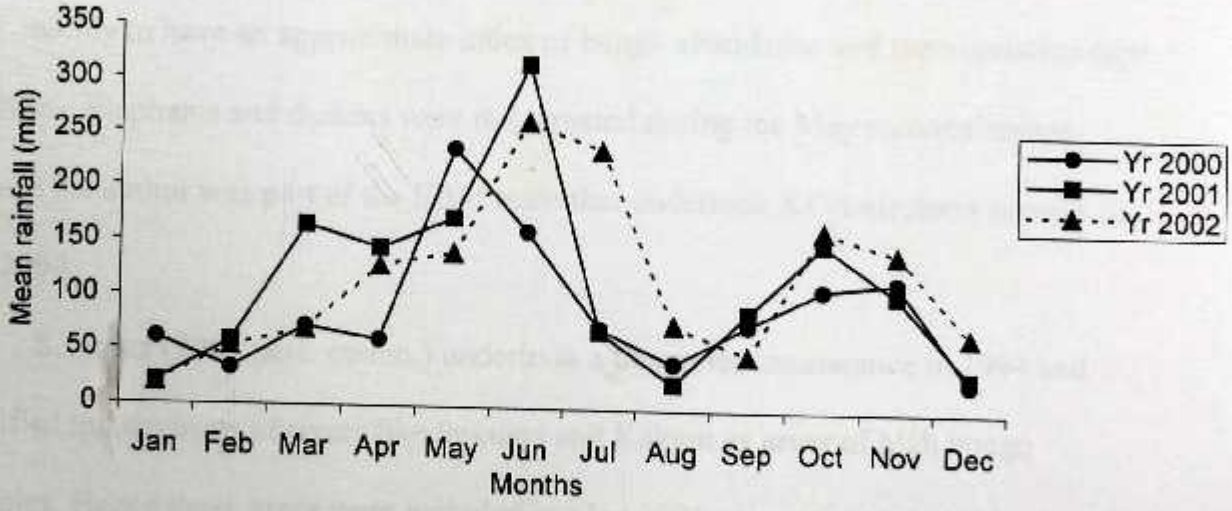


Figure 5b: Mean monthly rainfall for the years 2000-2002
(Data from six rainguages installed by EBM in the KCA).

The main rivers in the study site namely: Kakum, Nemeni and Nchemna drain in the southeast direction. Others such as Afia, Obuo and Sukuma drain westwards and the Ajuesu and Adawsu rivers flow eastwards.

The Conservation Area overlays the Cape-Coast granitic complex with outcrops in the Aboabo and Ahomaho ranges. Soils are however predominated by the Forest Ochrosols, with Gleisols along the rivers and streams. The topsoil pH ranges from 5.5-7 and ambient temperature fluctuates between 10.2°C-31.6°C

The study site is in a typical rural setting with 52 major communities adjacent to it. In its environs, both commercial and subsistence farming are practised. It is thus isolated in a sea of cultivated fields with its attendant crop raiding problems (Azika, 1992; Barnes, 1993a; Dickinson, 1998; Barnes, 1999).

3.2 Field Survey

3.2.1 Reconnaissance survey on Bongo

A reconnaissance is essential and this is particularly true for studies in the forest (Barnes *et al.*, 1992; Barnes, 1996). Reconnaissance surveys were carried out in May 2001, mainly to have an approximate index of bongo abundance and the vegetation type it prefers. Elephants and duikers were not targeted during the May reconnaissance because the author was part of the EBM team that undertook KCA elephant surveys in year 2000.

S. Azika (2001 pers. comm.) undertook a bongo reconnaissance in 1994 and identified the environs of rivers like Sukuma and Kakum as areas of high bongo activities. Hence those areas were included in May 2001 reconnaissance and traversed. Other sections of the study area were also randomly sampled apart from those identified by Azika (2001, pers. comm.). Accordingly, fourteen transects were randomly distributed and walked. Each transect was 1.84 km except one that was 1 km. Signs of

bongo abundance such as droppings, footprints, sleeping places and feeding spots were recorded. The walks followed lines of least resistance to minimize cutting. All distances were measured with a Keson Roadrunner (a long distance measuring wheel with a five-digit counter fitted with an adjustable handle and used for measuring straight or curvilinear surfaces).

Bongo reconnaissance surveys were also undertaken in Ajueso and the part of Pra-suhien that lies close to KCA in September and October 2001 respectively. The outcome of the reconnaissance is presented in the results section.

3.2.2 Elephant, Bongo and Duiker Dung counts

It was unsuitable to estimate the abundance of many terrestrial mammals population in the rainforest by direct observation because of poor horizontal visibility. An indirect method through dung counts was therefore used (Barnes and Jensen, 1987; Koster and Hart, 1988). Dung count was used as a measure of abundance and habitat occupancy by the different species (Jachmann and Bell, 1984).

A survey was conducted at the peak of the wet season (WS) i.e June- July 2001 and repeated in the dry season (DS) i.e January-February 2002. The wet season survey was fixed to coincide with the peak crop raiding period since there was no information on elephant distribution during that period. Thus elephants, bongos and duikers were surveyed on the same transects. Duikers were only surveyed in the 2001 wet season because of the high leaf falls in the dry season. Maxwell and Black duiker droppings would have been obscured by the fallen leaves and thus undercounted.

On the basis of the outcome of the bongo reconnaissance, the study area was divided into three strata namely; the western (Antwikwaa-Afiaso) sector was designated high density (HD), the eastern sector (Briscoe 1-Briscoe 2 area) was considered as the medium density (MD) and the rest of the study area, low density (LD) strata (Figure 6).

A survey conducted in KCA in February and October 2000 by EBM showed that 15- 17 transects is the optimum sample size for elephant dung count (Figure 7). This was increased to 20 transects for the 2001 and 2002 surveys. The twenty transects were placed in the proportion of 8:5:7, that is, HD: MD: LD respectively, instead of 8:7:5 (if the bongo reconnaissance is solely considered). This was done to reasonably capture the numbers and distribution of elephants and duikers. In each stratum, for example, the high density sector, eight grid cells were randomly chosen from the total number of grid cells in that stratum. Each complete grid was one minute of latitude or longitude, equivalent to 1.84 km (Figure 6). The transects were placed in the middle of each selected grid and spanned its full length. Thus, each transect was 1.84km except two which were 1.71 and 1.47 km. They were aligned perpendicular to major streams and watercourses in the north–south or east–west directions.

The standard line transect technique was used for the dung counts (Barnes and Jensen, 1987; Buckland *et al.*, 1993). In order to reduce cuttings, the team followed a line of least resistance in the very thick vegetation along the transects but maintained a predetermined compass bearing of 90° or 270°(depending on the orientation of the transects) in the relatively open areas. The survey team of four was led by a compass man and a line cutter. All elephant, bongo and duiker dropping perpendicular distances were measured from the transect centerline using a measuring tape and placed in the morphological category described by Barnes and Jensen (1987) (Appendix II). The duikers dropping perpendicular distances were measured to the centre of the group of pellets considered as one defecation.

Distance along transects was measured with a Keson Roadrunner. It was calibrated in the forest with the Hip chain (which is a more accurate measure of distance) to obtain a conversion factor i.e.

Hip chain readings = 0.92 x Roadrunner readings (EBM, 2000).

Within two- three months prior to the 2002 dry season survey, poachers killed six elephants and the carcass spots were noted with GPS. This was done to examine the influence of dead elephants on the distribution of elephants.

3.2.3 Bongo Decay rate

To estimate bongo numbers from dung count, it was necessary to obtain estimates of bongo decay and defecation rates. The former was not available hence five fresh bongo dungs that were available between 12-02-2002 and 23-04-2003 were monitored biweekly in situ till they disappeared. The date of deposition was estimated visually by examining the dung when first sighted. The dates of disappearance were noted. The sample size was small but could not be increased because more dungs were not found.

3.2.4 Using Camera traps to Survey Bongos

This survey method became necessary when fewer bongo dung piles were recorded on the twenty transects in each survey period. There was therefore the need to explore other reliable methods to census the bongo population. Four camera- traps were set up in Antwikwaa area (i.e. HD stratum of bongo). To understand how the system works, two cameras were initially deployed in the forest for one month. The four camera traps that run on batteries were biweekly monitored and redeployed at the other bongo trails where their fresh signs were prevalent.

Locations of the traps were selected based on signs of bongo presence following the transect surveys. All camera positions were taken with GPS. The Camera-traps were programmed to automatically switch off between the hours of 9.00-15.00. This period was found to coincide perhaps with the less active period of the animal. The experiment was run for six months (May-October 2002).

The assumptions underlying the experiment were:

(i) bongo population is a closed one and that

(ii) individuals mixed randomly between sampling occasions and that each had an equal chance of being captured.

It was unlikely to have violated the first assumption. In KCA, crop fields have virtually isolated the study area. In addition, interaction or links of the KCA bongos with other population in Pra-suhien or elsewhere are unlikely because the southern part of KCA is usually disturbed by tourists and moving vehicles that ply Cape-Coast- Twifo Praso. Besides, the local people in search of non-timber forest products were constantly disturbing the narrow 'front' of Pra suhien that nearly abuts KCA. It was, however, uncertain if the second assumption was realistically met.

The equipment used was a Goodson Associates' Trail master brand camera-trap unit each consisting of camera kits (35mm, auto focus, rangefinder type) coupled with a cable to one TM- 1500 active infra red receiver which was aligned to an infra red emitter (plate 2 in Appendix I). The infrared emitter sent out an infra beam which was picked by the receiver. Whenever the beam was broken, it triggered the camera to take close–up photos on 200 or 400 ASA colour print films. The infra emitter and receiver were set up opposite one another and mounted on firm tree about 24" above the ground (see plate 3 in Appendix I).

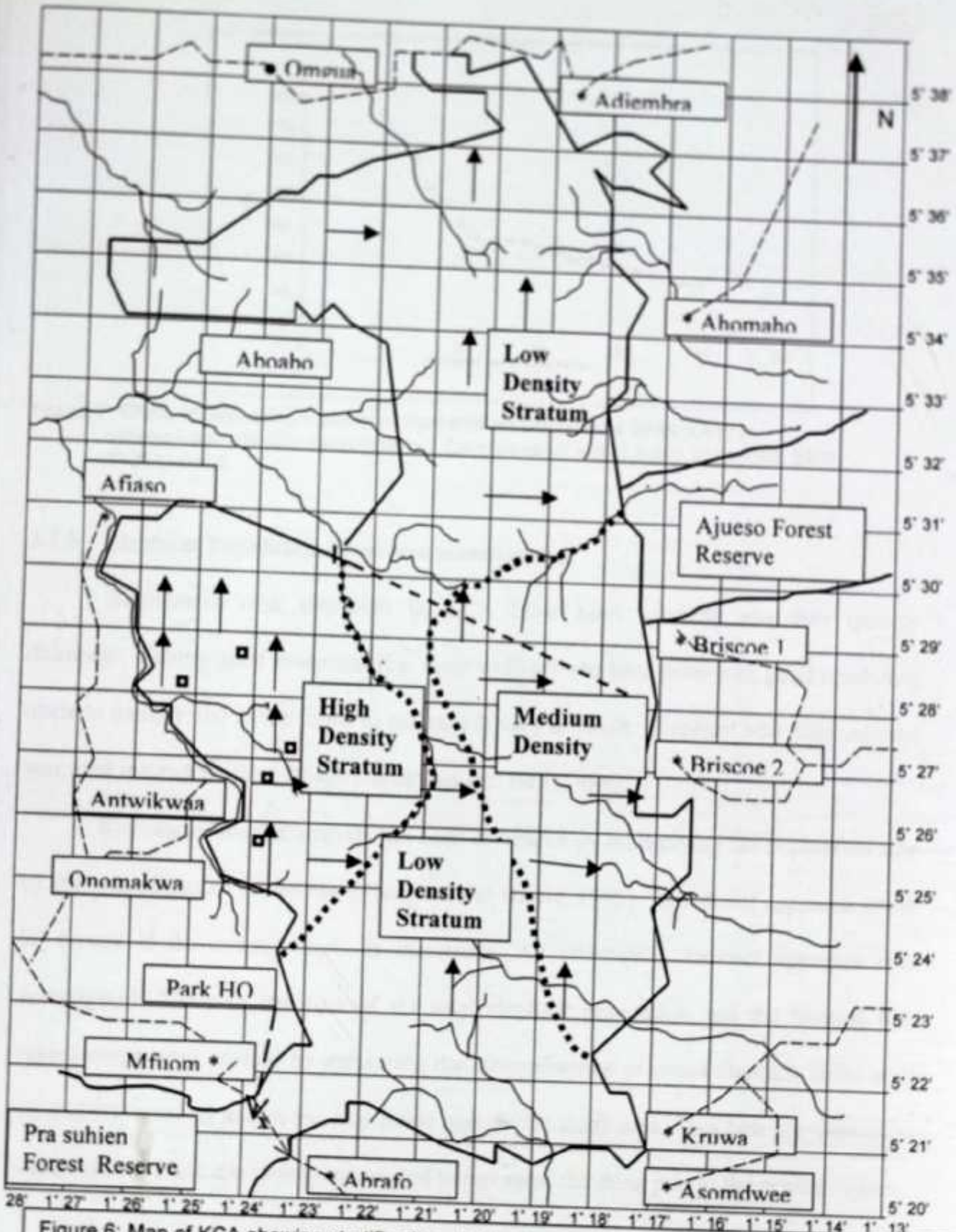


Figure 6: Map of KCA showing stratification, distribution of dung count transects and location of camera traps during the field survey.

Legend

- WD camps/ villages
- Roads
- KCA boundary
- Rivers
- Path
- Camera traps location
- scale = 1': 1.84km
- Limits of stratum
- Transects

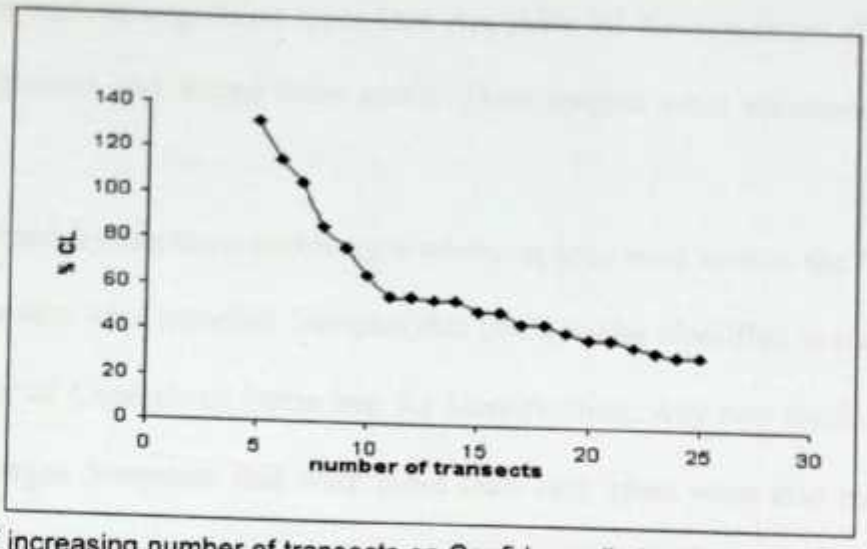


Figure 7: Effect of increasing number of transects on Confidence limits (CLs) in optimum sample size determination. Each transect was 1.84km (data from EBM, 2000 survey).

