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DEPARTMENT OF WILDLIFE AND RANGE MANAGEMENT

THE ECOLOGY AND MANAGEMENT OF ELEPHANTS (*Loxodonta africana Matschie*) IN THE BIA – GOASO FOREST ENCLAVE OF WESTERN GHANA

By

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DECLARATION

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

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ABSTRACT

Elephants are important mega fauna whose role in an ecosystem could ensure the health and survival of diverse species. However, drastic declines in their numbers since the 19th Century in Africa in general and West Africa in particular has necessitated the need to understand their ecology in the local context to help improve their survival. This study was therefore conducted in the Bia-Goaso forest enclave in Ghana to contribute to the achievement of the objectives of the Elephant Conservation Strategy of Ghana (2000) and the "*Action plan for the Management of the Transfrontier Elephant Conservation Corridor of Bia-Goaso-Djambarakrou,*" which contain activities geared towards ensuring the survival of forest elephants in Ghana and West Africa respectively. In February 2004, a dry season survey on elephants and an investigation into the different levels of human and ecological variables that affect their abundance and distribution was conducted in an extensive network of eleven forest reserves and two wildlife reserves in the Bia–Goaso enclave of western Ghana. These activities were repeated twice, first in the rainy season of 2007 and the following dry season which started in 2007 and ended in 2008 mainly to understand seasonal effects in distribution of elephants in the area. During this period, the most up-to-date method for surveying forest elephants, the retrospective method was employed. A desk-top exercise was then undertaken not only to prove the importance or otherwise of the elephant populations in the study area in comparison with other elephant populations in West Africa but also to determine factors that govern their abundance. A preliminary investigation into the feasibility of creating corridors between reserves in the study area and neighbouring Ivory Coast was initiated in May 2004. As part of this, the movements of elephants from Ghana into Ivory Coast along the Bia river was monitored every quarter between August 2005 and December 2006, as well as an investigation into the rate of forest degradation. The nature and extent of human – elephant conflicts in the Bia Conservation Area was also studied through administration of questionnaires using interviews and field measurements. One hundred and thirty (130) transects were systematically distributed in three strata (high, medium and low density) based on dung pile density estimates in an initial reconnaissance. Two models (rainfall and steady state assumption models) were used to estimate elephant dung pile density and numbers in the study area. However, the rainfall model is preferred since it makes no assumption about the state of the forest. Two major elephant populations were observed to be residing in the study area, with the possibility of a tiny third population of less than 10 elephants (in the Bia North FR). In the 2004 survey, a mean population estimate of 115 (CL: 90 - 148) elephants was obtained for the Bia Resource Reserve. The eastern portion of the Mpameso Forest Reserve (medium density stratum) had an estimate of 57 (CL: 33 - 100) elephants. Elephant numbers could not be estimated for the rest of the reserves (low-density stratum) because of inadequate number of dung piles on transects. In the 2007/8 survey, estimates of 133 (CL: 104 - 162) elephants and 137 elephants (CL: 98 - 170) elephants were obtained for Bia CA during the dry and wet season surveys respectively. While for the Mpameso elephant range, estimates of 83 (CL: 41 - 125) elephants and 90 (CL: 49 - 131) elephants were obtained in the dry and wet seasons respectively. Merged estimates for both seasons were 135 (CL: 114 - 156) elephants for Bia and 87 (CL: 58 - 116) elephants for Mpameso. Altogether, a total population of 172 (CL: 123-264) elephants were estimated to be occurring in the entire study area. Elephants were found to be clumped more to the southeast of BRR, the eastern part of Mpameso and the Bia Shelterbelt FR. Elephants were found to be more widely spread out in the wet season than in the dry season within BCA. Analysis of dung pile distribution in relation with human and ecological variables in both the 2004 and 2007/8 studies showed that within the reserves, water availability explained a high proportion (ca. 90%) of the variance in elephant density, with elephants being clumped around watering points created as a result of logging. Additionally, in 2004, distance to the Bia River was inversely correlated to the number of dung piles seen per km in the Mpameso Forest Reserve. Illegal activities (such as snaring and snail picking), however, did not affect elephant abundance but rather had a negative correlation with watering points, that is, they were undertaken away from these watering points. This suggests that poachers were avoiding areas of high water availability, possibly because of high elephant activity around those areas. Outside reserves, the distance to major towns and roads accounted largely for variances in elephant density in 2004. In 2007/8 on the other hand, logging roads and availability of raphia also entered the model as significant variables, though they did not add much power to the models. By all standards, the Bia population on its own is a very important one in the sub-region. The Goaso population is smaller. However, the security of its range, and the possibility of linking it with others makes it also even

more important for the overall conservation of forest elephants in West Africa. It was established during the study that elephant abundance in West Africa depends on the size of a population's range, to whether the range is protected, its geology and the quality of governance in the country where it occurs. Elephant crop damage is a serious problem in the area, especially to cluster of farms that border the southern portions of the Bia Resource Reserve, resulting in conflicts between farmers and nature conservation. Food crops such as plantain, cassava, cocoa and maize suffered severest damage. These are most preferred by the elephants when in the matured state and the quality is excellent. For each community, that suffered crop-raiding, the extent of crop-raiding depended not only on the area of land under cultivation but also the mean distance of farms from the reserve boundary, as well as the number of different crops planted on the farm. Interviews conducted in 2004 indicated that most migrant farmers do not see any advantage in preserving elephants and would do little to conserve them. While they were not willing to sacrifice part of their already overburdened farmlands for establishing elephant corridors, they also feared a possible increase in human-elephant conflicts in the future. However, most villages adjacent to streams/rivers showed a strong interest in restoring the riparian forest since they faced water and fish shortages in the dry season. More lately, there have been several forest restorative activities going on in the study area in the hope of returning wildlife into communal lands. Hence, there has been a generally increasing level of awareness concerning the conservation and protection of lands to serve as corridors. Of six potential corridors considered, one along the Bia river linking the Goaso population to those in Ivory Coast and from Bia Resource Reserve to Krokosue Hills Forest Reserve have the greatest potential in the short to medium term, and it is also likely that with a high level of interventions, two others could be achieved over the long term. A more detailed spatial analysis in combination with ground truthing is required before a conclusive decision on viable corridors can be made. Also a more participatory information gathering strategy (such as Timelines, H-Diagram) for soliciting community opinions on corridors have been suggested to complement the use of questionnaires. Recommendations also include a detailed study of elephant movements in the Ivorian side of the corridor.

ACRONYMS

AfESG	African Elephants Specialists Group
BCA	Bia Conservation Area
BP	British Petroleum
CA	Conservation Area
CREMA	Community Resource Management Area
DGW	Department of Game and Wildlife
EU	European Union
FC	Forestry Commission
FR	Forest Reserve
FRNR	Faculty of Renewable Natural Resource
GPS	Global Positioning System
HECs	Human- elephant's conflicts
IUCN	International Union for Conservation of Nature
KNUST	Kwame Nkrumah University of Science and Technology
MTC	Mim Timber Company
NP	National Park
NTFP	Non Timber Forest Product
OSS	Optimum Sample Size
PAC	Problem Animal Control
PADP	Protected Areas Development Programme
PAs	Protected Areas
RR	Resource Reserve
SB	Shelter Belt
SSAM	Steady State Assumption Model
SSC	Species Survival Commission
WD	Wildlife Division
WWF	World Wide Fund for Nature

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CHAPTER ONE: GENERAL INTRODUCTION

1.0 INTRODUCTION

1.1 Background and Justification for this study

Man has dramatically transformed the Upper Guinea rainforest over the past century. At the beginning of the 20th century, elephants were still widely distributed over the forest zone and were little affected by human settlements (Roth and Douglas-Hamilton, 1991) until the 1950s when intensive development started. Currently, elephants in West Africa are fragmented into 75 separate populations, many of which are small and threatened (AfESG, 2003).

Since Liberian forests do not hold large numbers of elephants, and Tai National Park of Ivory Coast, the next largest area of undisturbed forest in West Africa has been heavily poached (Blanc *et al*., 2003), then an examination of the elephant distribution map for the region shows the Bia-Goaso block (study area) to be the largest area of elephant habitat remaining in the sub region. However, very little is known about it. For example, it is not known how many elephants are there, how far they range in each season and which part of the habitat is most important for their survival.

With marked decline in soil fertility in the forest zone (WD/PADP, 1998) and fluctuation in rainfall from year to year (Barnes *et al*., 1997), in the face of increasing human population (Bos *et al*., 1993), the problem of competition for space between humans and elephants is bound to increase. With a better understanding of variables that negatively affect elephant distribution and numbers appropriate land-use planning could be used to minimise the effects of development (agriculture, settlements, industrialisation, etc.) on elephants.

The proposed study will investigate the feasibility of establishing corridors. A large part of the area consists of 11 forest reserves, seven of which contain elephants. Strips of forest (called shelterbelts) established in the mid-30s serve as corridors connecting some of these reserves and are currently used by elephants. Two protected areas, namely Bia National Park and Bia Resource Reserve both containing elephants are separated from the forest reserves. The forests on the Ivoirian side are also known to contain elephants. While Parren *et al*. (2002) argue that it is not too late to secure corridors for elephants within the study area many argue that it is.

The governments of Ivory Coast and Ghana intend to collaborate to establish a system of corridors within and between their countries. The possibility to work with a step stone approach before reaching the continuum based on the concept of shelterbelts already present in the region is the preferred implementation approach (Parren & Sam, 2003). However, corridor options that are feasible need to be determined to inform the preparation of the actual corridor establishment project, i.e. this project can determine and prioritise the most feasible corridors and which sections of each corridor should be tackled first when the implementation period commences.

There is a large human population living around the protected areas (PAs) in the study area whose farms suffer from elephant raiding. The extent and factors influencing the raiding are not known. It is not only far more cost effective to address the source of the farmer's grievance now but it is also the Wildlife Division's (WD) duty to prevent suffering caused by big game. With good information on the spatial and temporal distribution of crop-raiding, the WD would be able to plan an effective campaign to reduce crop-raiding.

Most of the above problems that this study attempts to address are mentioned in a new Sub-regional strategy on transfrontier elephant conservation prepared by the African Elephant Specialist Group (AfESG). Specifically, this study is contributing to the achievements of Objectives 1, 2 and 4 of the Bia-Goaso-Djambamakrou section of the strategy through conducting elephant surveys, investigating Human-elephant-conflict (HEC), prioritising major risk factors so far as mitigating conflicts are concerned.

1.2 Objectives of study

This study was aimed at contributing to the conservation of forest elephants in the Upper Guinea forest zone of West Africa. The specific objectives were to:

(i) evaluate the status of forest elephants in the Bia-Goaso forest enclave.

(ii) determine the importance of this area for the conservation of forest elephants in West Africa.

(iii) determine potential corridors for elephant movement between the forests of the study area and between those of the study areaand the forests in eastern Ivory Coast.

(iv) investigate the relationship between elephant density and types of human activity and ecological variables in the Bia-Goaso forest enclave.

(v) undertake a survey on the nature and extent of Human-Elephant Conflict (HEC) around the Bia National Park in the study area.

CHAPTER TWO: LITERATURE REVIEW

2.1 DESCRIPTION OF STUDY AREA

2.1.1 Location and Administrative Divisions

The study area comprises an extensive network of fourteen (14) forest and wildlife reserves, which include Bia-Tano, Goa Shelterbelt, Bonkoni Forest Reserve, Asukese Forest Reserve, Mpameso Forest Reserve, Ayum Forest Reserve, Subin Shelterbelt Forest Reserve, Bia Shelterbelt, Bia North Forest Reserve, Bonsam Bepo Forest Reserve, and Bia Conservation Area (Table 2.1). The study area lies within Western and Brong Ahafo regions of Ghana and falls within Latitude $6^0\ 35^/$ and $7^0\ 14^/$ N and Longitude $2^0\ 24^/$ and $3^0\ 10^/$ W (Figure 2.1).

Table 2.1 Forest Reserves, their administrative locations and sizes

RESERVE	ADMINISTRATIVE DISTRICT	FOREST DISTRICT	SIZE (Sq Km)
Bia-Tano Forest Reserve	Asunafo North	Goaso	194.30
Goa Shelterbelt Forest Reserve	Asunafo North	Goaso	23.80
Bonkoni Forest Reserve	Asunafo North	Goaso	75.10
Asukese Forest Reserve	Sunyani	Sunyani	265.00
Mpameso Forest Reserve	Dormaa Ahenkro	Dormaa Ahenkro	322.50
Ayum Forest Reserve	Asunafo North	Goaso	122.90
Subin Shelterbelt Forest Reserve	Asunafo North	Goaso	238.30
Bia Shelterbelt Forest Reserve	Asunafo North	Goaso	29.50
Bia North Forest Reserve	Bia	Juabeso	365.10
Bonsam Bepo Forest Reserve	Asunafo North	Goaso	124.30
Bia Conservation Area	Bia/Juabeso	Juabeso	306.00
Krokosua Hills Forest Reserve	Juabeso	Juabeso	481.70
Abonyere Shelterbelt Forest Reserve	Asunafo North	Goaso	41.20

2.1.2 Socio-Economic profile

Farming is the major occupation in both Western and Brong Ahafo regions. Cocoa is the major crop cultivated and it is the mainstay of the local economy in these regions. Farming practices in these areas tend to be traditional. Crop agriculture which combines food and cash crops under traditional shifting cultivation is the bedrock of the economy. The major food crops are maize *(Zea mays)*, cassava *(Manihot esculenta)*, plantain *(Musa poradisiaca)*, cocoyam *(Xanthsoma sp)*, yam *(Dioscora sp)*, rice *(Oryza sativa)* and vegetables with the main cash crop being cocoa *(Theobroma cacao)* (Agyare, 1996). Other minor activities include gathering of non-timber forest products (NTFPs), hunting, petty trading, small scale poultry and livestock rearing (PADP, 1999).

The demand for arable lands and the increase in population densities of these two regions (101.3 inhabitants/km^2) compared to the national average of 69.5 per km^{2,} excluding reserves) has led to serious encroachment on the study area resulting in a hard edge between the study area and the surrounding farmland. In 1989, Wildlife Division (Ghana) staff counted 278 farms on the perimeter of Bia Conservation Area (BCA) alone (EU, 1996). PADP (1999) estimates that about 626 individuals own farms around BCA and a total of 3,800 persons live within 200-300 meters of its boundaries.

Wildlife also contributes significantly to the socio-economy of the people around the study area. It is estimated that 20-22 “chop bars” around BCA use about 17,000 animals, weighing about 70, 000kg, valued at US $111,900 annually in preparing their meals (PADP, 1998). The average daily bush meat consumption per capita is about 0.18kg, while the annual catch per hunter is about 1,050kg worth US$1,240.