3.2.5 Elephant Population Structure investigation

Encounters with elephants in KCA have been sporadic and they quickly disappear. Getting good footprints (i.e. clear well-defined hind print with good resolution made in damp soils) in the forest to measure is very difficult. Elephant boli measurement was used instead as index of age (Jachmann and Bell, 1984).

Biomass of most mammals has been estimated by multiplying the population size by the mean mass of the animal (Plumptre and Harris, 1995). This direct approach could be flawed if the average mass is inaccurate. An alternative, indirect approach was investigated. The size structure of the total elephant population and the fraction that raided crops were studied by measuring the circumference of intact elephant bolus seen on and off transects and in the crop fields outside the study area. Two boli per defecation were measured and the average computed to represent the dung pile to the nearest 0.5cm.

3.2.6 Habitat Use investigation

Both natural (water sources, raphia swamps, vegetation type, fruiting tree spots) and human-related (illegal activities, signs of the old logging activities) variables were noted during the dung count. On the transect walks, gaps in the forest canopy, raphia

swamps and the various vegetation types (see Appendix III for vegetation classification details) when entered and exited were noted. Their lengths were measured using the Roadrunner.

Plants eaten by elephants and bongos wherever they were seen in the forest either on or off the transect were recorded. Samples that could not be identified in situ were sent to the University of Cape-Coast herbarium for identification. Any two feeding /sleeping spots and or bongos footprints that were more than 1km apart were also noted with a GPS.

To further study the feeding activities of elephants and bongos, one logging road each in Afiaso, Antwikwaa and Briscoe 2 was randomly selected and a 2.5km transect walk was undertaken on each road in the dry and wet season. All plants species on the logging roads seen eaten within 1.5m on both sides of the transect were noted. A logging road each in Afiaso, Antwikwaa and Briscoe 2 was chosen because of the observed variation in the degree of the vegetation succession and usage. For instance, the Afiaso area was first logged (E. Owusu, 2001 pers. comm.) and a shrub layer with canopy formation was common on the logging roads. An in- depth study on plants eaten by elephants was concurrently carried out by Danquah (2004), which also provided additional useful information.

3.3 Sociological survey

Farmers have experiences with bongos because bongos raid crops. Thus farmers whose farms share common boundary with the study site were contacted through questionnaire administration to establish whether bongos visit their farms.

To select the respondents, the perimeter of the study area was divided into one km sections and 10 were randomly selected. Six farmers whose farms were within the one km were randomly selected to fill the questionnaire. Out of sixty farmers randomly

selected and expected to fill the questionnaires, forty-three responded. The questionnaire was administered with the help of 10 locally based and trained elephant crop raiding assessment monitors employed by the EBM project (see Appendix IV for questionnaire sample). A different questionnaire was also administered to all KCA field staff to get their perception on bongo activities in the study site (see Appendix V for questionnaire sample). Thirty-two staff out of forty-two in all the 10 scout camps around KCA filled their questionnaires.

3.4 Data Analysis

3.4.1 Estimation of Elephant, Bongo and Duiker Numbers

The program DISTANCE (Laake *et al.*, 1993) was used to analyze the dung data to obtain the droppings density estimates for the elephant, bongo and duikers populations for each season. Elephant and duiker droppings seen more than 8m and 5m respectively from the transect centerline in the 2001 wet season were treated as outliers and thus discarded (Buckland *et al.*, 1993) in order to improve the fit of the model in the DISTANCE program. In 2002 dry season, elephant dungs seen beyond 5m were discarded in the analysis. These were done to improve the precision of the dropping density estimates.

For the sake of comparison with other documented estimates, animal densities were calculated using the Steady State Assumption model (McClanahan, 1986). The densities were then converted into numbers by multiplying the respective densities by the area of KCA. The analyses were done separately for each season and merged to obtain an overall estimate of numbers (Norton-Griffith, 1978).

Bongo decay rate used in the Steady state model was estimated by taking the inverse of the median survival days of the few droppings seen and monitored (Barnes, 2003 pers. comm.). Thus, if the median survival was 30 days, the decay rate was 1/30 i.e

0.033/day. The defecation rate of 4.4 droppings/day (Hoppe-Dominik 2003 pers. comm.) was used.

Duiker dung decay studies could not be carried out due to lack of time. Decay rate of 0.0496/day (Dickinson, 1996) was used in the Steady state model to estimate numbers. Captive Maxwell and Black duikers defecation rates of 4.19 and 4.76/day respectively (Dickinson and Abedi-Lartey, 1995) were also used. Where it was necessary to maintain the stratification of the study area, the same analysis was done separately for each stratum. To calculate the dung density (Y) per transect Buckland *et al.* (1993) formula was used:

$$Y = \frac{n \times f(0)}{2 \times L}$$

where n is the number of dungs recorded on each transect, L is the length of transect (in km) and f(0) is the reciprocal of half the effective strip width calculated by the DISTANCE program.

A nonparametric test, Mann-Whitney U- test was used (due to the small sample size of transects per stratum after the stratification) to find if there was significant difference in dung densities in the HD, MD and LD strata. If the difference between any two strata, for example, MD and LD was insignificant, estimates for the two strata were combined to have a population estimate (Norton-Griffith, 1978) for the season.

The confidence limit (CL) for the overall population estimate derived from the stratified sample count, for example, in 2001 wet season was calculated using Norton-Griffiths (1978). The population standard error SE (E) was first calculated using the formula:

SE (E) $= \sqrt{\sum} \text{Var}(E_s)$ where Var (E) is the variance of the population estimate

Thus CL = SE (E) x t where t is student t.

Where stratification was unnecessary as was the case in the 2002 dry season, the CL for the estimated animal numbers was calculated based on the formula in Barnes (1993b). Where very few droppings were sighted in the survey of a particular species, it was assumed that the probability of sighting dung was constant throughout the survey. The number of dungs seen per survey period was then used as an index of abundance (Sam et al., 2002).

The Rainfall model (Barnes *et al.*, 1997), which is more accurate and makes no assumptions concerning normality (Barnes and Dunn, 2002) was also used for the elephant density estimation. Elephant dung density (Y_t) is related to rainfall by this model:

$Y_t = 1020.24 - 0.79RAIN_{t-1} - 0.46RAIN_{t-2}$ (Barnes and Dunn, 2002), eqn. (1)

where Y_t is dung density if there is one elephant per sq km and $RAIN_{t-1}$ and $RAIN_{t-2}$ are respectively the total rainfall (mm) in the first and second months preceding the month of the survey. Thus the expected dung density, Y_t, was calculated by plugging the rainfall figures of $RAIN_{t-1}$ and $RAIN_{t-2}$ into equation (1). Elephant density, E was consequently calculated from the ratio of estimated dung density (Y) from the DISTANCE program (i.e the survey) to that expected (Y_t) if there was one elephant /km^2 in KCA.

Thus elephant density, $E = \frac{Y}{Y_t}$ eqn (2)

To have a better estimate of elephant numbers, the dung density (Y) and it CL estimate from the DISTANCE program was used to generate 1000 independent estimates of dung density from a lognormal distribution described by the parameters obtained from the DISTANCE program.

Y_t was also bootstrapped on $RAIN_{t-1}$ and $RAIN_{t-2}$ to get 1000 independent estimates of Y_t. The 1000 estimates of Y were multiplied by $1/Y_t$ to obtain 1000 estimates of elephant density (E). By ranking the E values generated, its median, lower

(26th) and upper (975th) values were used as the estimates of E, its lower and upper CLs respectively (Barnes and Dunn, 2002).

A matched paired t-test was used to compare the means of the elephant densities per transect after the treatments (i.e. the wet and dry seasons) to find if there was any significant difference between the two seasons before they were merged to have an overall estimate of elephants.

In order to obtain the elephant density per transect used for the t-test, the dung density per transect was multiplied by a conversion factor K, were K= elephant density for the season divided by its corresponding dung density.

By merging the wet and dry seasons density estimates from the bootstrapping, 2000 independent estimates of E were obtained. They were ranked in ascending or descending order of magnitude and the median was taken as the overall elephant density for the two seasons and the 26th and 1975th were taken as the lower and upper CLs of E (Barnes and Dunn, 2002) respectively.

3.4.2 Estimation of Bongo numbers from Camera- traps data

The camera traps were left in the forest for a total of 540 camera-days, where one camera operating for 24hrs is defined as one camera-day. Assuming there were adequate capture data, estimates of bongo numbers were generated using program CAPTURE (Rexstad and Burnham, 1991) in which the Jackknife and Chao models estimates were selected.

3.4.3 Age and Biomass estimation from dung Boli measurements

The indirect method of estimating biomass of the large mammal population through the boli sizes measurements were compared with the more direct method of multiplying the mean population size (estimated through the dung count) by the average

mass of each species. For example, the direct method of elephant biomass estimation involved the multiplication of its average mass of 1700kg (Drent and Prins, 1987) by the population size.

Alternatively, the indirect method, which is more reasonable, is also presented here. To estimate the ages of the KCA elephants from the boli records, the bolus-age curve of wild elephants in the savanna at Kasungu NP, Malawi (Figure 3) was used since such relationship has not been developed for elephants in the forest. Kasungu NP elephants are said to be relatively smaller (Jachmann and Bell, 1984) and may compare favourably in size to elephants in the forest (Martin, 1991). The age of elephants in the boli classes were roughly estimated. Thereafter, Laws (1966) weight-age curve was used to estimate the weights of an individual elephant that belonged to the boli class. With the overall elephant density known, the contribution of each boli class to the density was estimated. By multiplying the density of the various boli size classes to the estimated weight of an elephant in that class, the biomass of that class was estimated. By repeating the same for all the boli size classes and summed, the overall biomass was obtained.

Comparison of the boli size frequency distributions of all KCA elephants and the fraction of the population that raid crops was done using the two-sample Kolmogorov-Smirnov test. This test could detect differences in frequency distribution of two populations irrespective of having the same mean and median. The same test was used to compare the boli frequency distributions of the elephants of Kakum Conservation Area and that of Marahoue NP, Côte d'Ivoire.

Yellow-backed, Maxwell and Black duikers biomasses were estimated directly by multiplying the population size by the mean mass of each species. The masses used for the estimations were 68, 10 and 24 kg /individual animal respectively (Koster and Hart, 1988; Kingdon, 1997).

3.4.4 Analysis of Factors influencing Distribution

Dung pile data for either season was not normally distributed and was subjected to a logarithmic or square root transformation. To investigate the effect of natural (raphia swamps, water sources, fruiting tree spots), and human-related (old logging roads, vegetation types, gaps, illegal activities) variables on distribution, a Spearman correlation was first done. Only those variables that significantly influenced distribution in each season were selected for further analysis.

A Generalized linear model (GLIM) or log-linear analysis was done using the data of the selected variables. In this analysis, the change in deviance, which is a measure of the effect of the predictor variable (eg. raphia swamps, fruiting spots, illegal activities) on the null model, was compared to tabulated chi-square value. If the deviance is greater than the chi-square value then it is significant. Multivariate model was tried when more than one variable explains distribution.

The bongo dung data was insufficient to go through the full range of the above analysis. Besides, the distribution of duikers was not considered because it was not an objective of this project.

Illegal activities observed in three survey years (2000-2002) in KCA were compared with data from Ankasa in Ghana and Marahoue NP in Cote d'Ivoire. A G-test (Sokal and Rohlf, 1981) was used because of its high statistical power to determine any significant difference in the indices of illegal activities and also because of the small sample size.

Elephant and bongo abundance (densities per transect) were calculated and distribution maps using the densities were drawn.

3.4.5 Habitat Use

Indices of dung pile abundance in the raphia swamps and in the various vegetation types were calculated. To test the preference(s) of a particular vegetation type and other habitat variables (raphia and non-raphia areas) by elephants and bongo, Jacobs preference test (Jacobs, 1974) was used. The G-test was used to test the level of significance of any preference shown. Bongo data was inadequate to permit this analysis. Besides, duiker habitat use was not an objective.

CHAPTER FOUR

4.0 RESULTS

4.1 Reconnaissance survey on Bongo and stratification of the study area

A total of 32.10 km was traversed. In the western, eastern sectors and the rest of the study area, indices of bongo abundance were 0.93, 0.37, and 0.14 per km respectively. One bongo was seen in the eastern sector but was excluded in the indices computation to maintain uniformity for all the sectors. The stratification of the study area for the 2001 and 2002 surveys was based on the bongo reconnaissance results since an elephant survey in year 2000 by EBM did not suggest the need to stratify. No bongo signs were seen in Ajueso and the part of Pra-suhien surveyed. However, hunters confirmed the existence of bongo in some sections of Pra-suhien.

4.2 Estimates of Elephant Numbers from Dung count

4.2.1 Year 2001

A total of 180 elephant dung piles were spotted on 20 transects (i.e 36.03km) in the 2001 wet season. More droppings were encountered in the high density stratum than the medium and low density combined (Table 1, includes dung pile densities and their Standard error (SE) from the DISTANCE program).

Table 1: Dung pile densities and Standard error (SE) from the DISTANCE program.

	Wet Season 2001		
	High density stratum	Low density Stratum*	Total
No. of dung piles	105	75	180
No. of transects	8	12	20
Total transect length (km)	14.35	21.68	–
Area (sqkm)	64.33	301.67	366
f(0)	0.25	0.18	–
Density (Y)	923.42	305.28	–
SE (Y)	212.29	86.27	–
Model	Hz	Hz	

NB: * Low density data here means combination of medium and low density strata (see text for explanation). Hz is hazard rate model.

Even though, the stratification of the study area was not intended for the elephant survey, a Mann-Whitney U test of the dung pile densities in HD and MD strata indicated significant difference (Mann-Whitney U=4.5, n_1 = 8, n_2 =5, P< 0.05). The difference in dung pile density between HD and LD was also significant (U=8, n_1=8, n_2=7, P< 0.05) but there was no difference between the MD and LD strata (U=16, n_1 = 5, n_2 =7, NS). Thus the MD and LD strata data were combined and analysed as one and designated Low density (Table 1). There was generally an inverse relationship between the frequency of droppings sighted and distance of droppings from the transect line (Figures 8a and b).

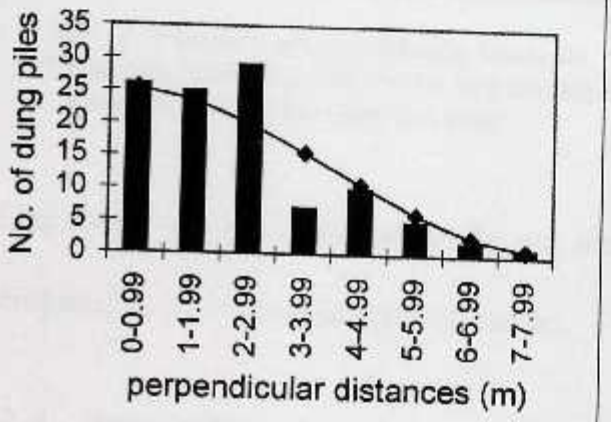


Figure 8a: Frequency distribution of perpendicular distances of elephant dungpiles in the high density stratum in the wet season [n=105, f(0)=0.24]

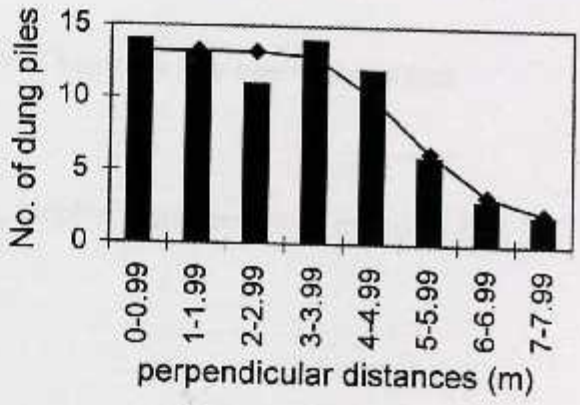


Figure 8b: Frequency distribution of perpendicular distances of elephant dungpiles:medium and low density strata combined in the wet season [n=75, f(0)=0.18]

NB: Bars are the observed number of dung piles and the threads are the expected.

Elephant numbers in 2001 wet and 2002 dry seasons were estimated using both the Steady State Assumption and the Rainfall models. However, to avoid repetition, the Steady state model is exemplified here whilst the Rainfall model has been exemplified using Year 2002 data.

Assuming Steady state, elephant numbers was estimated (E) using estimates from three variables (Y, r, D):

$$E = \frac{Y.r}{D} \times \text{Area of the stratum}$$

where Y is dung density given in Table 1, r = decay rate obtained from Barnes *et al.* (1994) and D= 19.8 is defeacation rate from Tchamba (1992). The formula for CLs estimations is detailed out in the data analysis section. The 2001 wet season estimate of elephant numbers was based on the stratification (Table 2).

Table 2 : Estimates of elephant numbers from stratified sample count in the 2001 KCA wet season survey.

Stratum	Steady state Estimate	Rainfall model Estimate*
High density	57 (24 - 90)	86 (57 -127)
Low density	89 (32 - 146)	131(80 - 232)
HD and LD combined	146 (83-209)	223(152-321)

NB: In brackets are Confidence intervals.
* The use of the Rainfall model to estimate elephant numbers has been exemplified using the year 2002 elephant data.

If the forest was at steady state in the wet season, elephant numbers was estimated as 146 compared to 223 from the Rainfall model.

4.2.2 Year 2002

In all, 58 dung piles were spotted on the same 20 transects in the 2002 dry season. All the dung data from the three strata were pooled (Table 3) and analysed as one since a Mann-Whitney U test indicated no significant difference in dung pile density between the HD and LD strata (U= 22.5, n_1 = 8, n_2 = 7, NS). Besides, total number of dung piles recorded per stratum was far less than the minimum (60) required by the DISTANCE program to achieve a satisfactory level of precision (Buckland *et al.*, 1993).

Table 3: Dung pile densities in 2002 and Standard error (SE) from the DISTANCE program.

	Dry Season 2002			
	High density stratum	Medium density	Low density stratum	Pooled
No. of dung piles	21	14	23	58
No. of transects	8	5	7	20
Total transect length (km)	14.35	8.94	12.74	36.03
Area (sqkm)	64.33	74.49	227.18	366
f(0)	0.38	0.17	0.35	0.42
Density (Y)	277.09	633.11	330.23	555.38
SE (Y)	110.35	336.06	123.62	146.93
Model	Fs	Hn	Fs	Fs

NB: Hn means Half normal.

The 2002 dropping visibility profile (Figure 8c) is much steeper compared to Figures 8a and 8b. It clearly exemplifies the underlying principle of the line transect methodology.

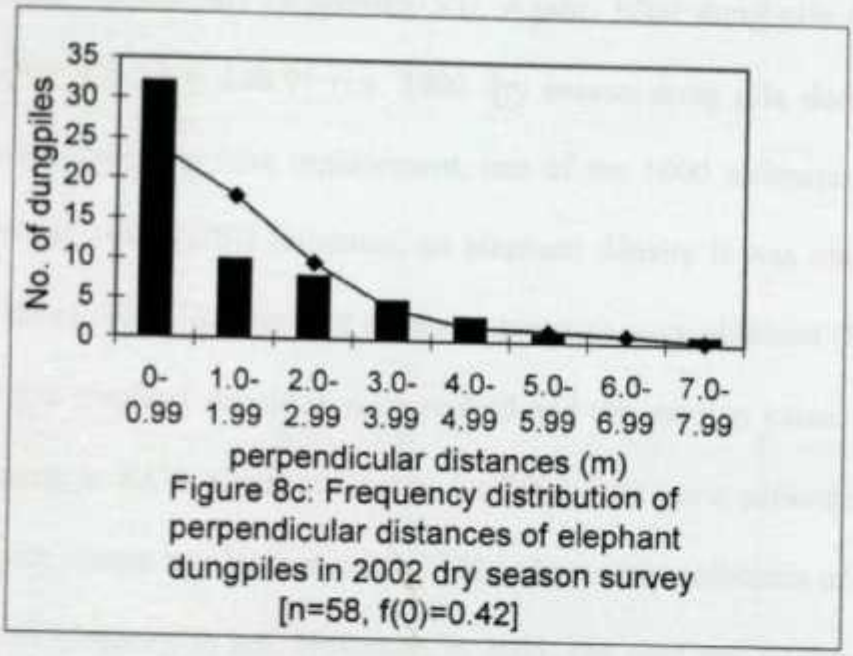


Figure 8c: Frequency distribution of perpendicular distances of elephant dungpiles in 2002 dry season survey [n=58, f(0)=0.42]

NB: Bars are the observed number of dung piles and the threads are the expected.

Comparatively, the total transect length (i.e. 36.03km) walked either in the 2001 wet and 2002 dry seasons was less than that of year 2000 (Table 4) but that was the optimum needed for a reasonable level of precision (see Figure 7).

Table 4: Elephant surveys at KCA in year 2000.

	Year 2000	
	Dry Season (DS)	Wet season (WS)
No. of dung piles (stage A-D)	247	148
Total length of transects (km)	45.59	45.59

The estimation of elephant numbers using the Rainfall model is exemplified here; The Rainfall model (i.e. equation (1) in data analysis section) was bootstrapped by plugging in the rainfall figures for the two months preceding the survey to obtain 1000 dung piles density (Y_t) estimates. In 2002 dry season, $RAIN_{t-1}$, $RAIN_{t-2}$ = 19.76, 32.23mm respectively (Appendix VI). Again, 1000 dung pile densities were generated from Y= 555.38 ± 146.93 (i.e. 2002 dry season dung pile density ± SE, Table 3). By randomly selecting with replacement, one of the 1000 estimates of Y and multiplied by one of the 1000 ($1/Y_t$) estimates, an elephant density E was obtained. By repeating this 1000 times, 1000 independent elephant densities were obtained (Barnes and Dunn, 2002). The 1000 elephant densities were ranked and the median value, i.e 0.57 elephant/sq km was taken as KCA elephant density for 2002. The same procedure was followed for the 2001 wet season to obtain another 1000 independent estimates of E and the median value was 0.61 elephant/sq km. However, in 2001, the data was analysed on stratum basis and then combined (Table 5).

Table 5: Estimates of elephant densities from the Rainfall model.

	Wet season 2001		2001 Wet season HD and LD combined	2002 Dry season	2001 Wet and 2002 Dry seasons Merged
	HD stratum	LD stratum			
Median density	1.3331	0.436	0.6094	0.5711	0.5928
LCL	0.8808	0.2655	0.4148	0.3424	0.3704
UCL	1.9877	0.7674	0.8779	0.9365	0.9183

NB: LCL and UCL are the Lower and Upper CLs.

A paired t- test showed no significant difference (t=1.11, df=19, NS) in the elephant densities per transect between the Year 2001 wet and Year 2002 dry seasons (data was natural log transformed). Hence the wet and dry seasons elephant densities generated from the bootstrapping were merged to have the merged estimate (Table 5). The frequency distribution of the 2000 estimates of elephant densities comprising 1000 independent estimates each of the wet season of 2001 and the dry season of 2002, was lognormal (Figure 9).

The overall elephant density was the median value i.e 0.59 elephants/sq km. When the 2000 estimates of density were ranked, the 26th estimate (LCL) was 0.37 and the 1975th estimate (UCL) was 0.92 elephants/sq km. The elephant numbers for each season was obtained by multiplying the median density by the area of KCA (Table 6). KCA elephant numbers was thus estimated as 217.

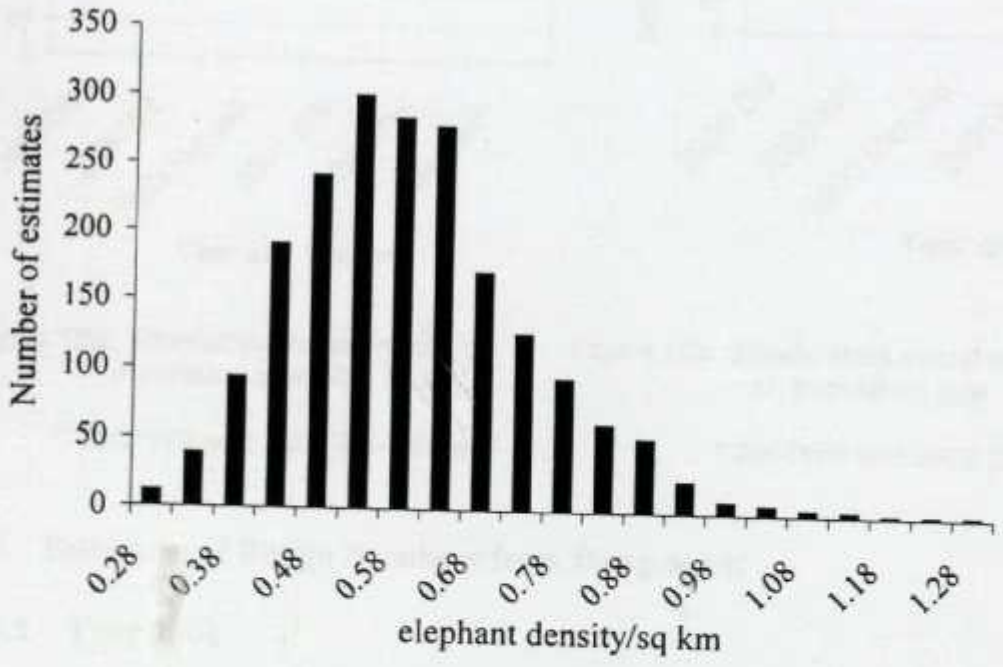


Figure 9: Frequency distribution of 2000 independent estimates of elephant density for KCA in the wet season of Year 2001 and the dry season of 2002.

There was consistency in the yearly estimates of elephant numbers when the Rainfall model was used compared to the estimates from the Steady state model, Figure 10a and

10b respectively. If one discounts the model used, the highest estimate of numbers was by EBM in the dry season of year 2000 (Table 6).

Table 6: Estimates of elephant numbers at KCA between year 2000 and 2002.

	Year 2000*			Year 2001	Year 2002	
Analysis method	DS (Feb.)	WS (Oct.)	Merged	WS (July)	DS (Feb.)	Merged
Steady state model	263(151 -375)	219(108 - 330)	241(164 -318)	146(83 - 209)	246(107- 385)	163(107 - 219
Rainfall model	239 (165-352)	228(158-337)	233(160-347)	223(152 - 321)	209(125- 343)	217(136 -336)

* Year 2000 estimates by EBM (2000). NB: In brackets are 95% Confidence Intervals. Table 6 was used to plot Figures 10a and 10b.

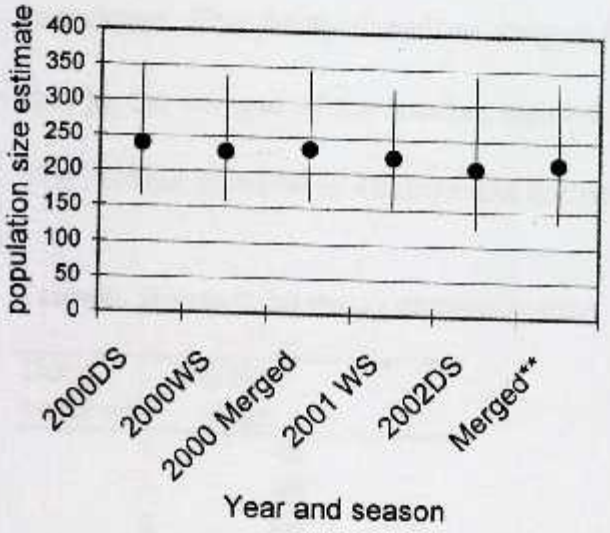


Figure 10a: Rainfall model estimates of population size with CLs.

** 2001WS and 2002 DS merged.

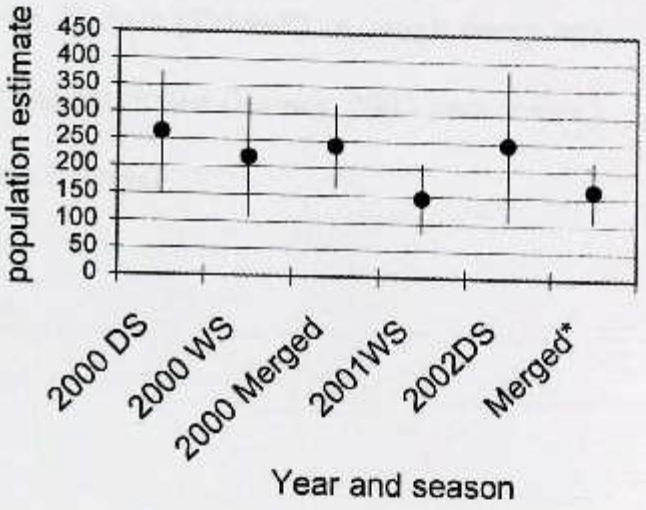


Figure 10b: Steady state model estimates of population size with CLs.

* 2001WS and 2002 DS merged.

4.3 Estimates of Bongo Numbers from Dung count

4.3.1 Year 2001

A total of 6 bongo dungs were seen on the twenty transects in the 2001 wet seasons (Table 7). The data was analysed on seasonal basis since there was no justification to maintain the stratification. The index of bongo abundance was 0.17/km.

To estimate bongo numbers using the Steady state assumption model, the decay of bongo dungs were monitored since wild bongo dung decay rate was not available.

Table 7: Abundance of bongo droppings in the 2001 survey.

	Year 2001
	WS
No. of bongo dungs	6
No. of transects	20
Total transect length (km)	36.03
No. of bongo dungs/km	0.17

Only five fresh bongo droppings were seen during the surveys and were monitored. The decay durations ranged from 41-71 days (Table 8). A rough decay rate, that is, the inverse of the median survival day was estimated (Barnes, 2003 pers comm.). The median survival is 46 days and the inverse is 0.02/day.

Table 8: Bongo dung decay duration in KCA

Dung serial no.	Duration days
1	46
2	46
3	60
4	71
5	41

NB: The wide variation in the decay days was that droppings were monitored both in the dry and wet seasons.

Bongo defecation rate was 4.4 droppings/day (Hoppe-Dominik, 2003 pers comm.). Reliable bongo dungs density could not be obtained from the DISTANCE program because the number of dung patches seen on the transects was far below the 60 needed for a reasonable level of precision. Therefore, the number of bongo was not estimated from the count of droppings. If the rate of sighting bongo dung was constant from transect to transect, it would still be impossible to get a reasonable population

estimate after 65km walk (Appendix VII). Only one bongo was seen throughout the study period. Bongo footprint observations and measurements clearly distinguished not more than three bongos in a group.

4.3.2 Year 2002

Four bongo dung patches were recorded on the twenty transects in the 2002 dry season (Table 9). In a subsequent bongo survey that same year, no bongo dung was seen. Again, bongo dung density and numbers could not be estimated from the dung count because of insufficient data.