2.1.3 Climate

The area lies within the tropical humid climate which is characterized by two-well defined seasons: a rainy season from March to October and a dry season from November to February. The amount of rainfall reaches a maximum during May-June and decline during September-October. Rainfall pattern falls within 1500 mm and 1750 mm annual rainfall belt (Hall and Swaine, 1976).

Temperatures are uniformly high with very narrow diurnal and monthly ranges. Maximum and minimum temperatures occur in March and January respectively. The average monthly temperature lies between 24^{o}C and 28^{o}C with the extremes being 18^{o}C and 34^{o}C (Sam, 2000). The greatest diurnal ranges occur in the dry season, that is, from January to March. Relative humidities are uniformly high and are highest in the rainy season and lowest in the dry season.

2.1.4 Topography, Soil and Drainage

The land undulates between 170m and 240m above mean sea level (Martin, 1982). There are no significant hills and relief is gentle. The area is fairly well watered, forming the watershed of Bia and Tano rivers. There are however, a number of waterlogged areas within the study area, occuring mainly among the numerous small tributaries and depressions that run within the area. They are regarded as potentially productive areas.

The area is covered by soils which belong to the Forest Ochrosol group. There is high clay content on the top of hills with an increasing fraction of sand towards valley bottoms which is more common in the Subin Shelterbelt. Most of the study area is covered by metamorphosed sediments of lower

Birrimian age, principally schists and phyllites, which give rise to clayey soil. There are two outcrops of acid igneous intrusions in the form of batholiths and consisting of fine to medium grained granites and veins of biotite schists (Cape Coast granite complex). These give rise to gritty sandy loams in the western sector of the Mpameso and also all the Bia Shelter Belt and the Bia-Tano reserves. Their soils belong to the Forest Ochrosol Great Soil Group (Martin, 1982).

2.1.5 Flora

The vegetation types fall under the Semi-Deciduous Forest Type (e.g. Asukese FR), the Tropical Moist Semi-Deciduous Forest (e.g. Mpameso FR, and Ayum FR) and the Moist Evergreen (M.E) Forest Type (e.g. Bia North FR). The semi–deciduous forest type corresponds to Taylor's *Antiaris-Chlorophylla* Association (Taylor, 1960). It has relatively high stocking of *Triplochiton scleroxylon*. The forest contains certain species of trees rarely found elsewhere in Ghana. *Musanga cecropioides* and *Trema orientalis* are the common pioneer species found in Bia North FR. Some tree species found in the study area are *Chlorophora excelsa, Enthandrophragma anglolense*, *Enthandrophragma cylindricum*, *Enthandrophragma utile*, *Khaya anthotheca, Khaya grandifolia*, *Khaya ivorensis, Tieghemelia heckelii*, *Nauclea diderrichii*, *Afromosia alata*, *Terminalia ivorensis*, *Triplochiton schleroxylon*, *Tarrietia utilis.* Martin (1982) identified 640 species of vascular plants in BCA. Some portions of the study area like Asukese, Bosam Bepo and Bia North have been exploited exhaustively resulting in large areas of very disturbed residual forest. Fire has also ravaged the reserve, particularly in the north and eastern portions.

2.1.5.1 Logging History of BCA

The BCA was originally under the Forestry Department as Bia South Tributaries FR. This classification was revoked and the forest placed under the jurisdiction of WD in 1974 as BNP. Two years later, after pressure from the timber industry, BNP was split into three reserves (namely BNP and Bia East and West Game Production Reserves) to allow logging in the GPRs.

Before its establishment, BNP had never been logged commercially, and it remains one of the few virgin rain forests in Ghana today. In 1982, the WD issued a permit allowing Mim Timber Company (MTC) to start extensive selective logging of Bia Resource Reserve (BRR). This gave the WD an opportunity to monitor logging impact on the wildlife. Logging progressed slowly until 1985, but by 1987 approximately two third of the reserve’s length and 73 out of 176 compartment had been logged intensively (Hawthorne, 1993).

Until 1990 control of timber removal from the forest was through a minimum girth limit. Hence, unlimited number of trees above the girth limit was allowed to be felled (Hawthorne, 1993). Species such as *Khaya ivorensis*, *Enthandophragma utile* and *Tieghemella heckelii* therefore suffered extreme logging. Between May 1990 and June 1998 all compartments were logged according to the “modified selection system”. According to PADP (1997) this restricted the felling of certain endangered species and limited the percentage of viable trees that could be exploited within the 40 years felling cycle.

The logging operations of MTC severely influenced the forest structure of BRR, with high logging intensity of over 300 trees from compartments of about 130 ha. According to Hawthorne (1993) two percent (2.3ha/compartment) of the forest was lost to roads and 1% to loading bays. The sizes of loading bays and roads far exceed the maximum limits allowed by the then Forestry Department's regulations (Hawthorne, 1993; PADP, 1997; 1998).

Farming and illegal encroachment was never a threat in the reserve. But surrounding areas of Sukusuku FR and Tawya FR (which used to be the largest FR in the country) have been completely cultivated over the past 10 years, leaving BCA as an ecological island, completely surrounded by oceans of cocoa farms (Sam, 2000).

2.1.6 Fauna

Sixty-two species of mammals have been recorded in Bia Conservation Area alone (Sam, 2010). These include 10 primates amongst which are the Black and White Colobus *(Colobus vellerosus)*, the Olive Colobus *(Procolobus verus)*, Western Chimpanzees *(Pan troglodytes verus)* and the highly threatened Bongo *(Tragelaphus eurycerus)*. Hefferman and Graham (1999) puts the elephant population in the reserve at 138. Over 160 species of birds have been recorded; they include the internationally endangered white-breasted guinea fowl (*Agelates meleangrides*) and the Bare-headed rock fowl (*Picarthartes gymnocephalus*).

According to Martin (1982), after Wildlife Division took over the management of BCA, elephants and primates, including chimpanzees and colobuses, particularly Red colobus numbers increased. Since then the extremely high hunting pressure has now reduced numbers of several species (particularly monkeys) below the critical limit for viability. The Red colobus, Diana Monkey and White-crested Mangabey are extirpated (Oates *et. al*., 2000). Several other species are likely to go extinct (PADP, 1999). Various surveys in BCA found signs of elephants concentrated especially in the recently logged south-east areas (Barnes, 1996; Sam, 2000).

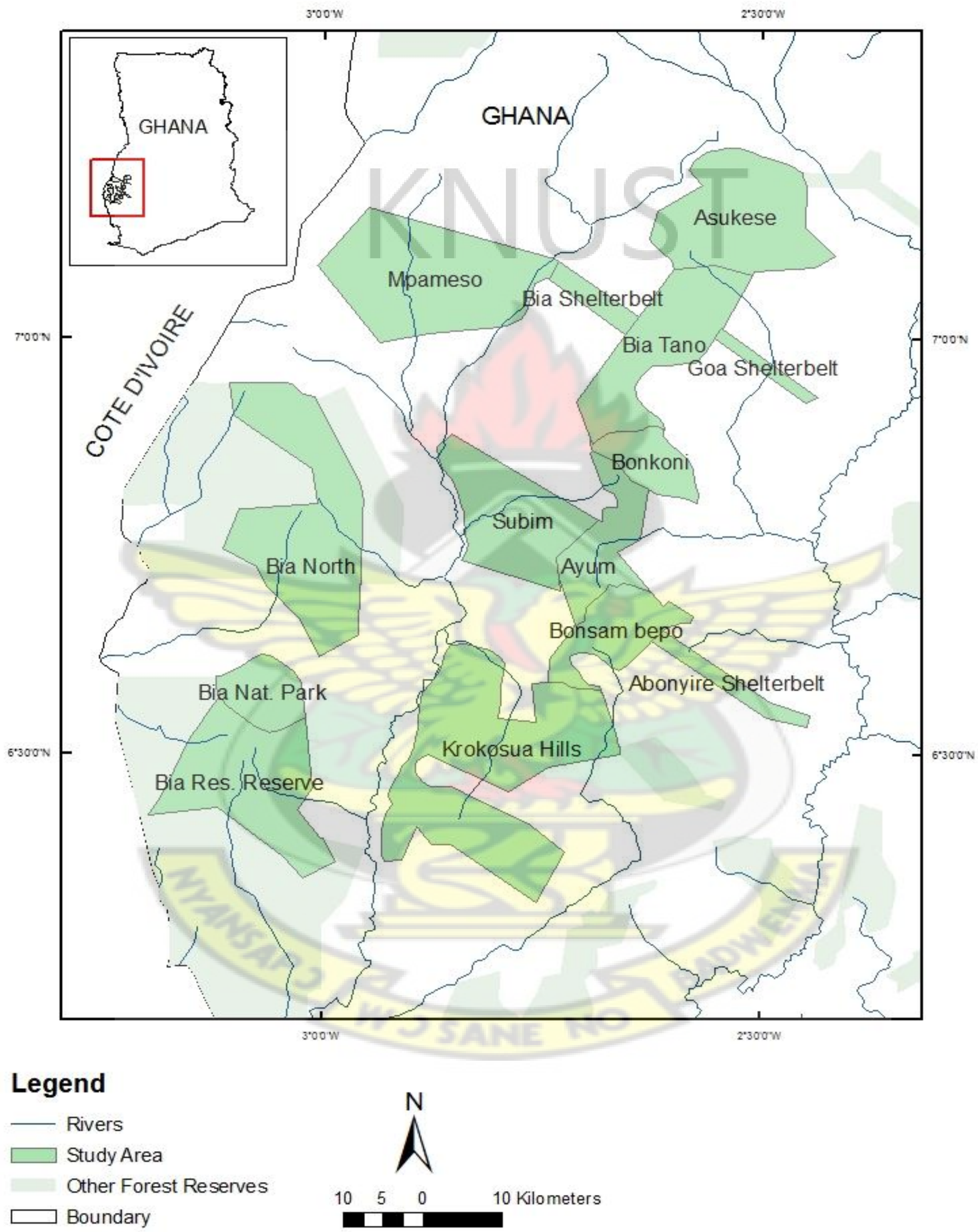


Figure 2.1: Study area showing forest reserves and shelterbelts. The inset maps show the location of study area in Ghana and Africa.

2.2 Distribution and status of Elephants

2.2.1 Distribution and status of elephants in Africa

There are two species of Proboscidae, namely the African (*Loxodonta africana*) and the Asian (*Elephas maximus*) elephants. Both species are relatively unspecialised in their ecology and originally ranged over diverse types of habitats (Cumming *et al.*, 1990). African elephants in particular were distributed historically from the Mediterranean coast through to the southern tip of Africa. At present however, their range is scattered, with fragmented populations occurring south of the Sahara (Said *et al*., 1995). Elephants were believed to have been extirpated from North Africa by 1600 (Said *et al.,* 1995). Further declines have been reported since the 19th century (Cumming *et al*., 1990). It has been speculated that these declines have been as a consequence of both ivory trade and habitat loss (Milner-Gullard and Beddington, 1993; Said *et al*, 1995). However, elephants are still found in varied habitats such as: the tropical rainforest (e.g. in Gabon); in woodland (e.g. in Botswana) savanna grassland (e.g. in Kenya) and desert (e.g. in Mali). Furthermore, elephants are also found from sea level to the highlands of Mt Kilimanjaro and Mt Kenya.

In the 1960s, the primary concern for conserving African elephants centred on local overpopulation in PAs (Laws, 1970, Laws *et al*., 1975). In the late 1970s and 1980s the primary concern centred on the massive continent-wide decline of the species from an estimated 1.3 million in 1979 to 600,000 in 1989, due to illegal hunting for ivory (Said *et al*., 1995). Certain local populations have increased and have caused increased conflicts with humans (Sam *et al.,* 1997). The conservationists are now faced with the problem of managing a species that needs urgent protection over most of its range, and yet in certain limited areas, occurs in numbers which cannot be supported by available resources or management strategies. Increase in human populations and subsequent expansion of their activities into what used to be elephant ranges has resulted in more conflicts between the two species. Though co-existence may not always be feasible, it is necessary to examine the nature and extent of conflicts under different circumstances, so as to devise appropriate strategies to reduce it.

2.2.2 Distribution and Status of Elephants in West Africa

West Africa lost more than 90% of its elephant range during the 20th century (Roth and Douglas-Hamilton, 1991), as a result, the remaining elephant populations in the sub-region are small and fragmented. Elephants survive in scattered, relic populations, threatened by both ivory poaching and loss of habitat associated with human expansion (Douglas-Hamilton 1987). About 75 separate elephant populations exist – 41 in the forest zone,27 in the savanna and 7 in the Sahel (IUCN/AfESG, 1999). These populations occupy about 5% of the land area of West Africa compared to 17%, 29% and 52% of East Africa, South Africa and Central Africa respectively making West Africa the sub-region where elephants are at greatest risk and where problems of elephants conservation and management are most urgent. The median population size in the West Africa savanna is 100 elephants, and only 40 for forest populations (Blanc *et al*., 2003).

The Guinean forest of West Africa, which is home to the forest elephant *L. cyclotis* has suffered drastic transformation in the past two decades from forest exploitation, agriculture and settlement expansion (Roth and Douglas-Hamilton, 1991). As at early 1990s, the only large primary habitat in the Guinean block was found in Liberia on the upper reaches of the Manu and Lofa rivers, and between the Cestos and Calvally rivers, and in the Ivory Coast between the Calvally and Sassandra rivers (Roth and Douglas-Hamilton, 1991).

In the Ivory Coast, until the early sixties when intensive forest exploitation and agriculture expansion started, forest elephants occurred in most areas of that country (Roth and Douglas-Hamilton, 1991).

Ghana's forest elephants were widely distributed in the Guinean forest zone until the 1950s when intensive development started. Roth and Douglas-Hamilton (1991) found that only small areas of primary forest are left around the Bia area. As at the 1960s, elephants could only be found in the Bia river system and within the Kakum forest block. Between 200 and 300 elephants were estimated to occur in the Bia area in 1978, and elephants in the Kakum area were estimated at 100 to 150. The forest elephant experienced comparable decline in the other range states of Sierra Leone, and Guinea.

Southeast Burkina Faso/Pendjari/W has the largest elephant population in West Africa, with about 3145 animals (IUCN/AfESG, 1999) followed by Gourma in Mali with about 950 elephants and Mole National Park in Ghana with about 500 (Roth and Douglas-Hamilton, 1991). Thus Mole National Park one of the three most important conservation areas for elephants in the savanna because it holds the third largest elephant population in the sub-region (IUCN/AfESG, 1999).

2.2.3 Distribution and Status of Elephants in Ghana

Various estimates of elephant numbers made in the 1980's varied from 970 to 3500 but all were based upon guesses and extrapolations (GWD, 1991). Using late 1980s data from the forest zone, GWD (1991) estimated that Ghana probably held between 700 and 2900 elephants. Today, elephants are found in 11 separate ranges but only the Mole National Park and Bia Conservation Area populations have been surveyed thoroughly within the last decade.