Table 9: Abundance of bongo droppings in the 2002 surveys.

	Year 2002 Dry season	Year 2002* Wet Season
No. of bongo dungs	4	0
No. of transects	20	25
Total transect length (km)	36.03	25
No. of bongo dungs/km	0.11	0

* In the 2002 wet season, each transect was 1km and data was collected by EBM (the author included) /Liberian Wildlife Officers joint team.

4.4 Estimates of Bongo Numbers from Camera traps

Fourteen 24 exposure 200 ASA or 400 ASA films were used (i.e 336 exposures were taken), but no bongo was photographed. Therefore, no estimate could be made using the capture/recapture method.

4.5 Peoples perception of Bongos at KCA

Thirty five (i.e 83%) out of the 43 farmers had knowledge about the existence of bongos. The owner of one of the farms monitored the footprints of bongo that led off the forest into an adjoining cocoa farm in Antwikwaa in order to trap it. Fifteen (35%) had not seen bongos on their farms since 1990 whilst 33 % had seen them in the last 5 years.

Two farmers at Onomakwa and Kruwa said they had at a time seen 15 bongos in a group but could not indicate when. However, their assertion seemed to corroborate with the information given by an old experienced hunter who used to hunt in KCA before the area was designated a wildlife reserve. The hunter added that he killed 7 bongos mainly in the Afiaso area throughout his hunting expeditions 15 years ago.

Four (9%) of the farmers alleged that they have had some of their young cocoa pods eaten by bongos and others (42%) reported cocoyam and /or cassava, and yam leaves eaten.

Eleven (34%) out of 32 field staff said they had seen bongo signs on their patrols since year 2000.Three (9%) reported of always encountering bongo signs in their patrols. Nineteen (59%) thought that the bongo population was increasing. And twenty four (75%) had not seen bongo dead on their patrols. Of the farmers and staff who filled questionnaires, twenty eight (37%) have heard of taboos about the killing of bongos.

4.6 Estimates of Duiker Numbers from Dung count

4.6.1 Year 2001

Maxwell, Black and Yellow-backed duiker droppings spotted on 15 transects in the 2001 wet season were 79, 24 and 0 respectively (Table 10). The duiker survey was carried out on the same 20 transects used to survey elephants and bongos. But five transects were flooded. The small- sized duiker droppings were difficult to survey under such conditions. Besides, duiker dropping density would have been underestimated. Therefore, duikers were not surveyed on five transects. This reduced the total transect length to 26.83km. The indices of duiker abundance ranged from 0 to 2.94 for Yellow-backed and Maxwell duikers respectively (Table 10).

Table 10: Duikers dropping abundance in the 2001 wet season.

	Year 2001 wet season	
	No. of droppings	Index
Yellow-backed duiker	0	0
Maxwell duiker	79	2.94
Black duiker	24	0.89
No. of transects	15	
Total transect length	26.83 km	

Duikers were surveyed only in the 2001 wet season because of the high leaf falls in the dry season. Hence no duiker pellet count was carried out in the 2002 dry season. The relationship between the frequency of droppings and dropping sighting distances, Figure 11a and b followed a similar pattern like that for elephants. However, droppings seen beyond 5m from the transect centerline were treated as outliers and discarded in order to improve the precision of the estimates (Buckland *et al.*, 1993).

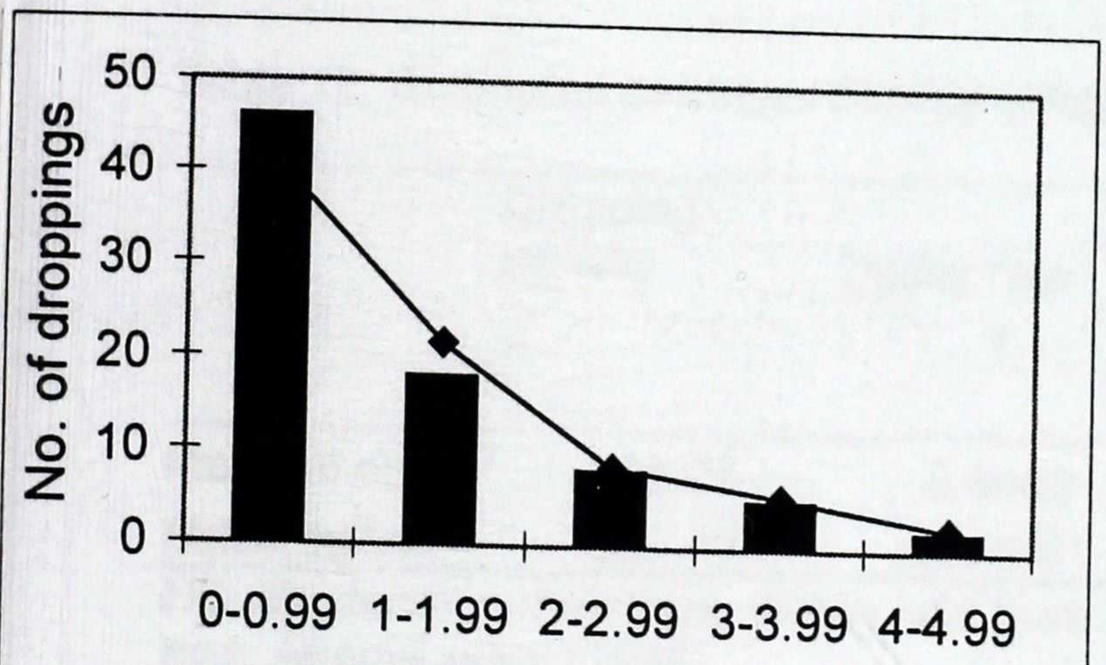


Figure 11a: Frequency distribution of perpendicular distances of Maxwell duiker droppings in the 2001 wet season [n=79, f(0)=0.58]

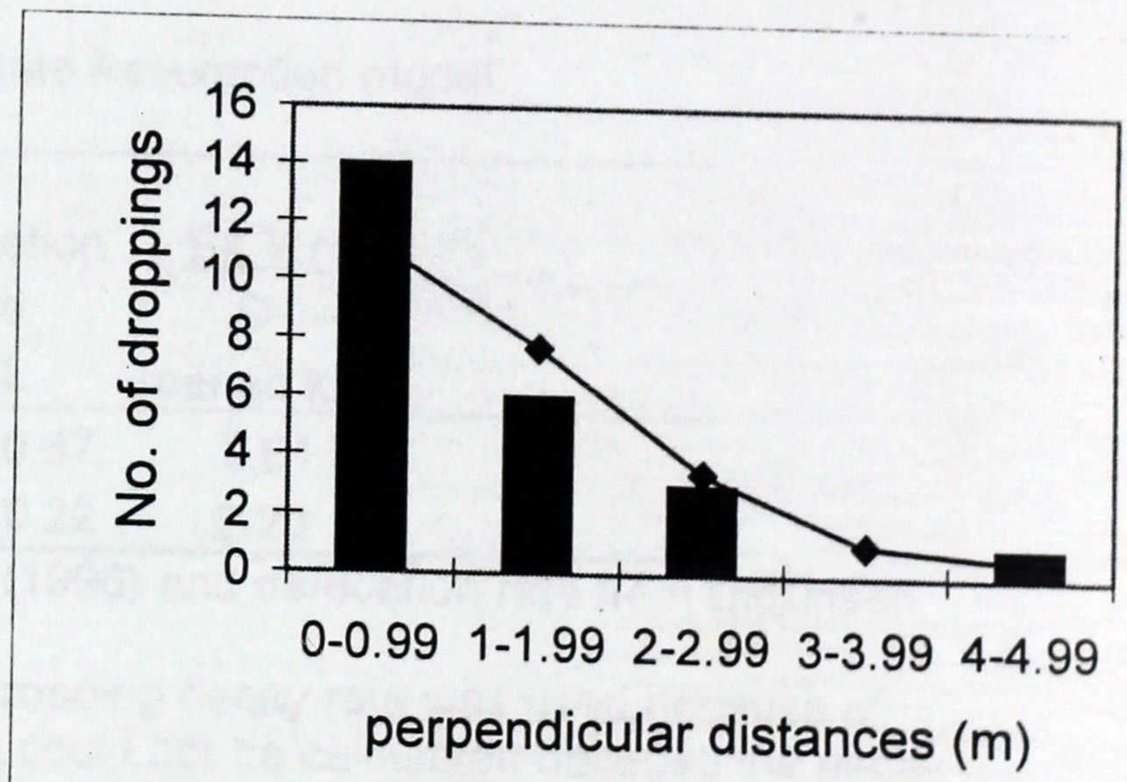


Figure 11b: Frequency distribution of perpendicular distances of Black duiker droppings in the 2001 wet season survey [n=24, f(0)=0.50]

Maxwell duiker dropping density estimated from the DISTANCE program was about four times that of the Black duiker (Table 11).

Table 11: Duiker dropping densities and SEs from the DISTANCE program.

	Wet Season 2001	
	Maxwell	Black duikers
Area (sqkm)	366	366
f(0)	0.58	0.5
Density (Y)	858.28	223.4
SE (Y)	285.76	88.89
Model	Fs	Fs

Using the Steady State assumption model (McClannahan, 1986) for the purpose of comparison with previous estimates, the decay and defecation rates in Table 12, Maxwell and Black duiker densities were estimated as 9.61 and 2.20 km^{-2} respectively (Table 12). Yellow- backed duiker density could not be estimated but one Yellow-backed duiker was directly seen off the transects. There was an inverse relationship between the density and the size of the duiker species as exemplified in Table 13.

Table 12: Estimates of duiker density using Steady State Assumption model.

	Dropping density Y	Decay rate r	Defeacation Rate D ± CL	$E = \frac{Y.r}{D}$ (per sq km)
Maxwell duiker	858.28	0.0469	4.19 ± 0.57	9.61
Black duiker	223.40	0.0469*	4.76 ± 0.22	2.20

NB: E= density of duikers, decay rate from Dickinson (1996) and defecation rate from Dickinson and Abedi-Lartey (1995).

*For the estimation of Black duiker density, Maxwell dropping decay rate was used because of lack of data. Similarly, CLs estimates for the densities could not be calculated because the decay rate had no CL.

Table 13: Estimated mammalian density and standing crop biomasses of some reserves in the rainforests of West and Central Africa.

Protected Area	Species	Density (sq km)	Mass (kg)	Biomass (kg/km^2)	Authors
(a) Ghana					
Kakum	L. a cyclotis	0.59**	1700	1003	This study
	C. maxwelli	9.61	10	96.1	This study
	C. niger	2.20	24	52.8	This study
Bia	L. a cyclotis	0.45	1700	765	Herffernan and Graham(1999)
Ankasa	L. a cyclotis	0.04	1700	68	Danquah et al., (2001)
(b) Cote D'ivoire					
Tai	L. a cyclotis	0.23	1700	391	Merz (1986)
Azangny	L. a cyclotis	0.22	1700	374	Merz and Hoppe-Dominik(1991)
(c) Liberia					
Sapo	L. a cyclotis	0.24**	1700	408	Barnes and Dunn (2002)
(d) Sierra Leone					
Gola east Forest	L. a cyclotis	0.27	1700	459	Merz and Roth (1984)
(e) Gabon					
Lope	L. a cyclotis	2.0	1700	3400*	White et al., (1993)
	C. callipygus	14.4	20.0	288	Feer (1988)
	C. dorsalis	8.1	22.0	178.2	Feer (1988)
	C. monticola	70.0	4.7	329*	Dubost (1980)
Central Afr.Rep.					
(f) Congo					
Odzala	L. a cyclotis	0.9	1700	1530	Fay and Agnagna (1991)
(g) Zaire					
Ituri forest	L. a cyclotis	0.3	1700	510	
	C. monticola	12.0	4.7	56.4	Koster and Hart (1988)
	Large duikers	6.45	18.5	119.33	Koster and Hart (1988)

** estimated using the rainfall model. NB: C.-Cephalophus, L. a- Loxodonta africana

*Biomasses were recalculated.

A crude and causual comparison should be made. Congnissance should be taken on the use of different methods (dropping counts, track) in the density estimations by the various authors.

4.7 Elephant Size distribution and Biomass estimation

A total of 161 dung boli were measured in KCA. The circumferences ranged from 17.5-56cm. Those with boli size 35-40cm made the highest contribution to the boli records (Figure 12a). Out of the 161 boli, 71 were boli from crop raiding elephants measured on the crop fields around KCA. Most of the elephants involved in crop raiding had boli circumferences that ranged from 28-43cm (Figure 12b). A Kolmogorov-

Smirnov test indicates no significant difference between all KCA elephants and their crop-raiding counterpart [D_{max}= 0.09, N_1=161, N=71, NS].

KCA boli size distribution was similar to the boli size distribution of Marahoue NP elephants in Cote d'Ivoire (Figure 12c). A total of 259 elephant boli circumferences were measured at Marahoue. Similar to the KCA peak boli frequency class, the 35-40 cm class made the highest contribution to the boli structure of elephants at Marahoue NP (Figure 12c). There was no difference in the boli size distribution of KCA and Marahoue populations [D_{max} =0.124, N_1= 161, N_2= 259,NS].

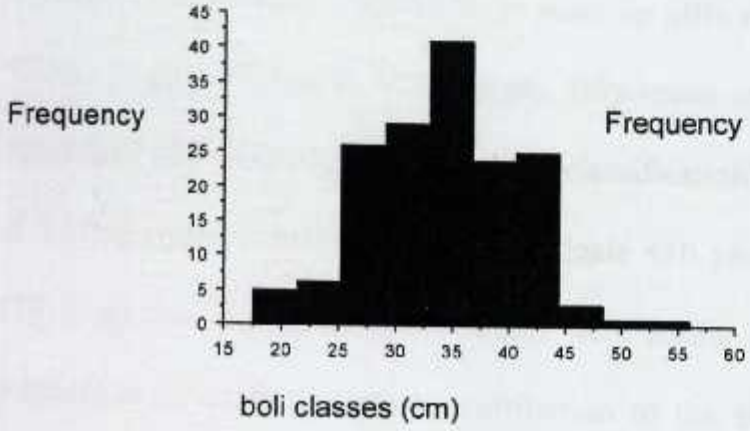


Figure 12a: Frequency distribution of dung boli circumference of KCA elephants fresh dung piles. n = 161 boli

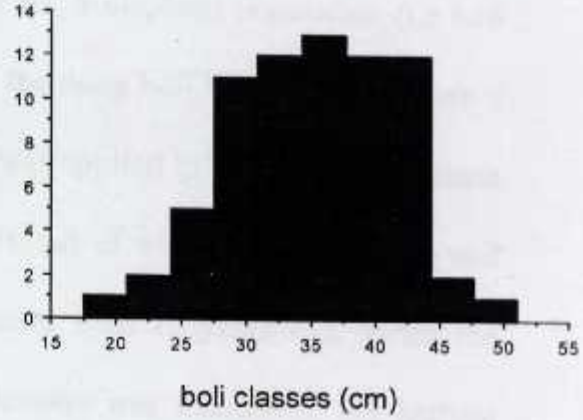


Figure 12b: Frequency distribution of dung boli circumference of crop raiding elephants at KCA. n = 71 boli

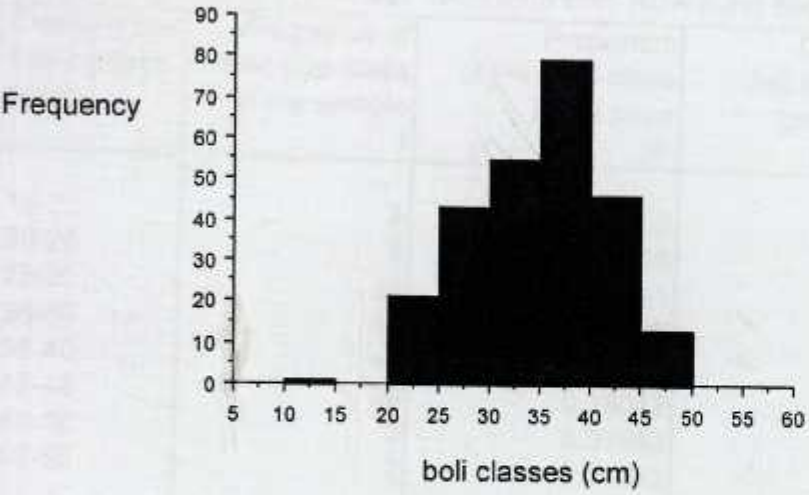


Figure 12c: Frequency distribution of dung boli circumference of elephants at Marahoue National Park, Cote d'Ivoire. n = 259 boli (Data from EBM 2002 July survey)

Generally, fewer droppings were found in the < 20cm and > 45cm boli classes in all KCA elephants, their crop raiding counterparts and at Marahoue (Figures 12a, b, c).

If the boli-age curve of known-age wild elephants at Kasungu NP, Malawi (Figure 3) was applied, the ages of the KCA elephants were determined from the boli data (see section 3.4.3 for further explanation). There were possibly 5 infants a year old and three males older than 25 years in the KCA population. The infants droppings measured were in association with the family groups whose boli circumferences were also captured. Thus the individual infants were distinguishable by the individual boli sizes. Eggert (2001) estimated the juvenile population to make up 20% of KCA elephant population (i.e boli <32cm at age <10 years). In this study, fifty-seven of the dung boli had circumferences ≤ 32cm and 104 were >32cm. If Eggerts' classification was applied to the working estimate of 217 elephants, there were 43 individuals <10 years out of which 5 were infants and 174 elephants (i.e those boli >32cm) were adults more than 10 years old. When the proportion of each size class contribution to the biomass was examined, the highest contribution was from 35-45cm boli class (Table 14).

Table 14: Summary of biomass estimation from KCA dung boli data.

Elephant boli size-classes (cm)	Frequency of that size-class in the sample f	Proportion of that size-class in the popn f/n	Density of that size-class (per sq km) (f/n) x E*	Body mass of an animal in that size-class (kg)**	Total biomass of the size-class (kg/sq km)
15-20	5	0.03106	0.0183	250	4.58
20-25	5	0.03106	0.0183	375	6.87
25-30	28	0.17391	0.1026	500	51.30
30-35	42	0.26087	0.1539	850	130.83
35-40	47	0.29193	0.1722	1470	253.19
40-45	29	0.18012	0.1063	1700	180.66
45-50	3	0.01863	0.0110	1700	18.69
50-55	2	0.01242	0.0073	1700	12.46
Total =	161	1.00	0.59		658.58

*E is the median elephant density (i.e 0.59/sqkm) and n = 161. ** Masses were estimated from Figure 12 in Laws (1966). Drent and Prins (1987) adult mass of 1700kg was maintained after boli circumference > 40cm because of the marked sexual dimorphism.

The biomass of KCA elephants was also directly estimated by multiplying the conservative mean adult elephant mass of 1700kg by the density of elephants i.e. 0.59 (Plumptre and Harris, 1995). This works up to 1008kg/km^2. This was done for the purpose of comparison with other estimates in literature (see Table 13).

4.8 Bongo and Duiker Biomass Estimations

The biomass of bongos was not estimated because of lack of data as was the case with Yellow-back. By multiplying the estimated masses of 10kg, 24kg (Kingdon, 1997) respectively for Maxwell and Black duikers by their densities i.e. 9.61 and 2.2/sq km, the biomasses worked up to 96.1 (i.e. 10 x 9.61), 52.8 (24 x 2.2) kg/km^2 for Maxwell and Black duiker respectively (Table 13).

4.9 Spatial Distribution of Elephants in 2001 and 2002

Figure 13 shows the distribution map of elephant dung piles densities in the 2001 wet and 2002 dry seasons. It is important to note that the distribution of elephant dung densities in the grid cells reflect the distribution of transects. In order to identify the variables that significantly influence elephant abundance and distribution, Spearman correlation and log- linear analysis were performed with water sources, fruiting spots, gaps in the forest, illegal activities, vegetation types, etc as the predictors variables.

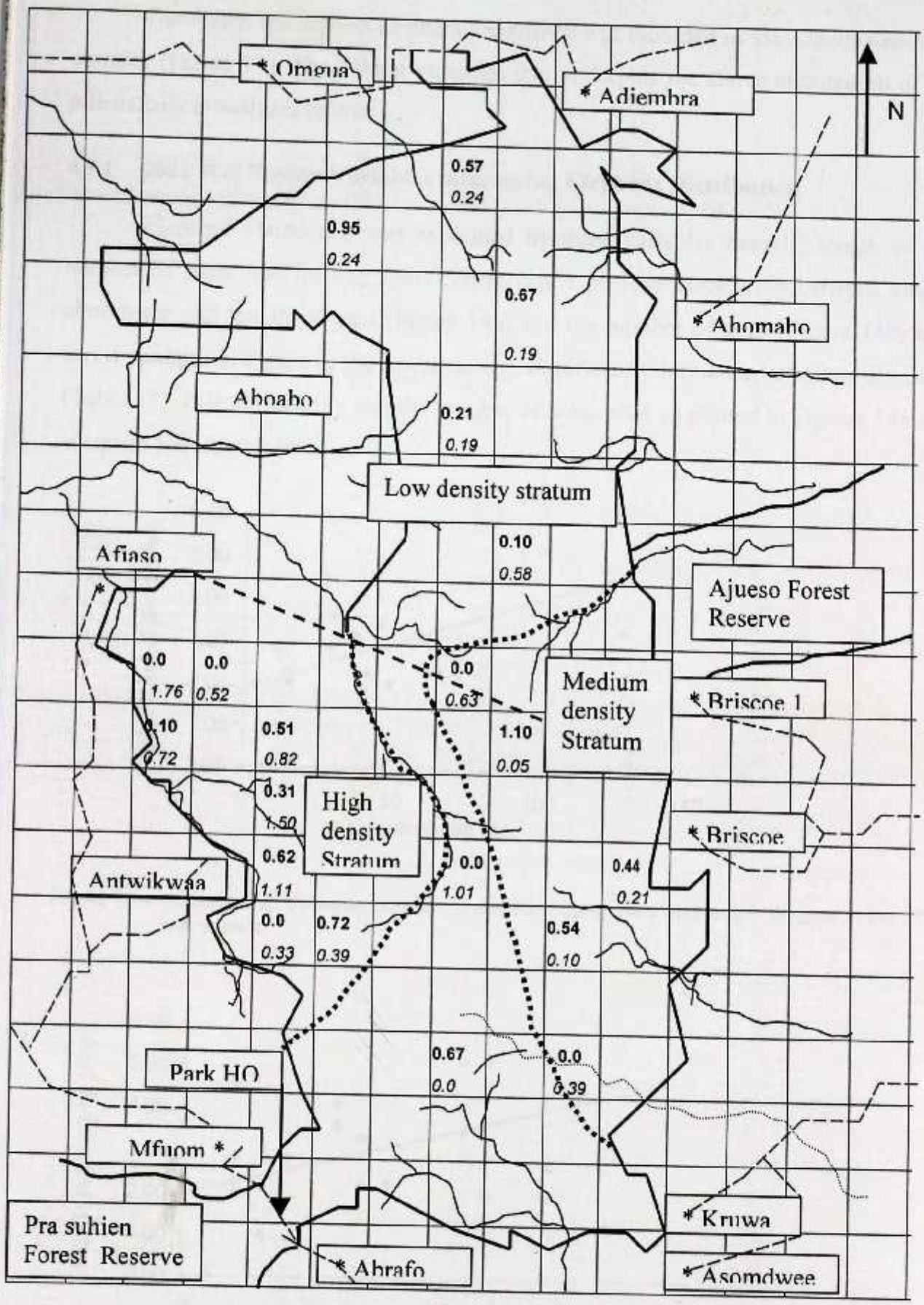


Figure 13: Map of KCA showing the density of elephant dungpiles in the three strata during the survey. The italized and bold figures are densities for the 2001 wet and 2002 dry seasons respectively.

Generally, the highest elephant abundance was recorded in the Antwikwaa-Afiaso corridor (Figure 13). The habitat variables that underpins the above distribution of dung pile density is outlined below:

4.9.1 2001 Wet Season Variables influencing Elephant Distribution

Elephant abundance was explained by three variables namely, length of gaps, number of gaps, and fruiting spots. There was a positive correlation between elephant abundance and length of gaps (Figure 14a) and the number of gaps (Figure 14b) in the forest canopy. The gaps in the forest canopy significantly influenced elephant abundance (Table 15). It is noteworthy that the number of dung piles as plotted in Figures 14a and b is square root transformed.

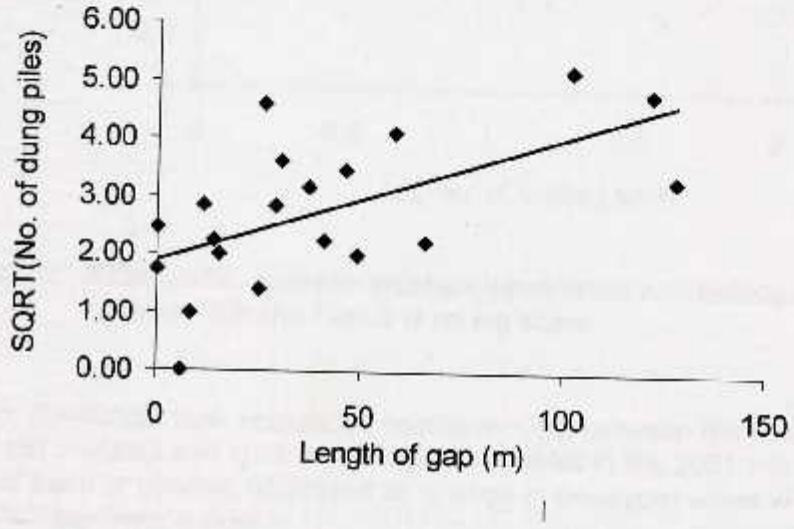


Figure 14a: Relationship between number of elephant dung piles and length of gaps in the 2001 wet season.

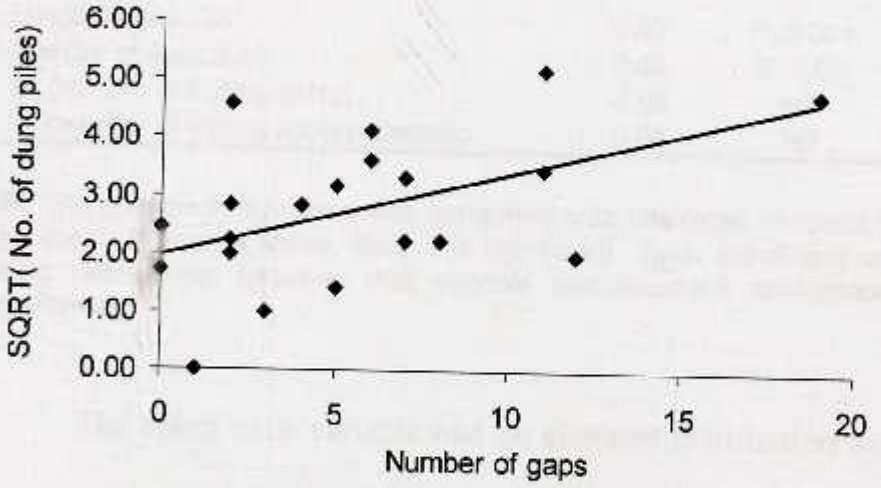


Figure 14b: Relationship between number of elephant dung piles and number of gaps in the forest canopy in the 2001 wet season.

A quadratic term however, best explained the relationship between elephant distribution and fruiting spots (Figure 14c). There was a threshold of fruit abundance (approx. 2.80 fruiting tree spots/km) beyond which fruits seemed less attractive.

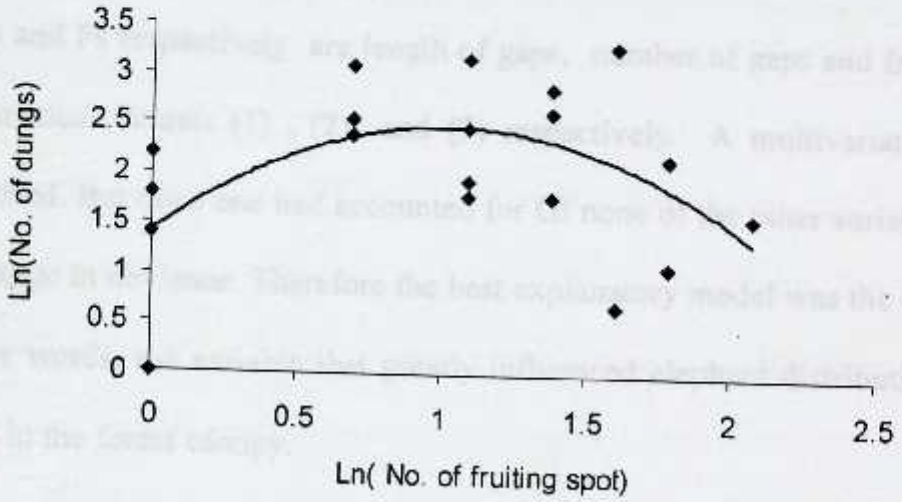


Figure 14c: Relationship between elephant abundance and fruiting spots in the 2001 wet season. NB: the Figure is on log scale.

Table 15: Spearman rank correlation coefficients (r_s) between the number of dung piles per transect and suite of ecological variables in the 2001 wet season and the effect of each of variable (indicated as change in deviance) alone when it was added to a null log-linear model.

Variable	r_s	Level of significance	Change in deviance	df	Level of significance
Length of gap (Gl)	0.62	P<0.001	10.59	1	P<0.01
Number of gaps (Gn)	0.45	P<0.05	7.55	1	P<0.01
Ln (number of fruiting spots)	-0.06	NS	0.18	1	NS
Ln (number of fruiting spots)-quadratic	0.06	NS	8.53	2	P<0.05

NB: The change in deviance was compared with tabulated chi-square; if the deviance is greater than the chi- square value, then it is significant. Each significant variable means there was a strong relationship between that variable and elephant abundance. Fruiting spots was log-transformed.

The effect each variable had on elephant distribution and abundance was further investigated when fitted to the null model in a log-linear analysis. Again, gaps in the forest were critical factors that significantly influenced elephant abundance (Table 15).

Fruiting spots (quadratic) was also a significant determinant of elephant distribution (Table 15). The individual equations that describe elephant abundance (D) are as follows:

$D = \exp [1.666 + 0.2457Gl]$ eqn (1)

$D = \exp [1.723 + 0.2483Gn]$ eqn (2)

$D = \exp [1.452 + 2.277LnFs - 1.110(LnFs)^2]$ eqn (3)

where Gl, Gn and Fs respectively are length of gaps, number of gaps and fruiting spots in the mathematical models (1) , (2) and (3) respectively. A multivariate log-linear analysis was tried. But once one had accounted for Gl none of the other variables made a significant change in deviance. Therefore the best explanatory model was the one with Gl alone. In other words, the variable that greatly influenced elephant distribution was the length of gaps in the forest canopy.