2.2.3.1 Savanna elephant range in Ghana

The Red Volta Valley

The Red Volta elephant range comprising the Red Volta/White Volta/Morago River valleys in northeastern Ghana form an internationally important elephant migratory corridor that link the Red Volta range to the Kabore Tambi National Park and Nazinga Ranch in Burkina Faso, and to a lesser extent links the Fosse Aux Lion National Park in Togo through the Forest of Doung in Togo.

Elephants move between Burkina Faso and Ghana along the Sissili and Red Volta valleys and less frequently along the White and Black Volta Rivers. The most important cross-border movements are along the Red Volta valley. The same elephants used to move eastwards towards the Fossi-aux-Lion NP in Togo (Sam *et al*., 1996). Sam (1994) estimated that the number of elephants in the Red Volta valley was between 100 and 150.

This population probably moves as far as Kabore Tambi NP and Nazinga Game Ranch in Burkina Faso. It also uses the Sissili River valley as a corridor into Ghana. In 1999 a meeting between the Ghanaian and Burkina wildlife authorities resulted in a joint proposal to study the ecology and movements of these elephants.

Mole National Park

Mole National Park is Ghana's largest national park and covers an area of 4,840 square kilometers. It is home to approximately 600 elephants (WD, 2000), which reside mostly in the southern portion of the park. An aerial sample survey in 1993 estimated 589± 218 elephants in the park (Grainger, 1994).

There is clear evidence that the Mole elephants migrated north along the Sissili and White Volta in the past (Jachman and Croes, 1991), but this appears to have reduced to a trickle today (Sam *et al.*, 1996). It is not clear all the factors that have affected this migration but increased farming and human development in the southern portion of the Sissili River Valley are likely to be the main cause.

2.2.3.2 Transitional zone elephant range in Ghana

With an area of 3,479sq km, Digya is Ghana's second largest national park. An aerial survey in 1993 recorded no elephants in the transects, suggesting a very low density. However 89 were seen from the air outside the transects (Grainger, 1994). To the southwest of Digya a small number of elephants exist, perhaps a dozen in the Chichibon corridor. Those elephants are known to have been there 40 years ago when they lived in an area of untouched forest near Kogyae Strict Nature Reserve. As their forests were felled they found refuge in the caves at Bomire on the Afram Plains near Drobonso and they have become troublesome crop-raiders (WD, 2000).

2.2.3.3 Forest elephant range in Ghana

In the forest zone of Ghana five different surviving elephant populations are living completely isolated from each other in Kakum NP/Assin Attandanso Game Production Reserve (GPR), Ankasa GPR/ Nini Suhien NP, Trans Bia Area, Goaso Area Forest Reserves and the Boin river Forest Reserve. The Bia population is estimated to be around 200-250 individuals (Martin, 1982). Dickson (1990) estimated the same magnitude for the Goaso population.

The Goaso and Bia complex of the forest reserves may harbour more forest elephants than any other place in West Africa. Until recently it was assumed that south-eastern Liberia was the largest area of potential forest elephants. The Tai NP in Cote d'lvoire also has the potential to hold many elephants but numbers were cut down from 800 in the early 1980s to about 100 in 1989 (Merz and Hoppe Dominik, 1991) and since then, there have been further losses. The Goaso and Bia complex is the largest block of forest elephant habitat in West Africa after south-eastern Liberia and Tai. Therefore it may now be the most important area for forest elephants in the sub-region.

2.2.4 Conservation Importance of the Bia –Goaso elephant populations

In the Elephant Conservation Plan for Ghana (1991) it has been proposed that neighboring "Forest Reserves, National Parks and Game Production Reserves should be linked by extensions of the 'shelterbelt' system and new connections developed between the numerous small reserves, to allow elephants to travel more freely between protected areas.

According to de Leede (1994), in Ghana the most suitable populations to be connected with each other by forest corridors/shelterbelts seem to be first of all the Bia and the Goaso population in Ghana, and secondly the Ivorian populations on the other side of the border with the Bia population. The distances between the areas where the other populations in Ghana reside are too far to be a realistic possibility for the creation of corridors.

The existing landuse between the present home range of forest elephants prevents the elephants from crossing to other suitable habitats. Because of this isolation, it can be expected that in the long term the exchange of genetic material will be reduced which can result in inbreeding and finally in extinction of the entire population (de Leede, 1994). De Leede, (1994) again states that inbreeding should preferably be kept below 1% pre generation which means an effective population of at least 50 individuals should be maintained at the very minimum. In a normally sex/aged-structured elephant population, this would comprise a minimum population of 150 individuals.

The Goaso-Bia area is one of five priority regions for biodiversity conservation identified by the West Africa Priority Setting workshop held by Conservation International in Elmina in December 1999. It was proposed as a transfrontier corridor for elephants by Parren *et al*. (2002). The population in this corridor is greater than the average population size (approximately 40 for forest elephants) making them important (West African Sub-Regional Strategy for the Conservation of Elephants).

Dispersal corridors for enlarging effective population sizes should be created. The creation of a forest network would encourage animal movement and in consequence stimulate gene flow between isolated populations. This network should consist of the elephants home ranges, presently restricted to parts of the permanent forest mainly designated as production forest, in conjunction with corridors. The key components are establishment of connectivity, channelisation and movement.

2.3 Determinants of elephant distribution and numbers

The population dynamics, home range, migration patterns, diet, group size and composition of elephants are affected by environmental factors (tree density, canopy cover, presence of water-bodies etc.) which in turn influence the dynamics of the elephants and their habitat (Poche, 1974). Information on elephant abundance and factors that affect abundance over time is essential to manage wild elephant populations effectively (MIKE, Elephant Survey 2004).

Speculation that resources determine the distribution of elephants identify fruit, browse, and mineral deposits as aspects (Blake *et al.*, 2004) of elephants home range areas, which vary greatly, both within and between sites. Resource requirements, as well as variability in resource quality, quantity and dispersal have all been touted as explanations for such variability within and between sites. Landscape heterogeneity, a measure of how fragmented a landscape is, may also explain such variability within and between sites.

In the equatorial rain forest of northeastern Gabon, elephant distribution is governed by the presence and activity of humans (Barnes *et al.*, 1991, Barnes and Jesen 1987). Elephants were attracted to secondary forest with thick undergrowth, growing on abandoned villages and cultivation, and avoided areas close to roads and villages. Elephants are attracted to secondary forest by the greater diversity of food plants which is within reach, and the fact that most fast growing secondary species are less likely to be protected by toxins and tannins.

Sam *et al*., (2002) found that increasing number of cattle reduces the probability of finding elephants outside the Red Volta forest reserves thus influencing their distribution. The authors (Sam *et al*., 2002) however acknowledged that the distribution of elephants was influenced by a combination of factors among which cattle distribution is counted. Elephants may also avoid areas with increased human presence and disturbance, and their movement may be governed by several combining factors including, seasonal fluctuation, variation in the availability and quality of food, water and cover, and high poaching or prevalence of physical barriers (Sam *et al.*, 2002, Hillman Smith *et al*., 1995).

The loss and degradation of habitats reduce the space available for elephants and their quest for forage leads them into conflict with people on the edges of ranges because they damage crops. According to an elephant survey carried out in Kakum Conservation Area in 2004, elephant movement and distribution during the long wet season (study period) might largely be restricted by low fruit availability within the park and/or increased food abundances outside the park's confinement (Danquah *et. al*., 2008). This suggests that fruiting trees have effect on the seasonal movements of elephants in KCA. The different indices of illegal human activity within the park did not influence elephant density significantly.

Illegal hunting for almost all species of animals occurs in Bia Conservation Area as well as all forest reserves in the Goaso area. Most forest elephant killings in Ghana have been recorded from these two populations. In 1999, there were at least 4 official elephant-poaching cases in BCA alone (Bia National Park Annual Report to WD Hq 1999). The poaching causes elephants to move to more secure areas within conservation area.

Elephants in Bia Conservation Area have been reported to confine their movements, to the same traditional routes (Martin, 1982). Sam (2000) observed that elephant distribution was clumped or aggregated in the BCA. Both illegal activities and water sources accounted for a large portion of this variation. Barnes (1996) also observed that, elephants concentrated in a small (south-east) part of the Conservation Area. He reported that, four-fifth of the CA "showed no signs of elephant occupation" and that there was a positive correlation between elephant abundance and number of fruiting trees per km.

In the Goaso area, de Leede (1994) observed that, lack of water appeared to be the main reason for elephants moving out of the forests. Sam *et al*. (1997) also observed at the Red Volta Area that, elephants concentrated along the banks of the Red Volta River which had water throughout the year, there was no correlation between elephant abundance and watering points (other than the Red Volta River itself) within the area. However, in Bia Conservation Area, water availability does not seem to be a problem as there are many artificial pools in the reserve. These pools were created as a result of the logging activities by MTC (Sam, 2000). In the construction of their "over-elaborate" logging and hauling roads (PADP, 1998a), many streams have been blocked.

According to Sam (2000), this is due to the fact that, while many of the roads are raised above ground level, bridges were badly constructed or not provided at all, and the streams have therefore collected into several small pools along the sides of sections of the roads. Some of these pools are often visited by elephants and may account for the positive relationship between watering points and elephant abundance (dung-pile density) at the periphery (Sam, 2000). Also according to Sam (2000), it was observed that, apart from the swampy nature, the areas around these pools had vegetation (thickets with some thorny climbers), which were very difficult to traverse and hence likely to be avoided by many hunters. Therefore while pools provided water for elephants, the vegetation at their banks also gave protection to the elephants.

2.4 Decline in Elephant Populations

2.4.1 Decline in Elephant Populations in Africa

According to Dudley (1996), humans and elephants have co-existed in Africa for at least the past million years, with the continent serving as their common centre of evolutionary development. The scope and scales for human-elephant interactions have altered markedly through time, first with the development of agriculture and more recently with the widespread availability of modem firearms. Olivier (1978) and Cumming *et al., (*1990) reported that the earliest recorded extinctions (1,500-4,000 BC) of regional elephant populations occurred in major centres of early agricultural civilisation: North Africa, the Middle East, and the Yangtze Valley of China. The ability and propensity of elephants to damage crops has led to their killing by man. This, together with the effectiveness of firearms as a tool for killing elephants have resulted in their extirpation throughout much of their range during the past century.

Between 1960 and 1980, most of the elephant populations were in decline across Africa (Douglas-Hamilton, 1987). As early as 1980, the African elephant population stood at 1.3 million (Parker and Graham 1989, Douglas-Hamilton 1987), but this figure has decreased drastically over the decades partly due to habitat loss in the range states. Across the continent, elephants experienced a drastic decline in the late 1970s through the 1980s, except in Zimbabwe, Malawi, Botswana, and in South Africa (Douglas-Hamilton, 1978). During the early 1970s, concerns grew over the decline of elephants. However there was no hard data to support such claims (Blanc *et al*., 2003). This led to the implementation of the African Elephant Survey and Conservation Programme in 1976, which recorded and publicized the decline in elephant populations in Africa. Blanc *et al*., (2003) reported that such declines continued through the 1980s in much of West Africa.

To avert a further decline of the African elephant, it was placed on Appendix I of the Convention of International Trade in Endangered Species of Flora and Fauna (CITES) in 1989. However, currently the elephant populations of Bostwana, Namibia, Zimbabwe and South Africa have been transferred to Appendix II to allow regulated trade in elephant products by these countries. Current issues affecting the conservation of the African elephant include insufficient level of international cooperation and coordination among range states, habitat fragmentation and lack of adequate information on several elephant populations on the continent, particularly in West Africa (Blanc *et al.*, 2003).

2.4.2 Decline in Elephant populations in West Africa

The twentieth century witnessed a decline of 90% of elephant range in West African primarily because of ivory hunting and the rapid expansion of human activities (Roth and Douglas-Hamilton, 1991). Roads, railways and settlement split the remaining range into isolated fragments, so that today West African elephants are found for the most part in small isolated populations. Because the remaining elephant refuges are surrounded by dense human populations, crop-raiding and other forms of human elephant conflict are frequent. The remaining habitats are often degraded, and encroachment by farmers and grazers is common (AfESG, 1999). Poaching for both ivory and meat is a constant risk.

The elephants of West Africa have suffered a long history of human disturbance. Even before 1800 their numbers had been reduced by the pre-colonial empires of the savanna and Sahelian zones, the ivory trade across the Sahara and then the ivory trade towards the Atlantic Coast (Wilson and Ayerst, 1976; Alpers, 1992). The increasing demand for ivory from Europe and North America, the colonial invasions and the evolution of breech-loading rifles devastated elephants during the nineteenth century. Ivory exports from West Africa continued to grow during the last part of the nineteenth century and the first decade of the twentieth century but then collapsed just before the outbreak of World War 1.The collapse was due to over hunting (Douglas-Himilton, 1979; Roth and Douglas-Hamilton, 1991) and it pre-empted the decline that would have occurred anyway due to rapid growth of the human population and consequent loss of habitat (Barnes, 1999). Human populations quadrupled in West Africa during the last century (McEvedy and Jones, 1978, Bos *et al*., 1994). Roads, villages, towns, farms and logging expanded rapidly fragmenting elephants' habitats into small patches.

In the 1800s, much ivory was sold from the West Africa sub-regions. In Senegal alone, at least 392 tons of ivory were exported between 1825 and 1845 (Roth and Douglas-Hamilton, 1991). At that time, there was no conflict between agriculture and elephants. Ivory exports also increased in the Sudanian zone of West Africa in the mid 1800s but suddenly collapsed before 1914. Bush elephants in the Sudanian zone started to be deprived of their habitats only in the 1930s when agricultural development intensified. However, forest elephants in the Guinean zone are well adapted to human disturbance that modify the forest (Merz, 1982) and were not much affected until 1945 when forests underwent large scale transformation into industrial plantations (Roth and Douglas-Hamilton, 1991).

2.4.3 Decline in Elephant populations in Ghana

Elephants were found over much of the country in the early years of the twentieth century. Ghana's forest elephants were widely distributed in the Guinean forest zone until the 1950s when intensive development started. As at the 1960s, elephants could only be found in the Bia river system and within the Kakum forest block (Merz, 1976). Between 200 and 300 elephants were estimated to occur in the Bia area in 1978, and elephants in the Kakum area were estimated as 100 – 150.

The need for land as the human population expanded caused a widespread loss of elephants' habitats. The contraction of elephant range in the northern savannas has been described by Sam *et al*. (1996) and in the southern forest by Barnes *et al*. (1995).

2.5 Habitat Fragmentation

For wildlife dependent upon forest environments, fragmentation of the forest results in the formation of a mosaic of habitat patches surrounded by expanses of inhospitable terrain. Some species, notably birds, may readily traverse gaps between patches of suitable habitat; but for many fauna1 species, even small habitat discontinuities may pose a distributional barrier, or a severe limitation to free movement (Barnett *et al.*, 1978; Campbell, 1981; Mader, 1984).

According to Tchamba and Mahamat (1992), habitat conversion and fragmentation caused by agriculture and deforestation greatly increase incentives and opportunities for the decimation or extermination of local elephant populations. Habitat loss is currently the greatest threat to the survival of the Asian elephant (Santiapillai and Jackson, 1990), and will in all probability become the ultimate threat to survival of the African elephant (Cumming *et al*., 1990). Parker and Graham (1989) further reaffirms this by predicting that human population increases are likely to cause further major reductions in habitat for African elephants during the coming century. The long-term importance of habitat loss as a threat to the survival of the African elephant needs wider recognition (Armbruster and Lande, 1993).

2.5.1 Fragmentation of elephant habitats in Ghana

Once covering 82,300 km^2 of Ghana's land mass (Hall and Swaine, 1981), forests now cover less than 20% of their original extent in Ghana. According to Whitmore (1997), the most fragmented tropical forests today occur in the Philippines, peninsular Malaysia, Costa Rica and Ghana. Tropical forest in Ghana consist of fragments of differing size and shape, protected as extractive reserves and separated mostly by agricultural land (Hall and Swaine, 1981). According to Beier *et. al*. (2002), given the needs of growing human populations, and the agricultural economies of many tropical countries, tropical forests will increasingly become fragments in an agricultural landscape.

Usually, consequences of habitat fragmentation consist of reduced population size and increased isolation (Saunders *et al*., 1991; Van Rossum *et al*., 2004), leading to genetic erosion and increased genetic differentiation among populations, through random drift, increased levels of inbreeding and reduced gene flow (Young *et al*., 1996; Chen 2000; Van Rossum *et al*., 2004). Ultimately these genetic processes may result in fitness declines and extinction (Keller and Waller 2002; Bacles *et al*., 2004).

According to Lovejoy *et al*. (1986), the ultimate effect of habitat fragmentation is extinction of species due to reduction of total habitat area and reduction of the remaining area into disjunct fragments. The first component affects population sizes, and thus extinction, while the second affects dispersal and thus immigration rates. Besides effects of fragmentation, such as a restricted range area, there is also a decrease in tree species diversity and depletion of food resources.

2.6 Habitat corridors

A corridor is a linear feature of vegetation connecting at least two isolated habitat fragments that were once connected (Saunders and Hobbs, 1991). The provision of habitat corridors - narrow connecting strips of favoured habitat - to link insular environments has been one of the most consistent recommendations proposed in recent strategies for the conservation of fauna in fragmented environments (Willis 1974, Diamond 1975, Wilson and Willis 1975, Friend, 1980, Breckwoldt, 1983). In Africa, the widespread conversion of natural habitats into agricultural land has pushed many species into ever smaller, isolated fragments of wild land and brought them into direct conflict with humans. The main threat to many species is now considered to be habitat loss and fragmentation leaving wildlife to survive in refuges linked by areas under high conservation threat (Harris, 1984). Linking areas of important wildlife habitat or high biodiversity has become an increasing priority in the conservation of natural habitats. Wildlife corridors, protected bands of suitable habitat linking core populations of plants and animals, are seen as the best solution to the problem of habitat fragmentation (Osborn and Parker, 2003). It is believed that the provision of corridors will facilitate the movement of fauna between populations that are otherwise isolated within disjunct patches. The resultant fauna1 interchange may increase the conservation value of the otherwise disjunct habitats in two ways: firstly, by reducing the vulnerability of insular populations to stochastic extinction from environmental disturbance, demographic fluctuation, or genetic deterioration; and secondly, by providing a means for recolonisation to occur should any local extinctions take place (Shaffer 1981, Simberloff and Cox 1987).

2.6.1 Rationale for creating habitat corridors

Currently, there are four rationales for creating corridors, namely increasing immigration rates (Harris and Scheck, 1991), providing movement routes for wide-ranging species, decreasing inbreeding depression (Harris, 1984), and reducing demographic stochasticity (Merriam, 1991). According to the Action Plan for the Management of Transfrontier Elephant Conservation Corridors in West Africa June 2003, there are two different types of corridor. The first may be called the migration corridor and consists of a strip of habitat that links two patches or reserves. This type of corridor promotes the movement of animals between the reserves and therefore reduces the effects of genetic isolation and allows access to a wider range of resources. This improved connectivity has been shown to bring wider ecosystem benefits such as enhanced pollination and seed-dispersal (Tewksbury *et al.*, 2002). The second type may be called a conservation corridor and comprises a portion of landscape embracing several different land uses that are managed to achieve specific conservation objectives (AfESG/IUCN, 2003). This is broader in scope than the first and is the type promoted by Conservation International and others in West Africa. When such a conservation corridor spans an international boundary, the scope is even greater and these have become known in the conservation community as transfrontier conservation area (AfESG/IUCN, 2003). All these concepts share the same general conservation aims and objectives.

2.6.2 Conservation importance of habitat corridors for elephants and other wildlife

Small habitats have a large ratio of perimeter to area, making the animals therein vulnerable to human pressures. For example, during the period of poaching in the 1970s and 1980s, elephants occupying small reserves had a low probability of survival compared to those in larger ranges

(Barnes, 1999). Small patches of habitat may not have the resources necessary to support an elephant population year round or during periods of scarcity such as drought, hence the need to ensure unobstructed movement of elephants for their conservation (AfESG, 1999).

According to the information provided by the African Elephant Status Report 2002 (Blanc *et al.*,2003), transfrontier elephant populations account for more than half the forest elephants in West Africa, and more than two-thirds of the savanna elephants in the sub-region. Cross border elephant conservation programs are therefore necessary for the conservation of forest elephants and the trans-boundary processes that sustain the ecosystem they depend on. The successful management of transfrontier ranges will make a significant contribution to the conservation of West African elephants.

The conservation of elephants will preserve the integrity and diversity of our natural ecosystems. Habitats managed to preserve elephants will also ensure the conservation of less charismatic plants and animals (Wildlife Division, 2000). Due to their wide-ranging habits, elephant conservation initiatives in the corridor will largely benefit other wildlife species sharing the habitat, thus the development of the corridor will ensure the conservation of biodiversity in general within the corridor area. Finally, continued rapid growth of human populations and their impact on the corridor habitat mean that in the next few decades, the possibility of developing this corridor to conserve the habitat and the wildlife within will be much more challenging. The situation is made more urgent by the new theory that West African elephants are different from those elsewhere on the continent and may represent a separate sub-species or species (Eggert *et al.*, 2002).

The corridor concept is an idea which is now trending. It has been embraced by conservationists during the last two decades because it provides the hope that we may be able to reverse deleterious consequences of habitat fragmentation. (West African Elephant Conservation Plan, 1999)

2.6.3 Relevance of habitat corridors in West Africa

In West Africa, 25% of the plant species and 29% of the vertebrate species in closed forest environments are endemic (Myers *et al*., 2000), but these environments are also the most deforested areas in the tropics. Of the original moist forest zone of 31.3 million ha that stretched from Guinea to Ghana at the beginning of the 19^{th} century, only 8.7 million ha remain (Parren and de Graaf, 1995). Some animal species may have been extirpated (Oates *et al*., 2000) and others may go extinct in the coming decades (Holbech, 1998; Caspary, 1999).

Apart from the two major activities, that is ivory hunting and rapid expansion of human activities, railways and settlement split the remaining range into isolated fragments, so that today West African elephants are found for the most part in small isolated populations. Forest elephants (*Loxodonta africana cyclotis*) populations in the Upper Guinea forest block of West Africa are nowadays small, scattered and isolated within relict patches of rainforest habitat (Dudley *et al*., 1992). Growth of the population, going hand in hand with deforestation and expanding agricultural activities, has resulted in drastic reduction of the habitat of the forest elephants.

The African Elephant Database of the African Elephant Specialist Group (Barnes *et al*., 1999) estimated that the total number of forest elephants *Loxodonta africana cyclotis* in West Africa in 1998 was about 3000. Ideally, a population of c. 1,000-5,000 should form a metapopulation, in which sub-populations can still wander from one sub-population to another (Vucetich and Waite, 1998). However, free migration of animals over large areas is no longer possible to counterbalance the low local population levels (Parren and Sam, 2003).

2.6.4 Relevance of a transboundary Ivory Coast - Ghana Corridor

Forest elephants in Ghana and eastern Ivory Coast live in small isolated populations and number fewer than 1,000 individuals in total. This metapopulation in the Ivory Coast - Ghana border area, the total of which numbered 685-855 individuals in the late 1980s is bordered by the savannahs of the Dahomey Gap to the east and by the so-called V-Baoule, a savannah zone that penetrates deep into the moist forest zone in Ivory Coast to the west (Parren and Sam, 2003).

According to the Action Plan for Management of Transfrontier conservation corridors in West Africa (2003), cocoa production and subsistence farming are the main agricultural activities on both sides of the Ivory Coast - Ghana border in the corridor area. The existing landuse between the present home range of forest elephants prevents the elephants from crossing to other suitable habitats. Because of this isolation, it can be expected that in the long term, the exchange of genetic material will be reduced which can result in inbreeding and finally in extinction of the entire population (de Leede, 1994).

In the eastern part of Ivory Coast and the western part of Ghana these animals are all scattered over highly fragmented forest reserves. If the forest elephants will continue to live in small isolated groups, it can be expected that they will become extinct in the near future due to genetic erosion and poaching. In order to prevent this, it is necessary to ensure the exchange of genetic materials between the different groups and to protect their actual living ranges effectively (Versteegden, 1996). The habitat of the population can be extended and populations can interact. A connection between these groups can be established by creating corridors between their living ranges as proposed by Parren and de Graaf (1995).

According to Versteegden (1996-), in future if the survival of these elephant populations is to be assured, efforts will have to be made to connect the elephant populations in Ghana with those in Ivory Coast. This can only be done by establishing a corridor along the Bia river and a corridor from Bia National Park through Diambarakrou to Bossematie, which will imply a major reforestation program in cooperation with the people in those areas.

2.6.5 Characteristics of successful corridors

According to Parren and Sam (2003) corridors should be designed to attract forest elephants into them. Important aspects to take into consideration are the presence of food plants, availability of water, and the size and structure of the corridors.

Food: Forest elephants feed opportunistically on certain fleshy fruits when these are available and rely upon less nutritious foods during periods of fruit scarcity. In Ghana and east Ivory Coast the period of fruit scarcity is from May to October, during the rainy season. In that period elephants will be tempted to leave the forest and raid cultivated crops (Merz, 1986), like plantain. Favourite forest tree species are *Parinari excelsa, Balanites wilsoniana, Duboscia viridiflora, Panda oleosa, Sacoglottis gabonensis* and *Tieghemella heckelii* (Sachtler, 1968; Martin, 1991; Hawthorne and Parren, 2000; Dankwah *et al.*, 2008). Planting T. heckelii and S. gabonensis trees as well as other preferred fruit trees in corridors (Alexandre, 1978; Merz, 1981; Short, 1981; Lieberman *et al.*, 1987; Hawthorne and Parren, 2000), or enriching forests close to the entrance of corridors could attract elephants and increase the chance that they use these corridors.

Water: In the moist forests of West Africa many elephants favoured tree species fruit in the dry season (Taylor, 1960; De la Mensbruge, 1966; Alexandre, 1980). However, the water provided by fruits is not enough as in this season elephants come out of the forest in search of water. Artificial waterholes could be created in forest elephant range reserves to ensure they stay within the reserve boundaries. This has already been successfully done inside FC Bossematie (Waitkuwait, 1992). Corridors on riverbanks, such as the Bia river corridor, would have the advantage of providing drinking water for the elephants.

Form and structure: At present elephants use four shelterbelt forest reserves in the Goaso home range. The 1.5 km wide Amama Shelterbelt probably is recolonized (Mann and Plummer, 1995), a unique situation. Shelterbelts even incur fewer crop raiding reports than forest reserves, even though the surface to boundary ratio is higher for the shelterbelts. This shows that 1.5 km wide linear corridors have the potential to be used as passage by large mammals such as elephants in Ghana. Elephants and logging activities seem to be compatible, even within shelterbelts, since the easily available fruits and foliage at logging sites attract the animals. In general, elephants appreciate a more open forest where pioneer species and shrubs are abundant (Short, 1981; Martin, 1982; Dudley *et al.*, 1992; Hawthorne, 1993) as long as a diverse fruit resource is available. On the other hand logging can also chase elephants out of the forests through the excessive noise and other indirect effects which come along with the presence of people into the forest.

2.7 Human-elephant conflicts

Human- elephant conflict has been a problem to many parks and reserves across Africa (Sam *et al*., 2005) and is certain to escalate due to increase and decline in human populations and elephants habitats respectively (Sam *et al.*, 2005). Most of the elephants' home range has been converted into human settlements and farms due to the increase in human populations.

According to Laws *et al.* (1975) and Eisenberg (1981), elephants are keystone herbivores whose foraging activities profoundly influence the structure, composition and productivity of vegetation communities within their habitats. This keystone ecological function of elephants often directly conflicts with the requirements of human agro-ecosystems. Agriculture, silviculture and human settlements within or adjacent to elephant habitats typically result in severe human-elephant conflicts (Eltringham, 1990; Newmark *et al.*, 1994). Competition for resources (e.g., water, grazing, and trees) and physical confrontations may result in injuries and deaths among both humans and elephants (Pitman, 1934; Seidensticker, 1984). Free-ranging elephant populations are for the most part incompatible within or adjacent to areas of intensive agriculture. In this regard Cumming *et al.*, (1990) has identified human-elephant conflict as being historically the major factor in eliminating African elephants from large areas of their historic range.

The major human-elephant conflict in various elephant ranges has been crop raiding. Although not the most common crop pest, elephants may cause considerably more damage per conflict incident than other species (Sitati *et al.*, 2005). Moreover, elephants are more dangerous than other herbivore species, resulting in more human deaths and injuries (Sitati *et al*., 2005). For these reasons elephants are generally less tolerated than other crop-raiding species (Sitati *et al.*, 2005). As approximately 80% of the African elephants' range lies outside protected areas, it is vital to find ways to reduce crop losses, thereby improving food security and maintaining the tolerance of rural communities to elephants (Sitati *et al.*, 2005). Other human- elephant conflicts include competition for water (Adjewodah *et al.*, 2005).

2.7.1 Factors influencing crop-raiding

Crop raiding occurs throughout elephant ranges and probably began with the advent of agriculture 10,000 years ago. It has intensified as agriculture has spread throughout the elephants' ranges (Adjewodah *et al*., 2005).