4.9.2 2002 Dry Season Variables influencing Elephant Distribution

None of the variables identified in the 2001 wet season influenced elephant abundance in the following dry season. Variables such as raphia abundance, fruiting spots and spots where elephants were killed within three months prior to the season's survey, were investigated. But none significantly affected elephant abundance (Table 16). Unexpectedly, water sources did not also markedly influence elephant abundance (Spearman correlation, $r_s = 0.167$, NS). On the ground observation seem to suggest that elephants avoided areas where some were killed. With this factor, few droppings were spotted in the areas known to record high elephant densities.

Table 16: Spearman rank correlation coefficients (r_s) between number of dung piles per transect and variables in the 2002 dry season and the effect of each variable by itself when added to the null model in a log-linear analysis.

Variable	r_s	Level of significance	Change in deviance	df	Level of significance
Length of raphia	-0.069	NS	0.363	1	NS
Number of fruiting spots	0.276	NS	0.094	1	NS
Carcass distance*	0.125	NS	0.159	1	NS

* Elephant carcass distance to transect.

Six elephants were illegally killed in KCA within two to three months prior to the 2002 dry season survey. The numbers killed could be higher but these carcasses were the ones found. Prior to the event, KCA elephants had been relatively undisturbed. On the ground observation seem to suggest that elephants avoided areas where some were killed. With this factor, few droppings were spotted even in areas known to record high elephant densities.

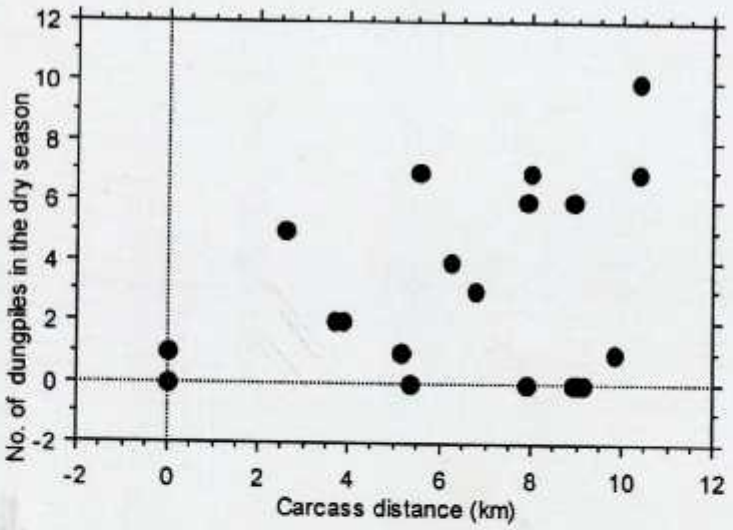


Figure 15: Relationship between elephant density and carcass distance.

The Illegal activities recorded during the 2001 wet and 2002 dry season surveys and their influence on elephant distribution is presented in section 4.11 on illegal activities.

4.10 Spatial Distribution of Bongos in 2001 and 2002

Bongo activities were more concentrated in the Antwikwaa area whilst no activity was observed in the extreme south of the study site (Figure 16). The bongo distribution map (Figure 16) shows all signs of bongos spotted on and off transects in 2001 (solid circles) and 2002 (solid squares). Fewer signs were spotted in the middle of KCA. Signs of bongos were more widely distributed in the wet than the dry seasons.

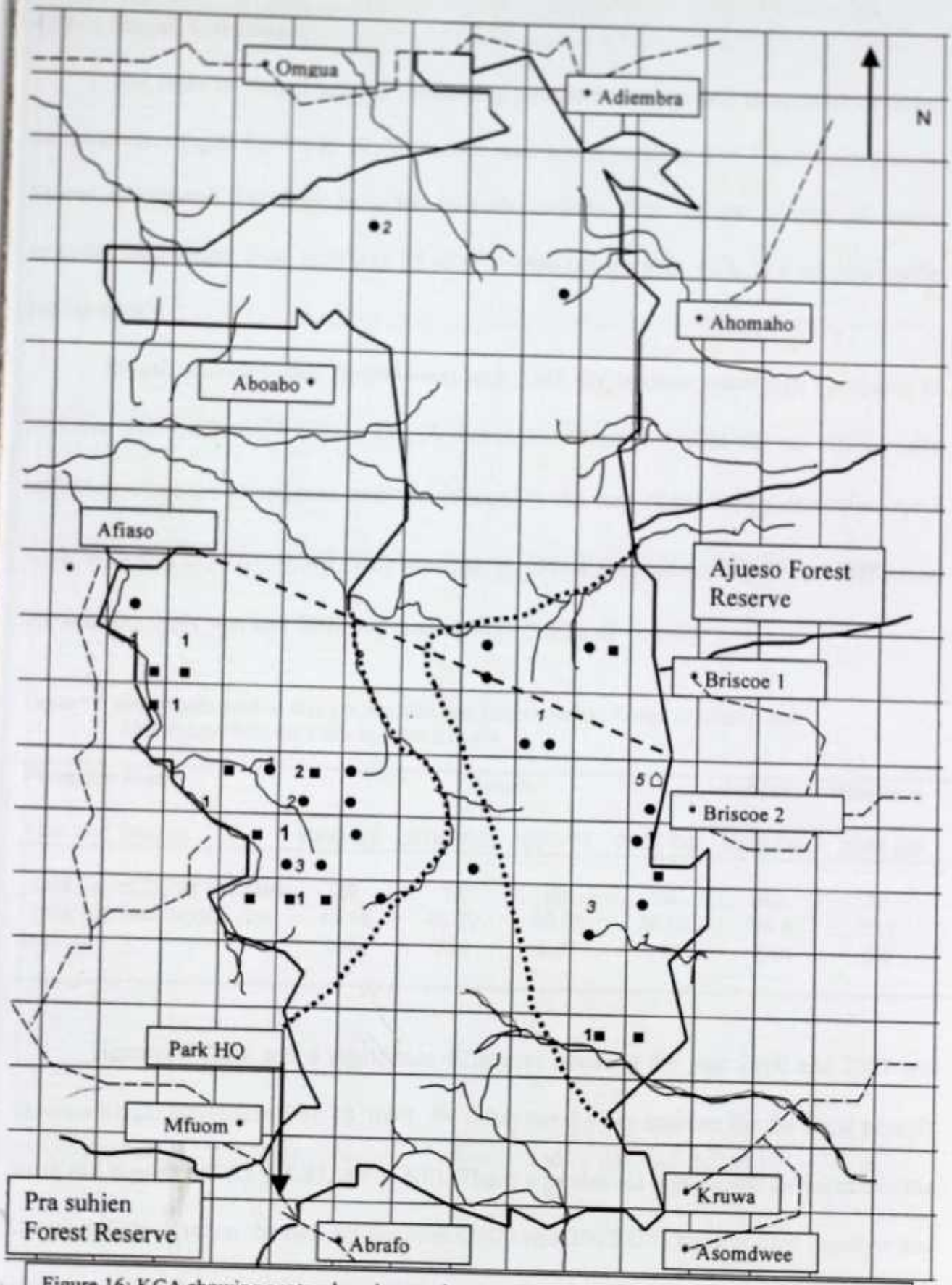


Figure 16: KCA showing spots where bongo signs were seen on and off transect in year 2001 and 2002. The italized and bold figures in the grid squares are number of dungs seen in 2001 and 2002 respectively. The symbol ● refers to 2001 signs and ■ refers to 2002.The spot where a live bongo was seen is denoted by ⌂

NB: The intervals between any two feeding sign spots less than 1km were not represented on the map.

4.11 Illegal Activities

The signs of illegal activity (excluding poachers cuttings and footprints) recorded on transects, ranged from 0 to 10, in the wet season compared to 0 to 7 in the dry season. Snares dominated the signs recorded in both seasons. The highest number of snares recorded in a single field visit was 35 after a 3-km off transect walk in a predominantly raphia sites.

Illegal activities seen in 2001 wet and 2002 dry seasons were high compared to previous surveys in KCA (Table 17). However, the illegal activities did not significantly influence elephant abundance and distribution in the wet (Spearman Correlation r_s= -1.79, NS) and dry (r_s= 0.058, NS) seasons. A G-test showed no significant difference between the 2001 wet and 2002 dry seasons (G= 0.008, df=1, NS).

Table 17: Illegal activities at Kakum and Ankasa Conservation Areas in Ghana and Marahoue National Park in Côte d'Ivoire.

Protected Area	Kakum				Ankasa	Marahoue
Year and Season	2000 DS	2000 WS	2001WS	2002 DS	2001 DS	2002 DS
Total no. of illegal activites	20	18	32	33	42	12
Total transect length (km)	45.59	45.59	36.03	36.03	36.8	13.3
Indices	0.44	0.39	0.97	0.89	1.14	0.9

However, there was a significant difference between the year 2000 and 2001 wet seasons illegal activities (G=6.18, df=1, P< 0.05) but the dry seasons for the same periods were not significant (G =3.83, df=1, NS). There was also no significant difference in the illegal activities when the two dry seasons (2000 and 2002 DS) were pooled together and compared with the two wet seasons (2000 and 2001WS) (G = 0.01, df =1, NS).

Comparatively, Ankasa illegal activity in the 2001 dry season was high. It was significantly different from KCA in the 2000 dry season (G= 7.63, df=1, P< 0.05). Also, the 2002 dry season illegal activities in KCA were not significantly different from that of

Marahoue (G= 0.001, df=1, NS). The G- test figures are G- adjusted with the William's correction.

4.12 Habitat Use by Elephants and Bongos

Raphia swamps and the various vegetation types traversed were noted by recording their lengths on the 20 transects walked in the wet and dry seasons. Less disturbed vegetation type (Appendix III) was not encountered.

The abundance of elephant dung piles in the raphia swamps and areas without raphia were not significantly different (Table 18). However, elephant abundance in the Medium and Very disturbed vegetation types was significant in the dry season (Table 18).

Table 18: Effect of habitat type on elephant abundance in KCA.

	Indices of dung pile abundance			Indices of abundance in Meduim	Very		Level of
	Raphia	Non - raphia	G-test*	disturbed	disturbed	G-test	Significance
Season							
2001 Wet	9.14	4.47	2.29 NS	4.42	5.96	0.66	NS
2002 Dry	0.8	1.78	0.91 NS	2.66	0.58	10.41	P< 0.05

*G-test values were adjusted with the William's correction.

When Jacobs preference test was conducted using the data on the vegetation types in Table 18, elephants showed a weak preference for medium disturbed vegetation (Jacobs Index = 0.23) in the dry season. Bongo dung data was inadequate to go through this analysis. However, plant species seen eaten by bongos and elephants throughout the period (i.e. 2001 and 2002) were recorded either on or off transects. Fifty-two and Forty-five plants species were identified eaten by bongos and elephants respectively (Table 19a and 19b).

Table 19a: Species list of plants eaten by Bongos in KCA

SCIENTIFIC NAME	LOCAL NAME	FAMILY	REMARKS (Location seen)
Albizia adianthifolia*	Pranpran	Mimosaceae	
Alchornea cordifolia*	Ogyamma	Euphobiaceae	on logging road and by Kakum river
Aningeria robusta*	Asamfona	Sapitaceae	"
Annona Squamosa*	Aperede	Annonaceae	
Baphia afzelia*	Edwiniakoa	Papilionaceae	
Baphia nitida	Odwene	Papilionaceae	"
Baphia pubescens	Odwenkobiri	Papilionaceae	"
Bidens pilosa		Asteraceae	by Kakum river
Blighia sapida	Akyen	Sapindaceae	"
Cassia occidentalis	Mmofraborode	Papilionaceae	
Chromolaena ordorata**	Acheampong	Asteraceae	"
Combretum mucronatum*	Hweremunini	Combretaceae	"
Craterspermum caudatum*	kwaatadua	Rubiaceae	on logging roads
Culcasia angolensis			
Dacryodes klaineana	Kwabedua	Burseraceae	
Enantia Polycarpa	Wisamfenini	Annonaceae	"
Euadenia eminens*	Dinsinkro	Capparidaceae	on logging road
Euphorbia hirta		Euphorbiaceae	"
Flacourtia flavescens	Pitipiti	Flacaurtiaceae	"
Fleurya aestuaris	Aseseaa		by Kakum river
Garcinia afzelii**	Nsoko	Guttiferae	on logging road
Grewia carpinifolia	Sono-mprew	Tiliaceae	
Guarea cedrata	Kwabohoro	Meliaceae	on logging road
Hymenostegia afzelii	Nkuronyan	Caesalpiniaceae	"
Hoslundia opposita*	Aberewa-ani-nsu	Lamiaceae	"
Isolona campanulata	Duawisa	Annonaceae	"
Landolphia calabarica		Apocynaceae	"
Landolphia owerensis	Abontore	Apocynaceae	"
Malacantha alnifolia	Fafaraha	Sapotaceae	
Mallotus oppositfolius**	Satadua	Euphorbiaceae	on logging road
Mammea africana*	Bompaja	Guttiferae	
Massularia acuminata		Rubiaceae	on logging road
Milicia excelsa*	Odum		
Myranthus arboreus*	Asaben	Moraceae	"
Mytragyna inermis	Akyen	Rubiaceae	
Newboldia laevis	Okumanini	Bignoniaceae	"
Palisota hirsuta	Sommeyin		in swampy area
Paullina pinnata	Toantini	Sapindaceae	"
Petersianthus macrocarpus		Lecythiadaceae	on logging road
Phyllanthus amarus	Osoma	Euphorbiaceae	
Polyalthia longifolia		Annonaceae	
Polyalthia oliveri	Ofiawoshe	Annonaceae	
Psydrax subcordata	Ntetiadupon		
Pteris sp			seen also in cocoa farms
Richordia brasiliensis		Rubiaceae	
Setaria megaphylla	Awuram	Poaceae	
Sida acuta	Tweta	Malvaceae	
Strombosia glacescens*	Afena	Olacaceae	"
Thalia geniculata	Dodoben	Marataceae	in raphia swamp
	Asadwere*		
	Mogoahoma		
	Nsansonoakoa		

NB:* Species eaten by both bongos and elephants

** Species was also eaten by Yellow-backed duiker

Table 19b: Species list of plants eaten by elephants in KCA.