In Africa, seasonal movement of elephants brings them into contact with farmlands, which have encroached and fragmented on their traditional range (Adjewodah *et al.*, 2005). In India seasonal elephant movement, competition for water, reduction and degradation of natural habitat, and the higher nutritive value of cultivated crops as compared with uncultivated food are associated with increased crop raiding (Adjewodah *et al.*, 2005). In Zimbabwe, rainfall and plant moisture may influence the movement of elephant into communal land from a protected area (Adjewodah *et al.*, 2005). Insufficient habitat in protected areas and modification of the landscape by humans contribute to elephant crop raiding in the Upper Guinean forest zone of West Africa (Adjewodah *et al.*, 2005). Sam *et al.* (1998) found that a growing human population and the need for new farmlands have also increased human- elephant conflict in the Red Volta Valley (Adjewodah *et al*., 2005). Elephants and humans are now competing for land due to the increase in human populations. In Kenya, the elephant has had the greatest effect on human activities and has led to severe human–elephant conflicts, mostly as a result of elephant habitats being fragmented and reduced. The major consequences of conflict have been an increased number of human deaths and injuries, and of elephant deaths and injuries, and habitat degradation.

In Uganda, human settlement blocked off the migratory corridors of elephants in Luwero District, leading to isolation of this small population. Increase in human population, which was accelerated by an influx of pastoralists into the area in the late 1980s and 1990s, led to drastic reduction of ranging space for these elephants and increased human–elephant conflict. The elephants competed for watering points that the people had dug out for their livestock. They also terrorized villagers, killing five people and wreaking havoc on crops and other property (Wambwa *et al*., 2001)

The introduction of ponds into or closer to elephant habitat has also increased crop-raiding. For example, in Waza National Park at Cameroon, the elephant numbers increased significantly after constructing dams at the place. According to De longh *et. al*. (2004), the number of Waza elephants crop-raiding in Kaelé increased gradually from 10 in 1980 to 200 in 1991 and around 350 in 1993 and 400 in 1998, while also the area of crop raiding increased. The area raided by Waza elephants increased from 10 ha in 1980 to approximately 10,000 ha in 1998.

Crop raiding by African elephants *Loxodonta africana* erodes local tolerance for elephants and thereby impedes conservation efforts, so solutions are urgently required. Within conflict zones, crop raiding is not distributed equally amongst farms, which may be a result of variation in local physical or geographical factors, or in farmers efforts to defend their fields (Sitati *et al.,* 2005). In Zimbabwe's unprotected areas, elephants are considered the greatest pest species yet the most valuable wildlife species, as a result of the economic benefits which are obtained from their utilisation (Sam, 2000).

Elephants in Kibale area of Uganda are described as “much feared, smart and dangerous animals capable of killing humans. In northeastern Ghana, they are considered as “malevolent creatures that destroy food supplies (Sam, 2000).

In Ghana crop damage by elephants around Bia Conservation Area (BCA) is a serious multifaceted management problem that authorities of the Wildlife Division face (Sam *et al*, 2005). While the problem has been investigated extensively to identify the underlying causes, there have not been many systematic data gathering attempts on this issue in the area for park management to understand and appreciate habitat requirements and the crop- raiding behaviour of BCA elephants (Sam *et al*, 2005).

In the Red Volta Valley in Ghana, crop raiding by elephants usually occurred from June to November. October was the peak crop-raiding month in each year with about 72% of the raiding cases during 2000 to 2002 raiding being recorded (Adjewodah *et al.*, 2005). The peak period coincide with the time when farm crops were mature, ripe or ready for harvest. However, in 2002 raiding started as early as June (28%) and ended in November (4%) (Adjewodah *et al.*, 2005). Adjewodah *et al*. (2005) reported that all crops raided by the elephants were on bush farms about 2.8km from the nearest village. Compared with the main village in each chief-dom, farms damaged by elephants were relatively close to the Red Volta West and Red Volta East Reserves. Malima *et al.* (2005) recorded that, elephants seldom raided fields without crops and severity of raiding peaked as the harvest period approached for rain fed crops (June and July). Sam *et al.* (2005) also reported that, severe crop raiding at BCA in Ghana starts in June and increases steadily before peaking in September and October. It declines in November and by December has become minimal.

At BCA, information gathered through questionnaire by Sam (2000) reveals that, elephant behaviour has changed; according to farmers in that area; though crop-raiding was primarily done by male elephants and only at night, in recent times, however, family groups consisting of adult females, males and especially sub-adults are often the culprits. Elephants have also been seen in the fields in broad daylight. This is also true at the Kakum Conservation Area also in Ghana.

In Kenya, crop- raiding elephant groups ranged in size from 1 to 40 individuals (medium 6), with 80% in groups of < 10 animals that were principally female-led family groups (Sitati *et al.*, 2005). According to Sam *et al.* (2005), at least 24 males and 12 females were involved in crop- raiding at eight different settings or occasions in BCA. In terms of age, some 43 adults and 33 sub adults and infants were seen on different occasions at BCA.

2.7.2 Mitigating Crop-raiding

Several attempts have been made to reduce human-elephant conflicts. Traditional methods for deterring crop-raiding elephants such as the use of fires, brush fences and noise, have generally failed, except where farms were close together (Sam, 1998). Various barriers (e.g. stone walls and moats) have been designed to exclude elephants from agriculture but electrified fences are considered to be the best solution. In Laikipia, crop damage has been a serious problem resulting in the evolution of several types of fences and barrier for over three decades (Sam, 1998). Electric fences have been erected also in many other countries in Africa: Malawi, Zimbabwe, and Namibia. Some of the simple and complex designs have worked, while others have not.

In the case of crop-raiding elephants, huge variety of relatively inexpensive, low-tech, non-fatal mitigation methods are in use by local farmers across Africa. These range from passive barrier methods such as ditches, fences, walls and hedges around fields, to active deterrent methods including shouting, banging tins and drums, throwing stones, lighting fires and burning chillies (Sitati *et al*., 2005). The extent to which any of these influence elephant crop-raiding behaviour remains relatively untested. Such tests are vital, however, if the most effective combination of methods is to be identified. Moreover, whilst predictive models of conflict and its mitigation have been developed for other species, independent tests of their predictions and recommendation are rare.

Wildlife staff and farmers try to frighten elephants away by shooting in the air or by banging drums, but often the elephants return soon. This method of mitigating crop-raiding by elephants is not the best because crop-raiding problems get worse year by year (Barnes *et al*., 2003). In spite of disturbance by firing shots in 1994 and 1995, the number of elephants raiding crops annually in Kaelé has fluctuated between an estimated 300 to 350 during 1994–1997 (de longh *et al*. 2004).

A new method of scaring elephants is often successful at first, and farmers assume that they have at last found a way of protecting their crops. Elephants are always suspicious of something new in their environment, but after a while they learn that it is harmless and they ignore it. Because elephants quickly habituate to these sorts of tactics, they must be used sparingly .They are more likely to remain effective if used only occasionally. But if one succumbs to the temptation to use such tactics often, then elephants will become habituated and they will become useless, then one will have no effective means of scaring elephants when they enter the farm.

Trip wires and methods for frightening elephants are not a solution, for they merely address the symptom to the problem. Analysis shows that the cause of the problem is the change in the landscape that has made it so attractive to elephants. Therefore the most cost-effective means of addressing the problem is to manage the landscape outside the park to reduce its attraction for elephants. Changing the farming system adjacent to the park will tackle the roots of the crop-raiding problem. The scaring tactics can be used occasionally when elephants leave the park. If used infrequently, then the scaring tactics will remain effective for long (Barnes *et al.*, 2003).

International bodies such as African Elephant Specialist Group (AfESG) are also making efforts to mitigate human-elephant conflicts around the world. In 2001, the AfESG's Human–Elephant Conflict Task Force submitted a proposal to the World Wide Fund for Nature's (WWF) African Elephant Programme for mitigating human–elephant conflict at 10 sites across the continent. The proposal, which was approved in March 2002, aims to reduce levels of conflict by training human–elephant conflict managers over the next three years in the latest mitigation methods. A secondary aim of the project is to test and improve the new human–elephant conflict decision support system, data collection protocol and training manual for enumerators of elephant damage. Another project underway is the production of maps from satellite images of human–elephant conflict sites with the help of a geographic information system. Producing up-to-date, standardized maps of sufficient resolution to show crop fields, villages, corridors of elephant movement between natural habitats, fencing and habitat types will be useful for designing strategies to reduce human–elephant conflict. Maps are currently being generated for three sites in Kenya, Zambia and Guinea-Conakry. If the exercise proves successful it is hoped that this methodology will be applied widely across the continent (Dublin, 2002).

CHAPTER THREE

DISTRIBUTION AND NUMBERS OF FOREST ELEPHANTS IN BIA-GOASO AREA OF THE GUINEAN RAIN FOREST

3.1 Introduction

In West Africa, both races of African elephants, *L. a. cyclotis*, the forest elephant and *L. a. africana*, the bush elephant, occur. The forest race, *L. a. cyclotis*, is found in the Guinean rainforest, from Senegal to western Ghana. By the turn of the 20th century, West Africa had lost more than 90% of its elephant range (Roth and Douglas-Hamilton, 1991). Consequently, the remaining elephant populations in the sub-region are small and fragmented. These populations occupy about 5% of the land area of West Africa compared to 17%, 29% and 52% of East Africa, South Africa and Central Africa respectively (AED, 2000), making West Africa the sub-region where elephants are at greatest risk and where problems of elephants conservation and management are most urgent

In Ghana, elephants were found over much of the landscape in the early years of the 20th century (WD, 2000). The need for lands as the human population expanded caused a wide spread loss of their habitats. The contraction of elephant ranges in the northern savannas has been described by Sam *et. al.* (1996) and in the southern forests by Barnes *et. al*. (1995).

The number of elephants surviving in Ghana has been a matter of concern and uncertainty. Various estimates of elephant numbers in Ghana were made in the 1980s. They varied from 970 to 3500 but all were based upon guesses and extrapolations (GWD, 1991). Some work in the forest zone in the late 1980s, estimated that Ghana probably held between 700 and 2,900 elephants (Anonymous, 2000). Today elephants are found in 12 separate ranges in Ghana, with 5 of these falling within the forest zones. The Goaso complex and the Bia Conservation Area (BCA) which are two of the forest ranges fall within the study area. These two ranges, excluding those in the Kakum and Ankasa areas support the major populations of elephants in the forest zone.

Some surveys have been undertaken on the elephants in the BCA portion of the study. In the Goaso area, only two reserves have been surveyed in the past (Dikinson, 1990). Apart from an estimate from Parren *et. al*. (2002) also based on only sampling portions of study area only guesstimates have been made (Sikes, 1975; Martin 1982; Heffernan and Graham, 2000; Sam, 2000) as no comprehensive and thorough study covering it has been undertaken. There was therefore the need to survey the entire study area within the two prevailing seasons to know how many elephants are actually using the area, not only to establish a baseline but for monitoring, in the light of increasing demand for farmland by the growing human population and the resultant fragmentation of elephant habitats which has the potential to lead to a decline in their numbers.

3.2 Research Objectives and Questions

a) Objectives

The specific objectives of this study are

i) To determine the numbers and densities of the various elephant populations in the Bia-Goaso forest enclave

ii) To assess how elephants use the entire elephant range according to seasons

b) Research questions

The primary research questions that this study sought to answer are as follows:

- ✓ How many elephant populations possibly reside in the study area?
- ✓ What are the approximate estimates of each elephant populations in the study area?
- ✓ How are elephants distributed over the study area?
- ✓ How different is the distribution of elephants in the dry season from the wet season?

3.3 Hypotheses

- ◊ Ho = Elephants numbers are increasing in the study area
- ◊ Ho = Elephants are fairly uniformly distributed in the study area
- ◊ Ho = The wet and dry season ranges of elephants are the same

3.4 Methods

3.4.1 *Reconnaissance Survey*

A two-month reconnaissance exercise was undertaken within the study area in 2004. The exercise was conducted by interviewing people on the presence or absence of elephants. Wildlife Division (WD) and Forest Services Division (FSD) staffs were also interacted with. A follow-up field visit to some of the forests was done. The study area which is about 5,000 sq. km comprised both reserves and non-reserve areas and was sub-divided into blocks of 5 sq. km and thoroughly searched using crow-fly transects. All signs of elephants such as dung, footprints and feeding activities were recorded. The reconnaissance exercise provided base-line information on the distribution and abundance of elephants in the area.

Based on dung density estimates (number of dung piles per km) made on crow fly transects and interviews conducted in villages and among Wildlife Division and Forestry Services Division staff, the study area was divided into three strata namely; high, medium and low elephant densities (Figure 3.1). The high-density stratum was designated to the southern half of the Bia RR. The medium-density stratum consisted of the remaining northern half of the Bia RR, the eastern portion of the Mpameso FR (about 6 km along the Bia River) and Bia SB. The low-density stratum covered the Bia NP, the remaining western portions of Mpameso FR and the rest of the forest reserves in the study area where very old or no elephant activity was found.

3.4.2 Field Survey during the dry season of 2004 year

3.4.2.1 Line transects for dung estimates

Since elephants are often difficult to count directly in the forest because they are difficult to see in the thick undergrowth, the survey was undertaken using an indirect method i.e. dung counts (Barnes and Jensen 1987; Barnes, 1993) applying the standard line transect approach for estimating elephant density and numbers (Burnham *et. al*., 1980; Buckland *et. al*., 1993). According to Barnes *et. al*. (1995), dung-pile density is a measure of the occupancy of an area by elephants. Jachmann (1991) also pointed out that depending on the season, habitat etc., the elephant dung seen on the ground reflects a measure of the accumulated occupancy over the preceding one or two months.

A grid consisting of squares, each one-minute of latitude or longitude was superimposed on the map of the study area. In all 130 transects of length one kilometre each were distributed within the various strata according to the proportion of dung density found during the reconnaissance (Norton-Griffiths, 1978) and the size of the strata. The first transect in each forest block was randomly laid and the others systematically laid in relation to the former. Thus, 30 transects were distributed in the high density (Figure 3.2). Another set of 30 transects were also distributed in the medium density strata (Figure 3.2 and 3.3). The remaining 70 transects were distributed in the low-density stratum within the Bia NP, Bia

North, Bia Tano, western Mpameso, Asukese, Bonkoni, Subin, Ayum, Bonsam Bepo and Krokosua Hills FRs.

Transects were placed in the middle of the selected grids and oriented perpendicular to the major streams (Norton-Griffiths, 1978). However, transects placed in the Bia NP and RR were oriented northwards as a rule of thumb because of the unavailability of major streams. The perpendicular distance of the dung piles seen on transects were measured from the transect centreline using tape measure. Dung was aged using the criteria by Barnes and Jensen (1987). The distance along transects was measured with a hip-chain.