Scientific name	Local name	Family name
Albizia adianthifolia	Pranpran	Mimosaceae
Albizia zygia	okoro	Mimosaceae
Alchornea cordifolia	Ogyama	Euphorbiaceae
Aningeria robusta	Asamfona	Sapotaceae
Annona Squamosa	Aperede	Annonaceae
Antiaris africana	Kyenkyen	Moraceae
Antrocaryon micraster	Aprokuma	Anacardiaceae
Balanites wilsoniana	Kabowoo	Zygophyllaceae
Baphia afzelia	Edwiniakoa	Papilionaceae
Carica papaya	Borofere	Caricaceae
Citrus sp		Rutaceae
Combretodendron macrocarpum		Lecythidaceae
Combretum mucronatum	Hweremunini	Combretaceae
Craterispernum caudatum	Kwaatadua	Rutaceae
Desplatsia dewevrei	Wisamfe	Tiliaceae
Dioscorea lecardii	Ahabayere	Hernandiaceae
Entandrophragma sp		Meliaceae
Euadenia eminens	Dinsinkro	Capparidaceae
Ficus capensis	Yankyerene	Moraceae
Hoslundia opposita	Aberewa-ani-nsu	Lamiaceae
Irvingia gabonensis	Abesebuo	Irvingiaceae
Klanedoxa gabonensis	Koroma	Irvingiaceae
Mammea africana	Bompaja	Guttiferae
Microdermis puberla	Fotie	Pandanaceae
Milicia excelsa	Odum	
Milletia zechiana	Fafraha	Papilionaceae
Musanga cecropoides	odwuma	Moraceae
Myrianthus arboreus		Moraceae
Omphalocarpum sp		Asclepiadiaceae
Ongokea gore	Bodwe	Olacaceae
Panda oleosa	Boba	Pandaceae
Parinari excelsa	Opam	Rosaceae
Pycnanthus sp		Myristicaceae
Raphia hockeri	Adobe	Palmae
Rauwolfia vomitoria	Kakapenpen	Apocynaceae
Ricinodendron heudelotii	Wamma	Euphorbiaceae
Strombosia glaucescens	Afena	Olacaceae
Strychnos aculeata		Loganiaceae
Tetrapleura tetraptera	Prekese	Mimosaceae
Tieghmella hecklii	Baku	Sapotaceae
Treculia africana	Totim	Moraceae
Trichilia prieureana	Tanuronini	Meliaceae
Uapaca guineensis	Kuntan	Euphorbiaceae
	Tusia	Lorataceae
	Asadwere	

Fourteen plant species were shared by elephant and bongos (single asterisks on the bongo list). Of the elephant food species, 29 were fruits tree species. Twenty-five (48 %) of the bongo "species' were seen on logging roads and gaps (see remarks on plant

species list for bongos). *Chromolaena odorata* has colonized most of the gaps and logging roads and was found to be fed on by bongo and Yellow-backed duiker but not elephants.

The extent of similarity of the feeding activities of the elephant and bongos was roughly estimated using formula of Sorensen's similarity coefficient (S_s) formula (Krebs, 1999):

$S_s = 2a/ (2a+b+c)$,

where a = number of plant species eaten which is common to both elephant and bongo (i.e.14 species) and b, c are the number of species eaten by elephants (i.e.45) and bongos (i.e.52) respectively. Thus $S_s = 0.22$. S_s is measured on a scale from 0 (no similarity) to 1.0 (complete similarity). The similarity index estimated was crude since trophic separation by time of feeding and plants parts preferences was not captured by the data used for the estimation. It should therefore be interpreted with caution.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Elephant numbers

The density estimate of 0.59 elephants/sq km is comparable to the estimate of 0.6 reported for the same population by genetic survey (Eggert *et al.*, 2003). Thus the working estimate of the elephant population for this study is 217(CI 136-336).

The consistency in the estimates of elephant numbers from year 2000 to 2002 (Figure 10a) demonstrates the reliability of dung counts and the Rainfall model. The Rainfall model possibly captured the variations in the dropping densities on the forest floor. It reflected the high influence of rainfall two months preceding a survey as shown in Barnes *et al.* (1997). This made the estimates from the Rainfall model more reliable. Similarly, the low estimate of numbers i.e 146 (CI 83-209) in the 2001 wet season using the Steady State Assumption model (Table 6) demonstrates that the forest was not in the state of equilibrium in June-July when rainfall peaks. Barnes et al. (1997) pointed out that it takes about two months after the end of the rains for steady state to be achieved. This perhaps explains why the estimate of elephant numbers from the October 2000 wet season survey (Table 6) by EBM (2000) using the Steady state model was close to the Rainfall model estimates.

MIKE programme recommends bi-annual surveys of elephants in Upper Guinea forests. But the closeness of the Rainfall model estimates of numbers in year 2000 and 2002 demonstrates that it may be impossible to detect changes in the population in biannual surveys unless the population is seriously affected by a stochastic demographic event like poaching. This finding agrees with Barnes (2002) who observed that the power to detect change in an elephant population that is less than 200 individuals under normal

conditions, is low. He found that for an elephant population (estimated from dung count) of say 1000 which had suffered a 50% decline within a decade, the probability to detect change in the population after five dung counts within the decade was 0.83. The difficulty to detect trend thus has a wider implication since most West African forests hold small elephant populations and the KCA population is the highest so far recorded in the West African forest (Table 13).

The study area was stratified on the basis of the reconnaissance survey on bongo. But analyses of the 2001 wet season data on stratum basis possibly reduced the variation between the stratum. This could have contributed to the insignificant difference in elephant density per transect between the 2001 wet and 2002 dry seasons.

Low rainfall slows down decay rates and droppings usually accumulate in the dry season (Barnes and Barnes, 1992). On the contrary, fewer dung piles were recorded in 2002 dry season compared to 2001 wet season. This might be the consequence of the spate of illegal killings prior to the dry season survey. The current poaching ridden area had high concentration of fruiting trees like *Parinari excelsa* and *Tieghmella hecklii* that attracted a lot of elephants in the 2000 dry season as observed by Danquah (2004 per comm). Elephants might have reduced their activities in the area during the 2002 survey. Furthermore, the transects possibly missed the high density area because they were not systematically distributed. Elephants also occasionally use the adjoining Ajueso forest reserve but mass movement from KCA and their residency in Ajueso is unexpected because of the high illegal activities there. The possible change in the elephant movement pattern after the 2001 wet season has been examined further in the section on distribution.

5.2 Bongo numbers

Estimates of bongo numbers could not be obtained from the dung counts and the camera trap surveys. However, it has been predicted through a random model simulation

that a capture programme that runs for about 1000 camera days has a 95% chance of obtaining at least one photograph for animal densities of roughly between 0.02-0.05 individuals/km^2 (Carbone *et al.*, 2001). This means that if there were 18 bongos in KCA (i.e 0.05 x 366 km^2 area of KCA) one would have to do 1000 camera days to have a 95% chance of getting one photograph of bongo. Through the dung counts and perhaps from Carbone *et al.* (2001) prediction of trapping success in relation to density, a conservative bongo density at the designated high density zone may not be more than 0.1 individuals/km^2. This is a subjective estimate but is the best that one is ever likely to have for the Kakum Conservation Area.

The camera traps had to be set on trails. But bongos were not found to strictly follow their trails as those in the forest of Dzanga National Park at Central African Republic (Kluas-Hugi *et al.*, 2000). It could not be proven whether KCA bongos exhibit any site fidelity even though their activities were relatively common in the Antwikwaa area. There was no strong evidence to suggest territoriality but two different piles of bongo dungs at various stages of decay in two distant areas were observed in the dry season and seemed to suggest a dropping behaviour similar to Maxwell and Black duikers (i.e. the "midden behaviour"). The use of the non-invasive photographic method to survey a small population though promising demands much investment (financial and time), which might be unjustifiable in terms of cost.

The opinion of farmers who share common boundary with KCA that bongos do not visit their farms as before was not supported by the Wildlife field staff (59% of staff) assertion that bongos are on the increase in KCA. The missing link here is lack of information from hunters around KCA who were unwilling to fill questionnaires. The assertion by the staff that bongos are on the increase is untenable and unsubstantiated by the dung count. In the dry period, there were relatively high bongo activities in the

Antwikwaa area possibly due to the retention of water by the Afia river compared to others. Bongos affinity for water (Kingdon, 1997) perhaps led them to water at the Afia river which flows down to Atwikwaa area. This situation perhaps created the illusion of bongo abundance at the Afiaso area and consequently the alleged increase held by field staff.

It has been proven that KCA bongo population is small and discrete. It is also isolated and thus runs the risks of demographic and environmental stochasticity and is unlikely to be potentially viable (Sukumar, 1993). A species face to face with a hunting culture is in grave danger if valuable, insular or big (Caughley, 1994) and KCA bongos fit all these three words. Surveys of small populations have always posed a serious challenge to the use of the traditional distance sampling methods in view of the wide confidence limits of small population estimates (Danquah *et al.*, 2001).

5.3 Duiker numbers

Maxwell, followed by Black duiker, were the most abundant of all the duikers and their densities were estimated as 9.61 and 2.2/sqkm respectively. Yellow backed duikers could not be estimated from the dung counts. This finding is consistent with that of Wilson (1994) observation in KCA but inconsistent with the estimates from Fordwoo (1992) and Dickinson (1996) who admitted that their survey had limited coverage of the study. The high densities of Maxwell and black duikers could perhaps be due to favourable habitat, availability of browse in the logged areas, which could have enhanced their reproduction. Prins and Reitsma (1989) made a similar observation in the Gabon forest. There was an inverse relationship between density and size of the species. This was also comparable to the findings at the Ituri forest in Zaire (Koster and Hart 1988,

Table 13). The modification of KCA forest by past logging activities might have benefited Maxwell and Black duikers since they like secondary forest patches.

The duiker population might have made hunting attractive and rewarding. Maxwell duikers, for instance, dominated the annual kill by hunters at Ankasa and Bia NP (PADP, 1998). Maxwell and Black duikers foothold and dominance in KCA perhaps demonstrate that they are more resistant to hunting pressure as reported by Waitkuwait (2001) and Barnes (2002).

5.4 Elephant Size Distribution and Biomass

Fewer boli were found in the ≤ 20cm (< 1year olds), which is the infant class. Those less than 1year olds were probably underestimated because they do not defecate frequently and their droppings break down faster because they are less fibrous. The small proportion of the infant class agrees with Jachmann and Bell (1984) observation. Furthermore, the high mortality rate in this age bracket as observed by Moss (2001) in the Amboseli population means that the fewer droppings are expected. A year old elephant was found dead in 2001 the cause of which could not be determined because carcass was in advanced stage of decomposition.

The size distribution of all KCA elephant and their crop raiding counterparts was found to be similar. In other words, the KCA population and the proportion of that population that raid crops are not different in their body size composition. In many places in Africa and Asia, mature bulls are reported to be the main culprits that raid crops (Sukumar, 1990). In KCA, field staffs have reported that family groups often raid crops. If only mature males were crop raiders, then one would expect a difference between the dung size distributions of the KCA population and their crop raiding counterparts since mature bulls would have left piles of big boli. The similarity in the boli size distribution

between the KCA population and the crop raiding counterparts' supports the observation made by the field staff.

The minimum and maximum boli circumferences of 17.5 and 56cm recorded at KCA were similar to Morgan and Lee's (2003) respective boli diameter estimates of 4 cm (i.e 13 cm bolus circumference) and 16 cm (i.e 50 cm bolus circumference) for the forest elephants at Petit Loango in Gabon (assuming the cross section of a bolus is circular). This not withstanding, they had 55% of their dung bolus with circumference less than 32 cm as compared to 35% in KCA. This emphasises perhaps the population-specific nature of the boli size distributions, as noted by Morgan and Lee (2003) which could be due to differences in diet and age at sexual maturity when maternal investments in reproduction limit size and weight increments (Moss, 2001; Lee and Moss, 1995).

The boli size distributions at KCA and Marahoue National Park were also found to be similar. The killing of particular sex or age class of elephant by poachers that skews elephant populations has not been reported at KCA (Dudley *et al.*, 1992). Such selective killing was not observed during the study period as found elsewhere (Sukumar, 1989; Barnes and Kapela, 1991). KCA elephant poachers have been opportunistic. If poachers in Marahoue exhibited such opportunism, then it is suggested that the similarity of the boli size distribution between the Kakum and Marahoue populations might be a natural attribute of the two populations.

Elephant dominance in the biomasses of KCA large mammals is similar to studies in Lope forest in Gabon (White *et al.*, 1993), (Table 13). Elephants dominated because they may have competitive advantage over the other herbivores that also prefer secondary vegetation. If the presupposition that elephants consume more vegetation than the other mammals investigated is valid, then it is suggestive that they will exert competitive pressure on the bongos and duikers that also prefer secondary vegetation. At

Lake Manyara National Park in Tanzania, the dominant animal species controlled the density of the other animal populations and the disadvantaged species only increased when the dominant species density fell (Prins and Douglas-Hamilton, 1990).

5.5 Bongo and Duiker Biomasses

The biomasses of bongos and Yellow-backed duikers were not estimated due to inadequate data. Maxwell duiker biomass estimate of 96.1kg/sqkm dominated the duiker biomass estimates followed by Black duiker biomass estimate of 52.8kg/sqkm. Koster and Hart (1988) made a similar observation in the Ituri forest in Zaire where small duiker (Blue duiker) abundance was not different from the abundances of four larger duikers (including Yellow-backed duiker) put together. The high Maxwell and Black duiker biomasses could be in response to the existence of a favorable habitat to thrive and reproduce.

5.6 Spatial Distribution of Elephants

Gaps influenced elephant distribution in the 2001 wet season even though it had no effect on elephant abundance in the dry season. The heliophile plant species that colonize forest openings are perhaps palatable and attractive to elephants as they are reported to contain less toxic compounds and tannins than the seedlings that grow on the forest floor. This finding is consistent with the well-known reports that elephants like secondary forest (Short, 1981; Tutin and Fernandez, 1984; Merz, 1986; Prins and Reitsma, 1989; Barnes *et al.*, 1991; Hoppe-Dominik, 1992; Struhsaker *et al.*, 1996).

Fruits form an important component of the diet of forest elephants (Short, 1981,1983; Dudley *et al.*, 1992; White, 1994; White *et al.*, 1993; Struhsaker *et al.*, 1995). Thus their influence on elephant abundance in the 2001 wet season was not coincidental. However, there was a threshold of fruit abundance (approx. 2.80 fruiting tree spots/km)

in the 2001 wet season beyond which they seemed less attractive to elephants. Other factors might have come into play at the threshold such as the maturity of farmed crops since the wet season was the peak crop-raiding period (Dickinson 1998, Barnes *et al.*, 2003). The decline in the fruit dependence after the threshold could also be that many of the fruits available at that point were not the first class or much preferred ones. A fruit like *Strychnos aculeata* was found to be available all year round at KCA as observed by Short (1983) in Bia NP but is not primary elephant foods like *Tieghmella hecklii* and *Parinari excelsa* (Danquah, 2003).

No variable recorded on the transects did explain elephant distribution in the 2002 dry season. Perhaps the variation between transects was more random in the dry season than in the wet or that the factors that influenced the distribution were not identified. The dry season for instance is the peak fruiting period as reported in Bia NP (Short, 1981). It is therefore on the contrary that the high fruit abundance by itself or in combination with others like water sources did not explain elephant abundance in that season. Elephant poachers possibly concentrated in the areas where fruits and water were more abundant to carry out their illegal activities and thus scared elephants away. EBM (2000) made a similar observation in that water sources in the relatively dryer period of year 2000 did not influence elephant distribution. It is known to KCA patrol team to check water sources, since illegal activities in such areas are relatively higher in the drier periods.

Illegal activities recorded on the transects in both dry and wet seasons did not explain elephant abundance, an observation similar to year 2000 (EBM, 2000). This could be due to the fact that most of the activities were wire snares and snaring which mainly targets the antelopes but could only be a nuisance to elephants. The intensity of illegal activities in the 2001 wet and 2002 dry seasons was not different. This contradicts the general expectation of the park management that attention of people to farming in the

wet season invariably reduces poaching during that period. High illegal activities were recorded in wet 2001 and dry 2002 in KCA compared to the year 2000 KCA survey. It was similar to the level observed at Marahoue National Park. But poaching in KCA forest was low compared to the Ankasa rainforest reserve. The higher poaching in Ankasa than all the reserves may lend support to the bush meat survey observation that hunting is more of a business for the locals involved than to supplement inadequate protein from other sources (PADP, 1998).