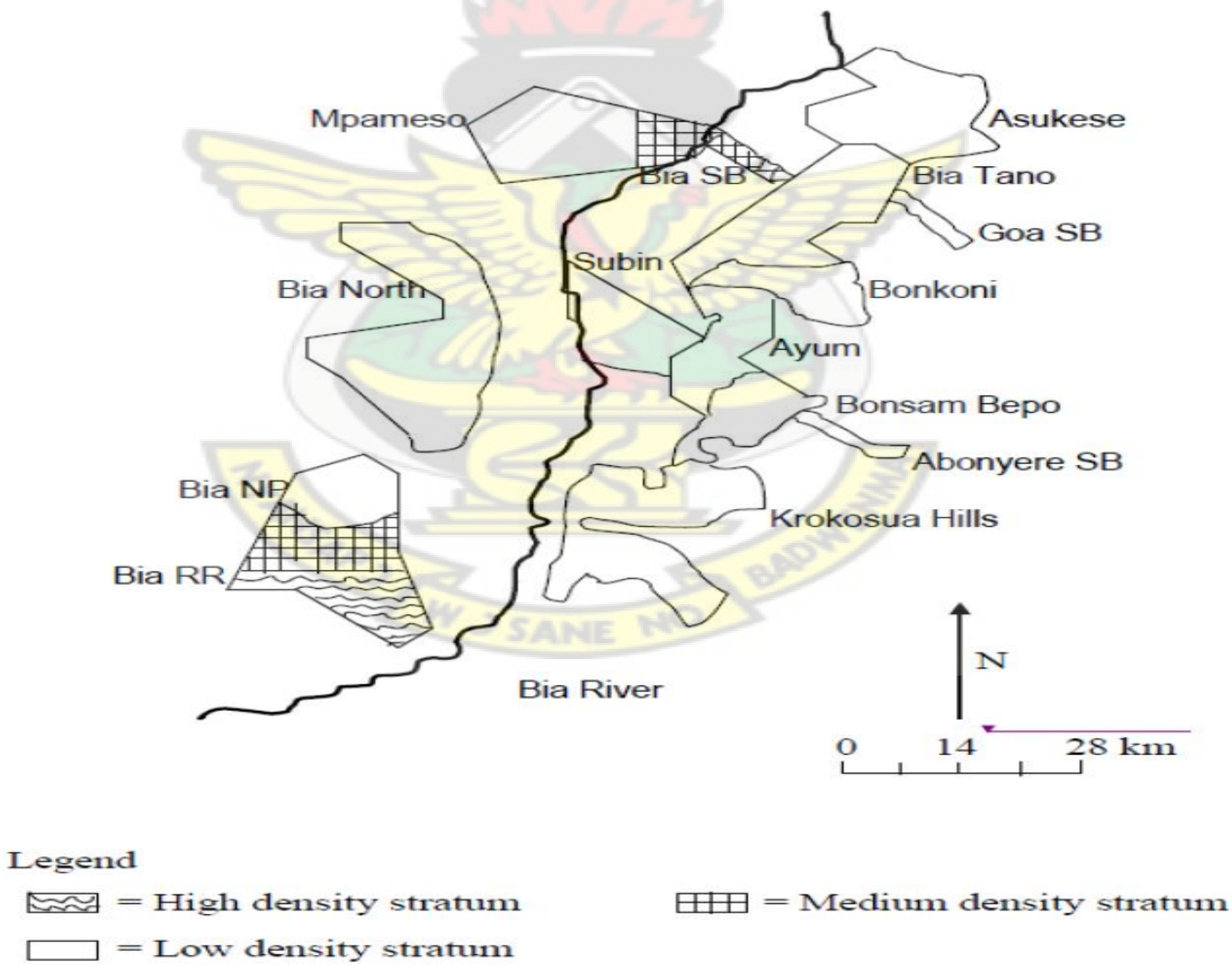


Figure 3.1: Study area showing strata of elephant density

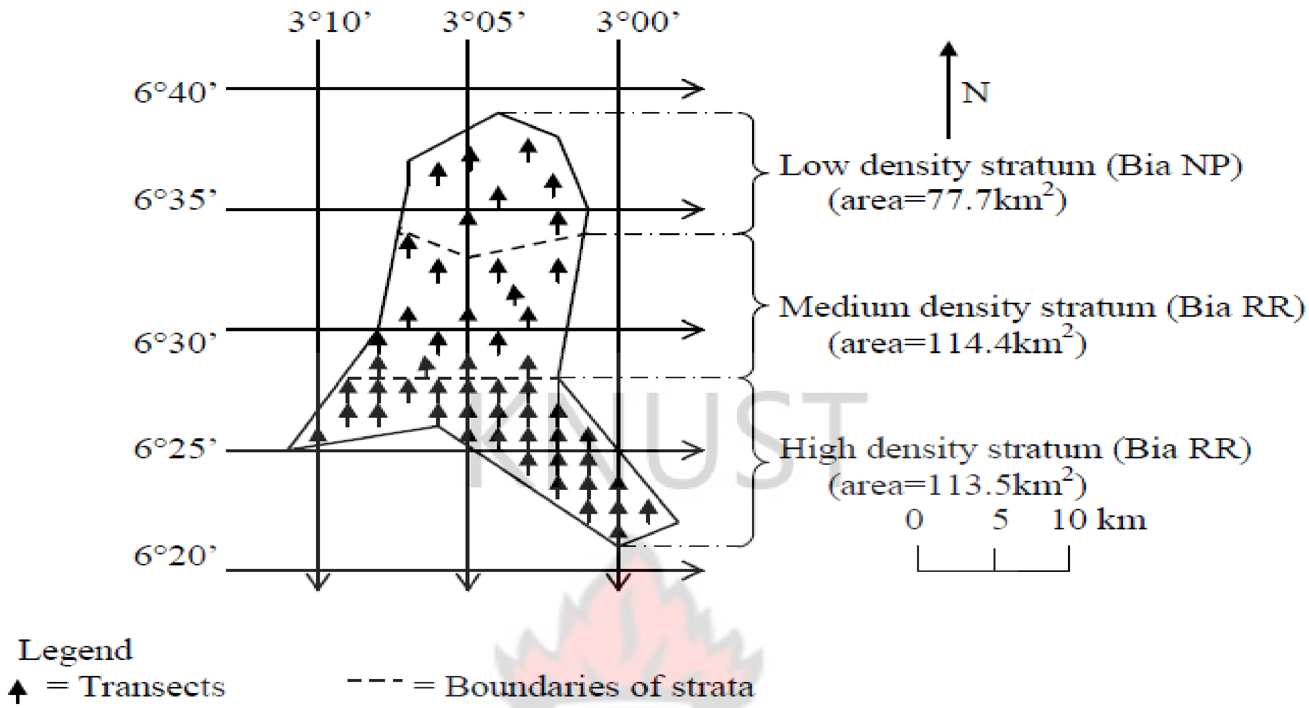


Figure 3.2: Map of Bia NP and RR showing transect distribution in the various strata

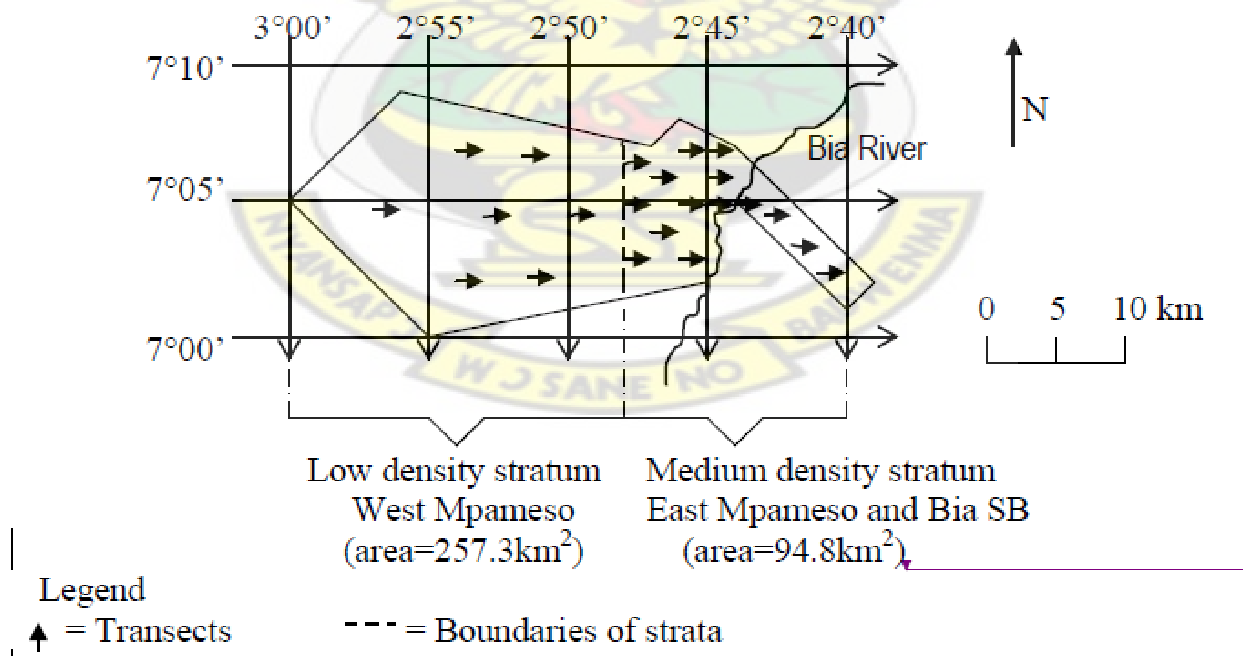


Figure 3.3: Map of Mpameso FR and Bia Shelterbelt FR showing transect distribution in the various strata

As an average of about 15 transects were walked by the survey team in a week, it took about two months to complete the transects in the study area. This exercise was undertaken during the dry season (February to April, 2004). Due to logistical problems the exercise could not be repeated in the wet season to determine any seasonal variability in occupancy rates.

Three teams of four persons each undertook the survey and were maintained throughout the counts to ensure consistency. Each team was made up of a transect cutter, compass and GPS/hip chain reader, and two dung spotters who were also involved in the measurement of transect length and perpendicular distances. Whenever an elephant dung was spotted, the distance along the transect length at the point was noted with its corresponding perpendicular distance to the dung also being recorded.

3.4.2.2 Determination of population structure

Any clear elephant hind footprint found while walking on the above transect was also measured with a tape measure. Also, the circumference of any intact elephant boli found along the transects was measured. These measurements were used to determine the age and social groupings of the elephants of the park. Lee and Moss (1986, 1995) established a strong relationship between age and the length of hind footprint of elephants and showed that this relationship differed for males and females. Similarly, Jachmann and Bell (1984) found that there is a correlation between the age of an elephant and the circumference of the boli.

3.4.3 Field Survey during the wet and dry seasons of 2007/8 years

As the team was already working in parts of the study area on crop-raiding issues and had more current information about elephants there was not the need to spend as much time organising a recce as in the 2004 study. Hence a one-week reconnaissance survey was undertaken in the second week of August 2007 in the study area to assess relative densities of elephant signs in the wet season. Field procedures were similar to those described in section 3.4.1. The elephant distribution pattern is shown in Figure 3.4.

3.4.3.1 *Estimation of dung decay rate*

To estimate the wet season rate of dung decay, six cohorts of fresh dung-piles were marked at regular intervals between August 2007 and mid-November 2007 (Laing *et al*., 2003), that is on six occasions, at regular intervals of two weeks, fresh dung-piles were marked throughout the study area (ARG, 2004). On each of the six occasions, 10 dung-pile search teams simultaneously spent a day following elephant trails and marked and recorded as many fresh dung piles as possible throughout the study area (ARG, 2004).

Each marked dung-pile was given an identification code, its location was recorded with a GPS, with the spot marked with a wooden marker stakes with rubber tags to identify piles or a flagging tape on which the code was written. The state of the decay of the dung was noted and its age determined using the criteria by Barnes and Jensen (1987). Only those of stage A were used in this study. This translates to dung piles that were very fresh, that is dung samples that were no older than 48 hours. The diameter of some boli were recorded where it was possible to do so without significantly disturbing the dung-pile.

All of the marked dung-piles were visited on one particular day (mid-period) during the actual line transect survey and their decay state noted. Thus, a mark for “decayed” or not decayed was assigned to each dung-pile/

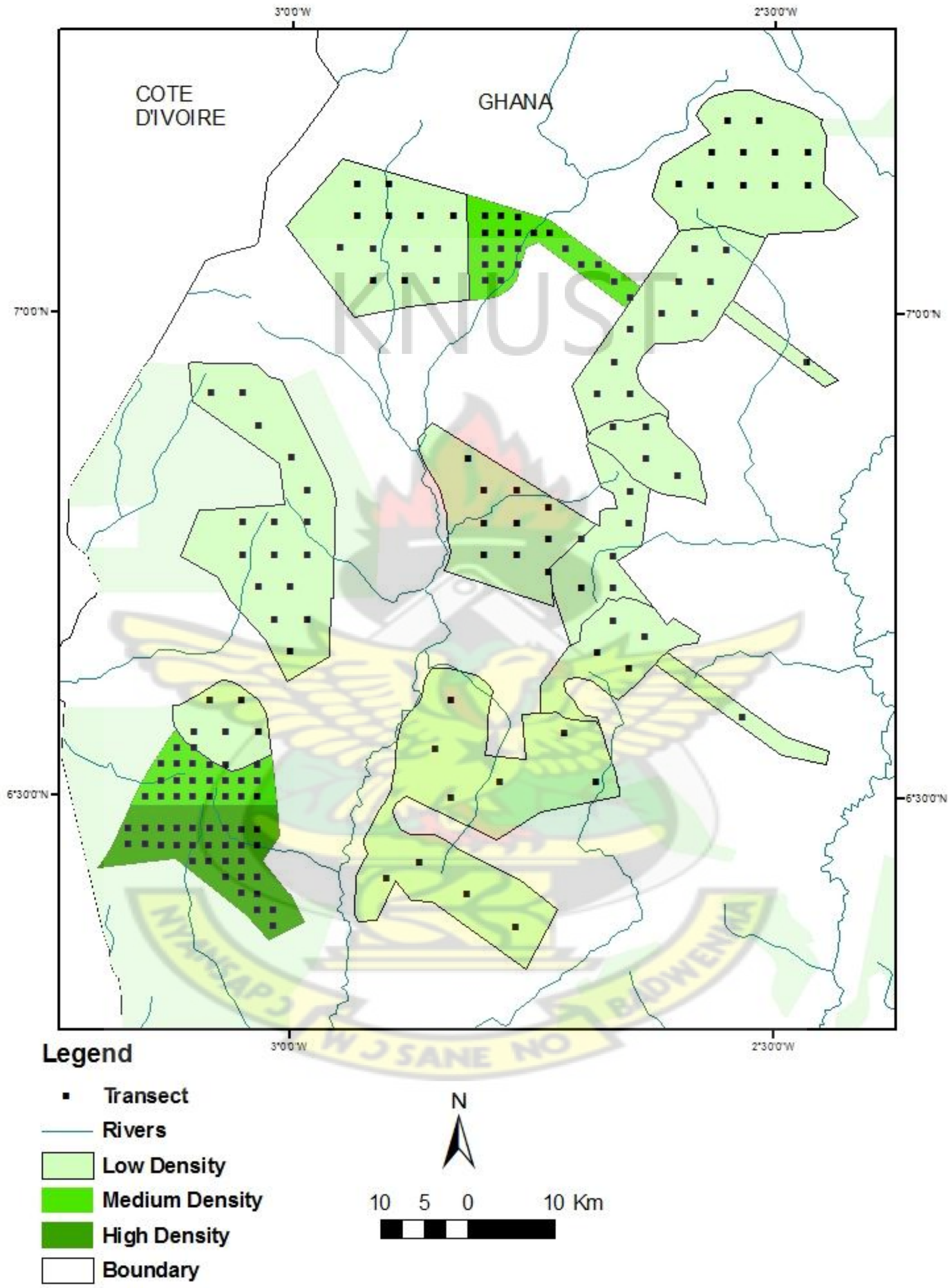


Figure 3.4: Study area showing distribution of transects in the high (dark green), medium (green) and low (light green) density strata

3.4.3.2 Distribution of transects and dung count

From a reconnaissance that was undertaken an average dung density of 1.79 elephant dung-piles per km was estimated resulting in the determination of an optimum sample size (OSS) of 169 transects (1 km each) for the study area (Hedges and Lawson, 2006). This gave 96 transects in the low-density, 43 in the medium-density and 30 transects in the high-density strata (Buckland *et al*., 2001; Norton-Griffiths 1978).

A grid of cells (one-minute of latitude or longitude each) was placed over a map of the study area, The intersections of the lines formed the mid-point for each transect. The first transect of each strata was randomly placed while subsequent ones were distributed systematically to the first one.

A systematic segmented line transect method (Burnham *et al.*, 1980; Buckland *et al.*, 1993, 2001) adapted for forest elephants (Barnes *et al.*, 1997) was used to count dung-piles in the study area.

The above field procedures described in sections 3.4.3.1 and 3.4.3.2 were repeated in the late dry season of 2008.

3.5 Data Analysis

The data on dung from the transects was analysed with the program DISTANCE (Buckland *et. al*., 1993; Thomas *et. al*., 2002). This program, apart from being able to give a more reliable strip-width also provides a Confidence Limit that is asymmetrical. Outliers (dung piles seen at extreme distances from the transect line) were truncated in order to improve the fit of the model in the DISTANCE program (Buckland *et al*., 2001).

3.5.1 Steady State Assumption Model (SSAM)

In order to compare estimates with the rainfall model, the steady state assumption model (McClannahan, 1986) was used to convert dung density to elephant density and subsequently into numbers based on the size of the area. This analysis was done separately for each stratum after which the separate estimates were pooled (Norton-Griffiths, 1978) to obtain the overall estimate of elephant numbers for an area.

3.5.1 1 Calculating elephant dung density

The perpendicular distance measurement were fed into the programme ELEPHANT (Dekker and Dawson, 1992), which estimates the value of f(0). This is a measure of the width of the transect (i.e. f(0) is the reciprocal of half the effective strip width). Then, the estimate of f(0) was substituted into Burnham *et al*. (1990) and Buckland *et al*. (1993) Equation 1, to calculate the dung-pile density (D) for each transect.

The dung pile density was determined using the formula below:

$$D = \frac{n.f\,(o)}{2L} \qquad \rightarrow \text{equation 1 (Burnham } et.\ al.\text{, 1980)}$$

Where,

D= Dung pile density

n= number of dung piles observed per unit area

L= length of transect

f (o) = a function of the inverse of the effective strip width.

3.5.1.2 Elephant numbers

Elephant number is:

$$E = \frac{D.r}{Y} \quad \rightarrow \text{equation 2}$$

Where,

E= elephant numbers r= decay rate

D= dung density Y= defaecation rate

3.5.2 Rainfall Model (RM)

The rainfall model is a more accurate method for analysing data on dung-count than the SSM because it takes into account the rainfall preceding the dung count and makes no assumptions concerning either steady states or normality. The dung decay rate is one of the three variables needed to estimate the population of elephants using dung counts. However, Barnes *et. al* (1997) determined the relationship between dung decay rate and rainfall for this part of Ghana. Hence, during the study period, rainfall data was collected and used as another analytical option for estimating the elephant densities in the area. Data on rainfall two months prior to the survey was collected from rain gauges mounted around the reserves and the mean total rainfall value calculated for each area. Hence a model that relates dung density (Y_t) to rainfall two month preceding the survey was used to estimate density (Barnes *et al*., 1997). Thus,

$$Y_{t\,=}\,1020.24 - 0.79RAIN_{t-1} - 0.46\,RAIN_{t-2} \quad \rightarrow \text{equation 1 (Barnes et. al., 1997)}$$

Where,

$Y_{t\,-}$ expected dung density for an elephant density of one elephant per km^2

RAIN- total monthly rainfall

t- the month of census

Elephant density (E) is represented by

$$E = \frac{D}{Y_t} \rightarrow$$

equation 2 Barnes and Dunn (1997)

Where D is dung density from the survey

3.5.3 Estimation of elephant numbers using the retrospective method (for 2007/8 surveys only)

The estimated mean survival time of the elephant dung-piles (reciprocal of decay rate), t with its standard error and Co-efficient of Variation (CV) was calculated using a Genstat program (Genstat version 7). Using DISTANCE 4.1, the six models recommended by Buckland *et al.* (2001) were applied. The most useful criterion is Akaike's Information Criterion (AIC); the smaller this value the better the fit of the model. Hence after determining the best fit, all further analyses were conducted using that model.

Buckland *et al* (2001) recommend that one truncates the data, that is one runs the analyses after deleting a few of the most distant dung-piles (those furthest from the transect line)., as truncation improves the fit of the model. However, truncation was avoided as it made little difference to the estimate of dung-pile density but rather the coefficient of variation (CV) to increase, and hence the precision of the estimate.

No estimate of defecation rate has been done in the study area. Hence, having estimated the number of dung-piles on the ground and the mean survival time in both surveys, Tchamba (1992) estimate of defaecation rate from Cameroon was used to calculate the number of elephants in the study area. Tchamba's defaecation rate was used because hehas the study of defaecation with the largest sample. Tchamba's data showed a mean of 19.77 defaecations per day and a variance of 0.911. The three variables were combined to provide an estimate of elephant density D_a (Laing *et al.*, 2003) in equation 1:

$$D_a = \frac{D_s}{p \times t} \quad \text{(1)}$$

where D_s is the estimated density of elephant signs (in this case, dung piles) in the study area, p is the estimated rate of production of signs per elephant (i.e. defecation rate of dung-piles) during the period preceding the survey and t is the mean survival time of elephant signs present when the survey to estimate sign density is conducted.

Precision of the estimate of elephant density depends on the precision of each of the three components in equation 1 (Barnes, 1993). Thus:

$$[cv\,(D_a)]^2 = [cv\,(D_s)]^2 + [cv\,(t)]^2 + [cv(p)]^2 \quad \text{(2)}$$

where cv (t) is the coefficient of variation of t, defined as its standard error divided by itself, and similarly for other terms.

3.5.4 Elephant distribution

As the dung-piles on the transects were marked with GPS, elephant distribution was depicted by mapping, showing which areas are used by elephants and their respective elephant concentrations.

3.6 Results

3.6.1 Estimate of elephant numbers in the study area in 2004

A total of 271 dung piles were recorded in the study area; 183 in the high density, 74 in the medium density and 14 in the low-density strata (Figure 3.5).

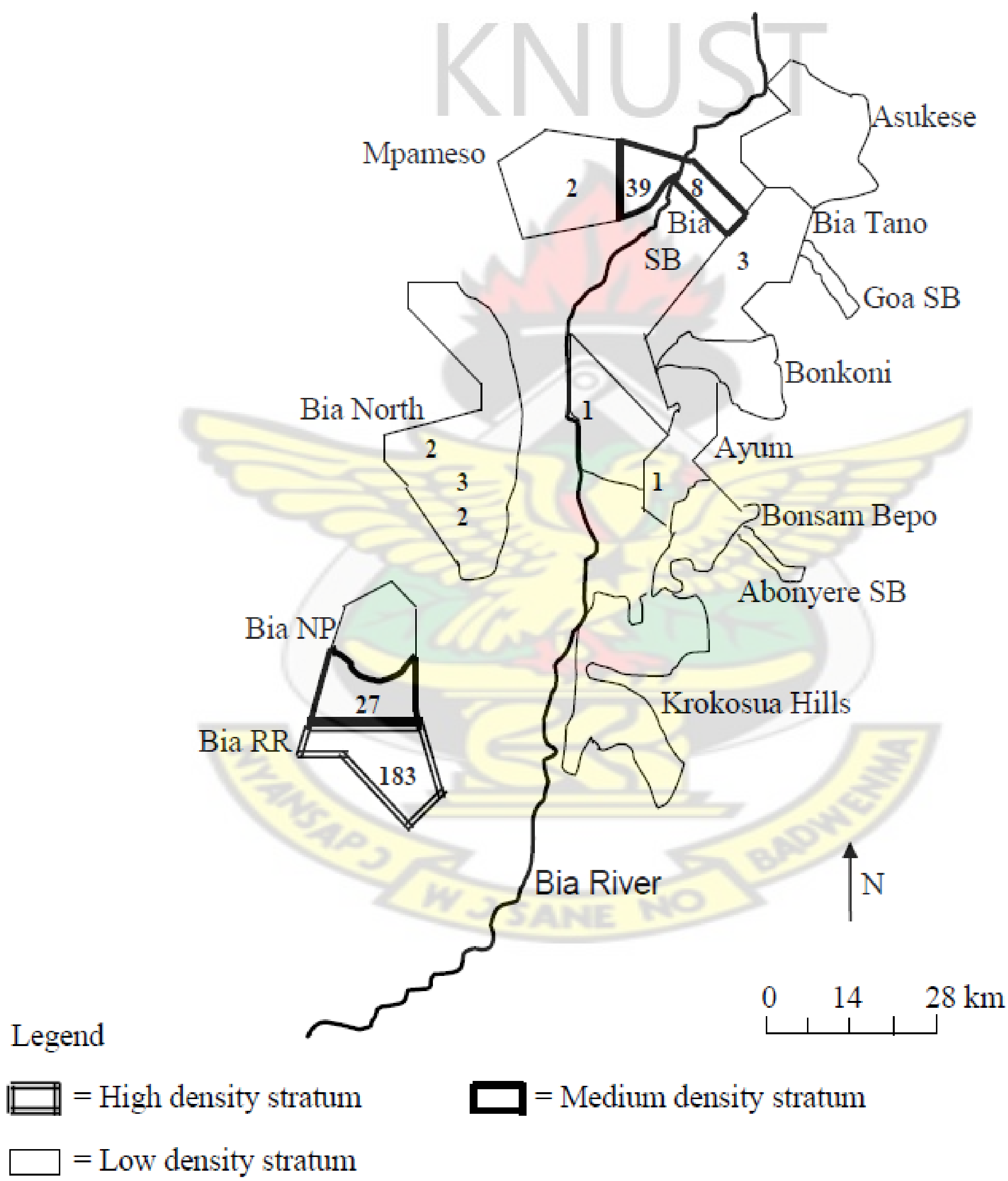


Figure 3.5: Study area showing distribution of dung piles (figures in bold) in the various strata.

3.6.1.1 The Bia Conservation Area (Resource Reserve and National Park)

A total of 210 dung piles were recorded; 27 in the medium density and 183 in the high-density stratum (Figure 3.5). The number of dung piles per transect ranged from 0 to 4 for the medium density stratum with an average of 1.8 dung piles per transect. In the high-density stratum the number ranged from 2 to 13 with an average 6.1 dung piles per transect.

No recent elephant activity was recorded in Bia NP (low density stratum). The high-density stratum had a higher density of dung piles, yet it gave a higher variance than the medium density stratum.

Elephant density in the high and medium density strata of Bia RR was 0.92 and 0.37 elephants per sq km respectively. However, the average elephant density for the whole conservation area, which includes the Bia NP was 0.38 elephants per sq km.

Table 3.1: Estimates of dung pile density per stratum in the Bia Conservation Area using the hazard rate (Hz)

Stratum	Area (km^2)	Dung-pile Density (Y)	Variance	Number of transects
Low-density Stratum	77.7	0	0	7
Medium-density Stratum	114.4	Hz 305.28	Hz 7650	15
High-density Stratum	113.5	Hz 758.61	Hz 10562	30

Table 3.2: The combined estimates (high and medium stratum) of elephant numbers in the Bia RR

	Population estimate	Confidence limits
Rainfall Model	115	90-148
Steady state assumption Model	146	±39

NB: Rainfall model gives asymmetrical CLs

From Table 3.2, the Rainfall Model gave a lower estimate (90 to 140 elephants) than using the steady State Assumption model (107 to 185 elephants).

More dung piles were seen further from the transects than within 1 m in the medium density stratum and then declined from beyond 2m (Figure 3.6).