Elephants did not completely avoid the area where members met their death, Figure, 15. This is consistent with the report by Hoare (2001) in Zimbabwe. But this finding is at variance with the expectation of most farmers around KCA. Farmers believe that the killing of elephants would keep them off the crop fields. Merely removing problem animals involved in crop raiding might only serve as a short term palliative. However to have a better picture about the distribution of elephants as a consequence of poached elephants prior to surveys, transects should be systematically distributed as recommended by Norton-Griffiths (1978) and MIKE.

5.7 Spatial Distribution of Bongos

The factors that possibly influenced the distribution of bongo were not fully investigated because of insufficient data. However, the distribution of bongo signs was wider in the wet season (solid circles in Figure 16) than the dry season (solid squares, Figure 16). Their relatively wider distribution in the wet season and the closeness of most bongo signs to water sources supports the observation made by Kingdon (1997) that bongo has affinity for water.

The southern part of KCA was not used and this could possibly be due to noise caused by visitors to the canopy walkway, which is located at the southwestern part.

Bongos are known to be shy and secretive (Estes, 1991; Kingdon 1997; Klaus-Hugi *et al.*, 2000) and they were found to have deserted an area where the transect team did some cuttings.

KCA bongo population is seemingly isolated from the population in Pra-suhien reserve. Reconnaissance surveys in the nearby reserves i.e Ajueso and Pra-suhien forest reserves did not indicate signs of Kakum bongos crossing to these two reserves. This is because the "arm" of Pra- suhien reserve that extends to KCA was fraught with high human activities. This, notwithstanding, hunters confirmed the presence of bongo in Pra-suhien, which is considered a separate population.

5.8 Habitat Use by Elephants and Bongos

Elephants did not show any preference for raphia swamps even though they browsed on the raphia palm (*Raphia hockeri*) in both seasons as observed by Dudley *et al.* (1992). The raphia palms dominate the boggy areas and perhaps reduce the diversity of the plant species.

There was a weak relationship in the sharing of food resources (Sorensen's similarity index, S_s= 0.22) by elephants and bongos. Herbs featured prominently in the diet of bongos unlike elephants. Besides, the plants elephant and bongo shared were not first class species in the diet of elephants (Danquah, 2004). It suggests that there is no strong competition between the two species at their current densities. Where competition exits it may be skewed to the advantage of elephants due to their dominance in biomass and ability to explore the food resources higher up the vegetation profile.

It is acknowledged that some issues need to be cleared to give a very illuminating interpretation to the measure of similarity in species consumed by both elephants and bongos. These include:

(i) a possible differing frequency of occurrence of the plant species

(ii) extent of utilization of each plant species and plant part eaten by elephants and bongos.

(iii) the renewability of each plant species.

The presence of *Chromolaena odorata* on logging roads and gaps in the forest is regarded as a nuisance (Theuerkauf *et al.*, 2001; Schulenberg *et al.*, 1999) but for bongos and Yellow-backed duiker in KCA it is a blessing. Bongo and yellow-backed duiker fed on species like *Chromolaena, Mallotus oppositifolius* and *Combretum mucronatum* (double asterisk on species list of plants, Table 19a).

There was no indication that elephants fed on *Chromolaena* and this agrees with the observation of Theuerkauf *et al.* (2001) at Bossematie Forest Reserve in Côte d'Iviore. What could not be investigated was whether the feeding on *Chromolaena* by bongo and Yellow-backed duiker demonstrates real need to survive in an environment dominated by Elephant, Maxwell and Black duiker.

CHAPTER SIX

6.0 CONCLUSION, RECOMMENDATIONS AND MANAGEMENT IMPLICATIONS

6.1 CONCLUSION

6.1.1 Introduction

The study was undertaken in Kakum Conservation Area (KCA) to estimate the population size of elephants, bongos and duikers by using dung count. For the first time in the West African forest, camera traps were also used to survey the cryptic bongos. The factors that underlined the spatial distribution and the use of the habitat by the elephant and bongo populations were identified. The size structure of the elephant population was investigated and the biomasses of elephant, bongo and duiker populations estimated.

KCA has suffered various degrees of logging in the past and this has created the enabling environment for animals like elephants that prefer secondary forest to thrive.

6.1.2 Major findings

6.1.2.1 Elephants

KCA elephant population density is the highest so far recorded in the West African forest and the size of the population was estimated as 217 with confidence interval of 136-336.

KCA is a MIKE site but the MIKE recommendation that the population should be surveyed biannually will not reveal the trend expected since the estimates of elephant numbers in year 2000 and 2002 were not statistically different.

Sub-adult elephants that had dung boli circumference ranging from 35-45cm also dominated the biomass of the elephant population. The size structure of the proportion of

the elephant population that raid crops was not different from the overall population. Thus elephants, in all age groups, were potential crop raiders.

Fruit availability in the forest peaks in the dry season but elephant abundance in the 2002 dry season was not significantly influenced by it. There was also a threshold of fruit abundance (approx. 2.80 fruiting tree spots/km) in the 2001 wet season beyond which elephants reduced their dependence on fruits. It is noteworthy, that the wet season survey coincided with the maturity of farmed crops like maize on the crop fields adjacent to the study site. The wet season has been reported to be the peak crop raiding period by elephants in KCA. Elephant abundance and distribution was also strongly influenced by length and number of gaps in the forest canopy. In other words, elephant density was higher where there were more openings in the forest.

6.1.2.2 Bongos

The bongo population was found to be small (< 0.1/sqkm), discrete, isolated and may not be potentially viable in the long term. The bongo population alleged by some hunters to be present in the Pra-suhien forest reserve was not linked to the KCA population. The gaps and logging roads at Antwikwaa and Briscoe II are critical sites for the survival of the KCA population.

There was a weak relationship in the sharing of food resources between bongos and elephants. Bongos and Yellow-backed duiker were found to feed on *Chromolaena odorata*, an invasive herb that has colonised some gaps and logging roads in the forest. Elephants, on the other hand, did not feed on the herb.

6.1.2.3 Duikers

KCA ecological environment was favourable to Maxwell and Black duikers. Maxwell, followed by Black duiker was found to dominate the biomass of the duiker

population.

6.1.2.4 Illegal Activities

The levels of illegal activities in the wet and dry seasons were not different. Illegal activities recorded during the study period were found to be higher than that recorded by the Elephant Biology and Management project team in year 2000. Nevertheless, the level in KCA was low compared to what was found in the Ankasa forest in year 2001.

Farmers who suffer crop raiding always claim that killing some elephants will keep them off the crop fields. However, illegally killed elephants prior to the dry season survey did not significantly influence the distribution of the existing population.

6.2 RECOMMENDATIONS AND MANAGEMENT IMPLICATIONS

Even though weak competitive demands exist between elephants and bongos, the current elephant density is significant and individuals are potential crop raiders. To maintain the diversity of the large mammal population, the elephant population trend would have to be closely monitored to keep it within tolerable conservation limits. KCA is isolated and it is one of the bastions of hope for the conservation of elephants in the Upper Guinea forest zone. The long-term survival of the population will depend on the reduction of human-elephant conflict. But attempt to crop the population would have a short-term effect on elephant distribution. An important biological buffer would have to be created around KCA through a proper and holistic management of the landscape.

The gaps and logging roads at Antwikwaa and Briscoe II sites are critical for the survival of the bongo population. They should therefore be secured from poachers. Awareness would have to be created among the field staff to erase their misconception about the distribution and numbers of bongos.

KCA ecological environment is favourable to Maxwell and Black duikers and their relatively higher densities, perhaps, make hunting attractive and rewarding. Attempts should therefore be made to discourage hunting in protected areas by making hunting fines punitive and by promoting alternative sources of protein through fish, grass cutter, snail and mushroom farming.

Elephant dung counts are reliable and the Rainfall model is recommended for the conversion of dung densities into numbers since it gives consistent estimates of numbers. It would however, be difficult to detect trends in the elephant population through biannual surveys as recommended by MIKE.

It is impractical to use dung counts to estimate the bongo population at the current density. Future long-term investments in bongo surveys should consider using genetic surveys and an improved form of camera traps (eg. motion detectors). Such studies should be done in the Antwikwaa area in the dry season.

Park staffs have always maintained that poachers are less active in the wet season because casual poachers would be tending their crop fields. This assertion was not supported by the study. There is therefore, the need to equally intensify patrol operations in the wet season as done in the dry season. It is also suggested that patrol teams should regularly check areas under fruiting trees to remove wire snares that target the duikers and bongos alike and could also be a nuisance to the elephant population.

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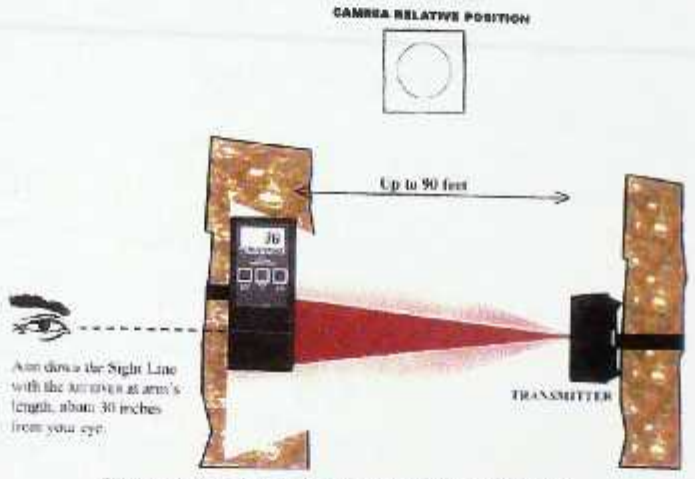
APPENDIX I

PLATE 1: Bongos (*Tragelaphus eurycerus*) at San Diego Zoo, U.S.A (Photograph by Dr. R.F.W Barnes)



Side view of RECEIVER alignment process using the SIGHT LINE

PLATE 2: A set up and alignment of a camera trap system.

PLATE3: Investigator fixing an infra red receiver.

APPENDIX II. Dung piles categorisation according to Barnes and Jensen (1987).

Category	Description of Dung pile
A	Boli intact, very fresh, moist, with odour.
B	Boli intact, fresh but dry, no odour.
C	Some of the boli have disintegrated,but some are still recognisable.
D	All dung pile completely disintegrated; dung pile now forms an amorphous flat mass.
E	Decayed to the stage where it would be unlikely to be spotted at two metres range in the undergrowth from a transect.

APPENDIX III. Subjective categorization of the vegetation types based on the past human disturbances in KCA (Source: EBM 2000).

VARIABLES	LESS DISTURBED	MEDIUM DISTURBED	VERY DISTURBED
1. Presence of upper canopy(> 30m high)	closed	Broken	Absent
2. Lianas	Absent	Present	Abundant
3. Horizontal visibility at ground level	whole person visible at 10m	More than ¼ person visible at 10m	less than a ¼ of person seen at 10m
4. Ease of movement	Easy to move about without the aid of cutlass	Occasional use of Cutlass required.	Very difficult to move without a cutlass.
	No cutting required. Easy to move in a straight line.	Moderate cutting and meandering.	Much cutting. Very difficult to move in a straight line.
5. Presence or absence of very big trees	Common	Less common/ less rare	Rare
6. Indicator tree species trees .	High-value timber present	*Musanga*, Logging roads present	*Musanga, Chromolaena*, Logging roads present

APPENDIX IV. Questionnaire for the sociological survey of farmers around KCA on Bongos.

Name:
Age :
Village:

(1) Since when have you been farming along the boundary of the Kakum Park?---

(2) Do you know bongo? Yes or No. Tick one.
If yes, have you seen bongo in your farm since the reserve was taken over by game people ? Yes or No. Tick one.
If yes, when was the last time you saw bongo? ----------
How many were they? ----------
What was it doing? (Eating / drinking / running /standing / resting). Tick one in the bracket.
If you saw it eating, what was it eating?----------
If you did not see it eating, do you know what it eats? Yes or No. Tick one.
If yes, please list what it eats. ----------

(3) Have you seen some one killing bongo since the reserve was taken over by game people? Yes or No. Tick one.
If yes, when did you see someone killing bongo? ----------
If no, have you heard someone killed bongo since the reserve was taken over by game people? Yes or No. Tick one.
If yes, when did you hear someone killed bongo?----------
Where did you hear someone killed bongo around Kakum Park? ----------
How was it killed? (shot / trapped / don't know). Please tick one in bracket.
Have you eaten bongo meat before? Yes or No. Tick one.
If yes, when----------

(4) Has bongo come to your farm before? Yes or No. Tick one.
If yes, has bongo been a problem in your farm before? Yes or No ----------
Is bongo still coming to your farm? Yes or No

(5) Apart from wildlife law, do you know any taboo that prevents people from killing bongos? Yes or no. Tick one.
If yes, what is it?----------

(6) Any additional information on bongo.----------

APPENDIX V. Questionnaire for the sociological survey of KCA field staff on Bongos

Name:
Age:
Camp:

(1) When did you start work in Kakum? ----------
(2) Have you seen bongo in your patrols before? Yes or No. Tick one.
(ii) If yes, when did you last see bongo in your patrols?----------
(iii) Where in the park did you last see bongo ----------
(iv) How many were they? ----------
(v) What were they doing? (Eating / drinking / running /standing / resting). Tick one.
(vi) If you saw it eating, what was it eating? ----------
(vii) If you did not see it eating, do you know what it eats in the Park? Yes or No. Tick one.
If yes, please list what it eats----------
(viii) I do (not commonly, commonly, always) see bongo signs during patrols. Tick one in the bracket.
(3) Have you seen bongo killed or dead in your patrols before? Yes or No
(i) If yes, when was the last time you saw dead bongo in your patrols? ----------
(ii) How was it killed? (shot / trapped / don't know). Please tick one in bracket.
(iii) If you have not met killed bongo in patrols, have you heard someone killed bongo since the day you started work in Kakum? Yes or No. Tick one.
(iv) If yes, when did you last hear someone killed bongo? ----------
(v) Where did the bongo killer come from?----------
(4) Apart from the wildlife law, do you know any taboo that prevents people from killing bongo in the village your camp is? Yes or no. Tick one.
If yes, what prevents people from killing bongo? ----------
---

(5) Do you think bongo numbers are (increasing / decreasing / remains same) since you started work in Kakum? Tick one in the bracket.
(i) If you say bongos are increasing, what do you think is causing bongos to increase? ----------
(ii) If bongos are decreasing, what should be done to stop the decrease?

(iii) Where do you think bongos are many? (Attandaso/ Kakum/ I don't know)Tick one in the bracket.

(6) Have you eaten bongo meat before since you started working in Kakum? Yes or No. Tick one.
If yes, when was the last time you ate bongo meat? ----------

(7) Add any additional information about bongo----------

APPENDIX VI. Mean rainfall two months preceding seasonal surveys for the period 2000-2002 and indices of elephant dung pile abundance.

	Year 2000				Year 2001		Year 2002			
	Dry season		Wet season		Wet season		Dry season		Wet season	
Two months preceeding survey month	Dec '99	Jan.	Aug.	Sept.	May	June	Dec.01	Jan.	July	Aug.
Mean rainfall (mm)	24.04	60.51	42.42	77.71	173.27	316.37	32.23	19.76	237.76	77.51
No. of stage A-D elephant droppings /km	5.42		3.25		5.13		1.72		2.52	

NB: Mean refers to the mean from six rainguages deployed by EBM around KCA.

APPENDIX VII. Cumulative frequency plot of number of bongo dungs randomly samples against effort.