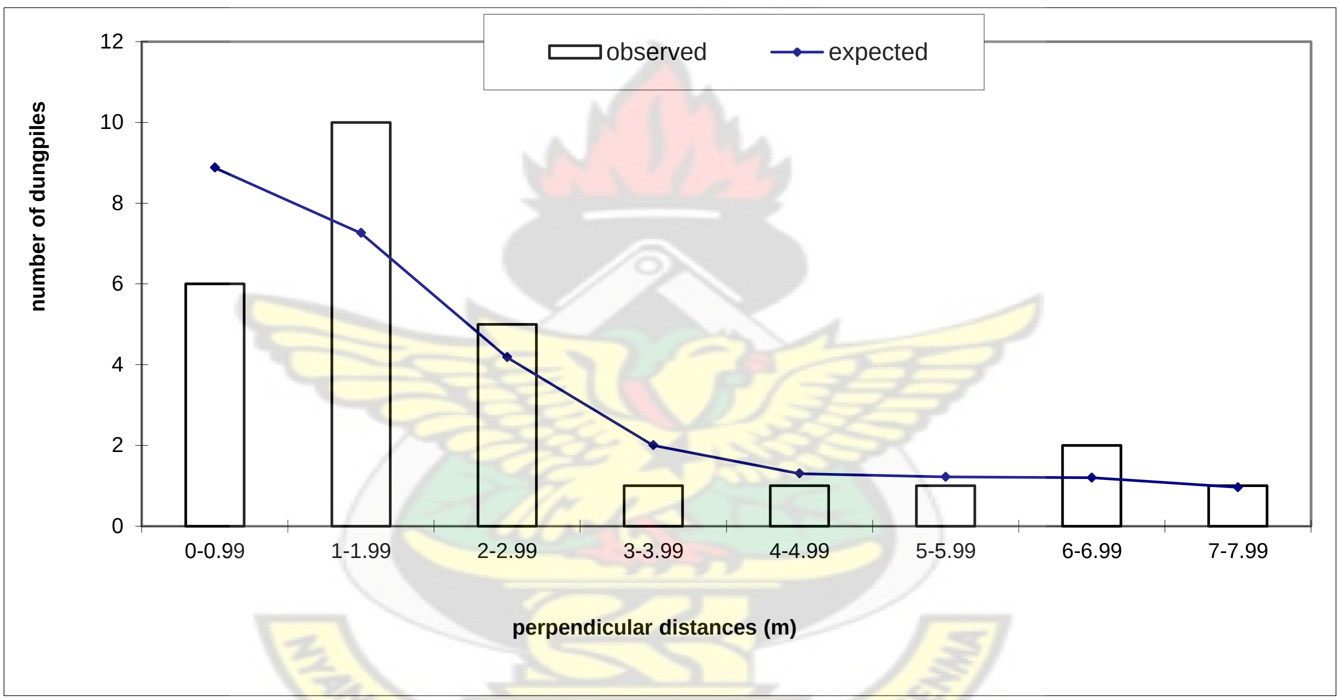


Figure 3.6: Frequency distribution of the perpendicular distances of dung piles in the medium density stratum of the Bia RR (n=27, f(0)=0.34).

On the other hand, more dung piles were seen nearer to the transect centreline in the high-density stratum (Figure 3.7), which also declined after 2m.

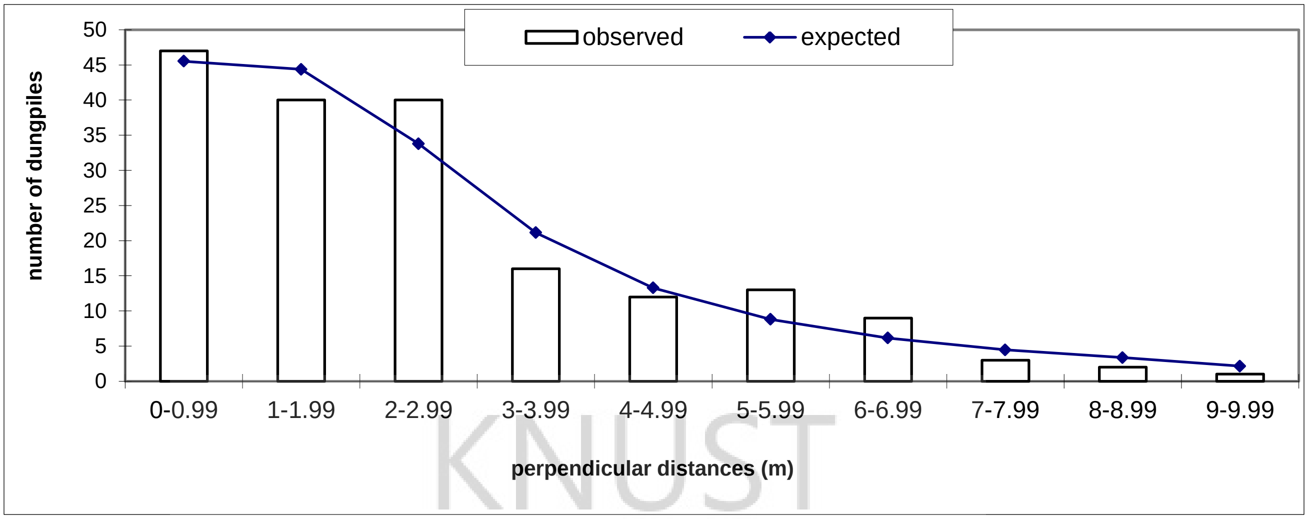


Figure 3.7: Frequency distribution of the perpendicular distances of dung piles in the high-density stratum of the Bia RR (n=183, f(0)=0.25).

3.6.1.2 Mpameso and Bia Shelterbelt FRs

In all, 47 dung piles were recorded in the medium density stratum (Figure 3.5). The number of dung piles per transect ranged from 0 to 8 for the medium density stratum with an average of 2.4 dung piles per transect. There was no significant difference (U=156.5, P>0.05) in dung piles density when compared with the medium density of the Bia RR, yet it was significantly lower (U=116, P<0.01) when compared with the high density of Bia RR.

Table 3.3: Estimates of dung pile density per stratum in the Mpameso-Bia Shelterbelt FRs

Stratum	Area (km^2)	Dung-pile Density (Y)	Variance	Number of transects
Low-density Stratum	257.3	0	0	7
Medium-density Stratum	94.8	Hz 625.96	Hz 29732	15

Apart from very old activities, no recent elephant activity was recorded in the low-density stratum of the Mpameso FR. The elephant density in only the medium density stratum of the Mpameso-Bia Shelterbelt FRs was 0.76 elephants per sq km.

Table 3.4: Estimates of elephant numbers in the Mpameso-Bia Shelterbelt FRs (medium density stratum)

	Population estimate	Confidence limits
Rainfall Model	57	33-100
Steady state assumption Model	72	±44

As in the case of Bia RR, the Rainfall model gave a lower estimate (57 elephants) compared to the SSAM which gave an estimate of 72 elephants.

Similarly, like the medium density stratum of the Bia RR, less than expected dung piles were seen within 1m of transects centre line in the medium density stratum (Figure 3.8) which then declined beyond 2m.

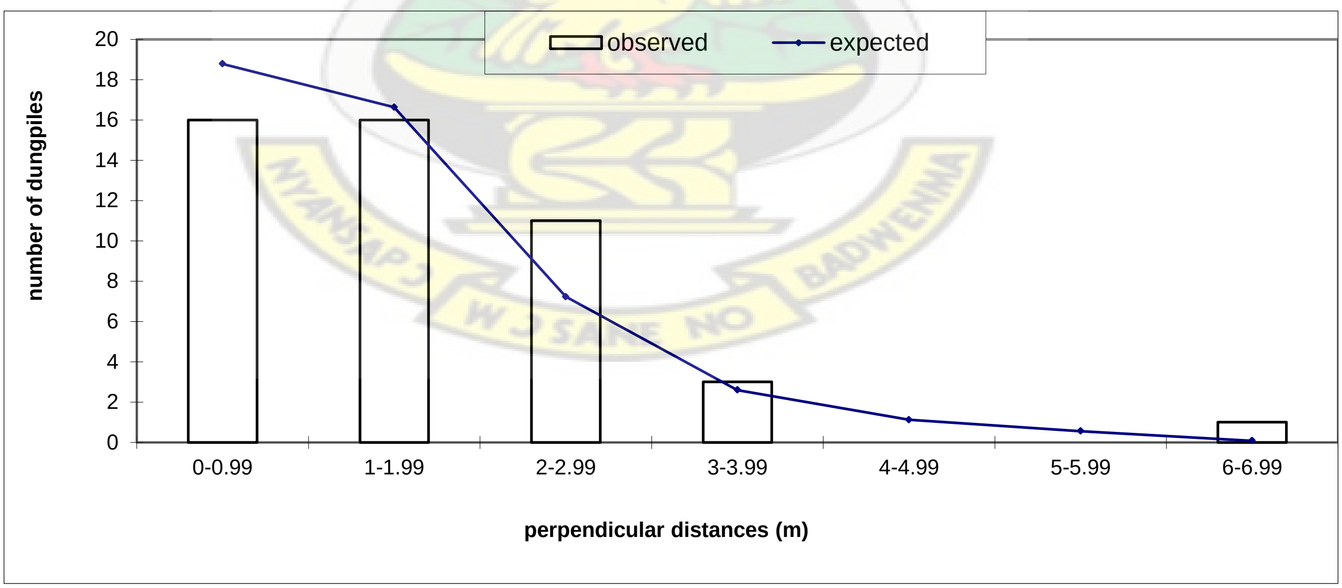


Figure 3.8: Frequency distribution of the perpendicular distances of dung piles in the medium density stratum of the Mpameso-Bia Shelterbelt FRs (n=47, f(0)=0.40)

3.6.1.3 *Other reserves (low density stratum)*

The number of dung piles per transect ranged from 0 to 3 with an average of 0.2 dung piles per transect. Only 14 dung piles were seen in five of the reserves constituting the low-density stratum (Figure 3.5). Hence, estimate of elephant numbers was not possible for the low-density stratum (The DISTANCE programme requires a minimum of 60 dung piles to operate efficiently).

An average density of 0.03 elephants per sq km was computed for the Goaso region, which includes about 80% of low density stratum. This was done by extrapolating elephant density in the Mpameso-Bia Shelterbelt FRs (the only significant elephant population in the Goaso area) to cover the entire Goaso region, an area of 2,035 sq. km. The assumption was that the Mpameso-Bia Shelterbelt population utilise the entire Goaso elephant range.

No elephant activity or dung piles were recorded in the Asukese, Bonkoni, Bonsam Bepo and Krokosua Hills FRs. Also only 14 dung pilles were seen in 5 FRs listed in table 3.5

3.6.2 Estimate of elephant dung-pile density in the study area in 2007/8

Two hundred and forty-five (245) dung-piles were recorded in the wet season survey: 165 in the high density, 80 in the medium density and none (0) in the low density stratum (Figure 3.9). However, in the dry season survey, 266 dung-piles were recorded: 176 in the high density, 85 in the medium density and five (5) in the low density stratum.

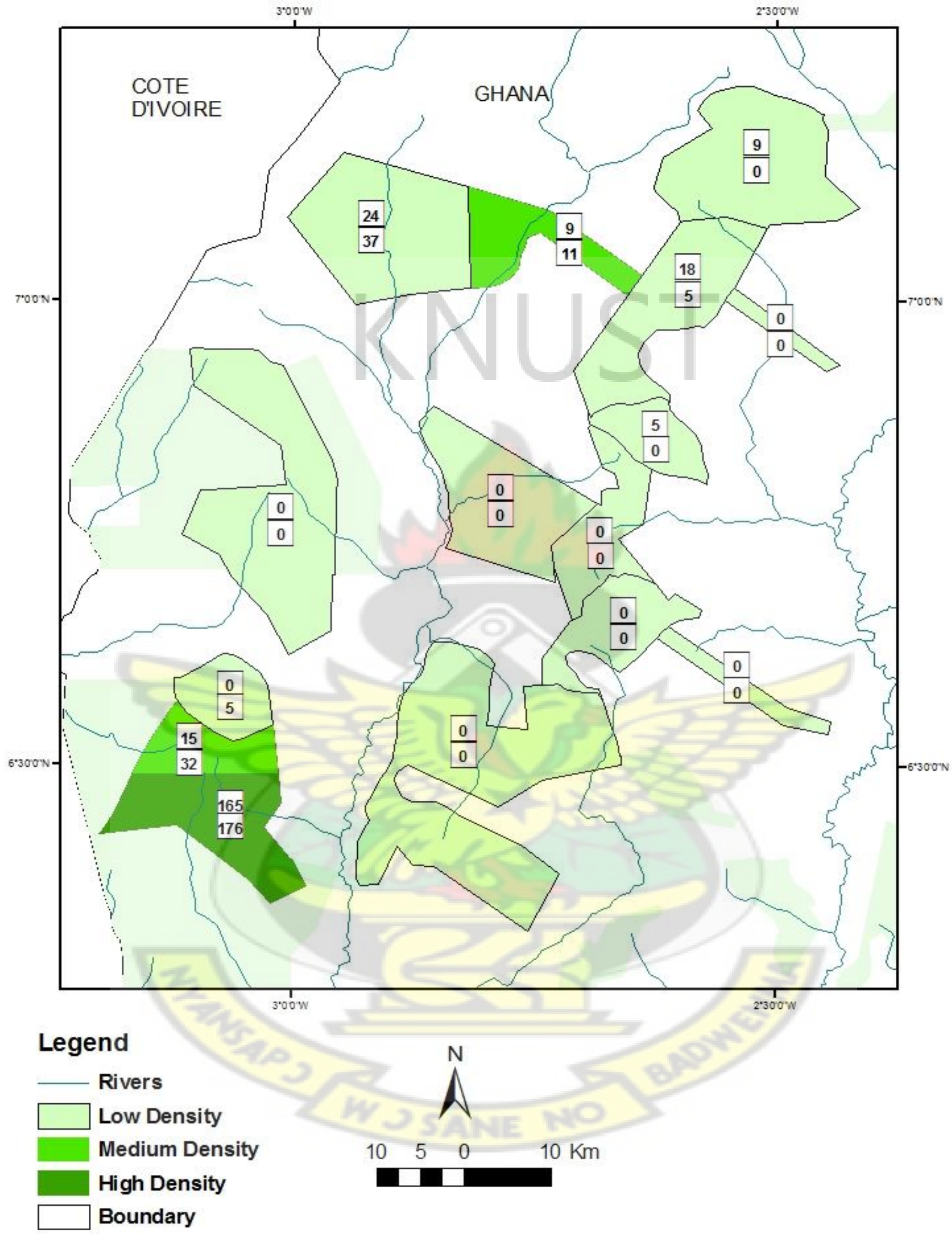


Figure 3.9: Study area showing distribution of dung piles in wet (upper figures) and dry (lower figures) season surveys in 2007/8.

3.6.2.1 The Bia Conservation Area (Resource Reserve and National Park)

One hundred and eighty (180) elephant dung-piles were recorded on 60 transects in BCA (306 sq km) in the wet season survey: 165 in the high density, 15 in the medium density and zero (0) in the low-density stratum resulting in an encounter rate of 3.0 dung-piles per km). Higher dung pile densities were recorded in the dry season survey: 176 in the high density, 32 in the medium density and 5 in the low-density stratum. The encounter rate was 3.6 dung-piles per km. For both surveys, number of dung piles per transect ranged from 3 to 11 in the high density stratum (average of 5.7 dung-piles per transect) and 0 to 3 in the medium density stratum (average of dung-piles 1.2 per transect).

The perpendicular distances in the wet season survey are shown in Figure 3.10. This shows a typical visibility curve for dung counts in the forest. No dung-piles were seen beyond 10 metres from the centre-line in both surveys.

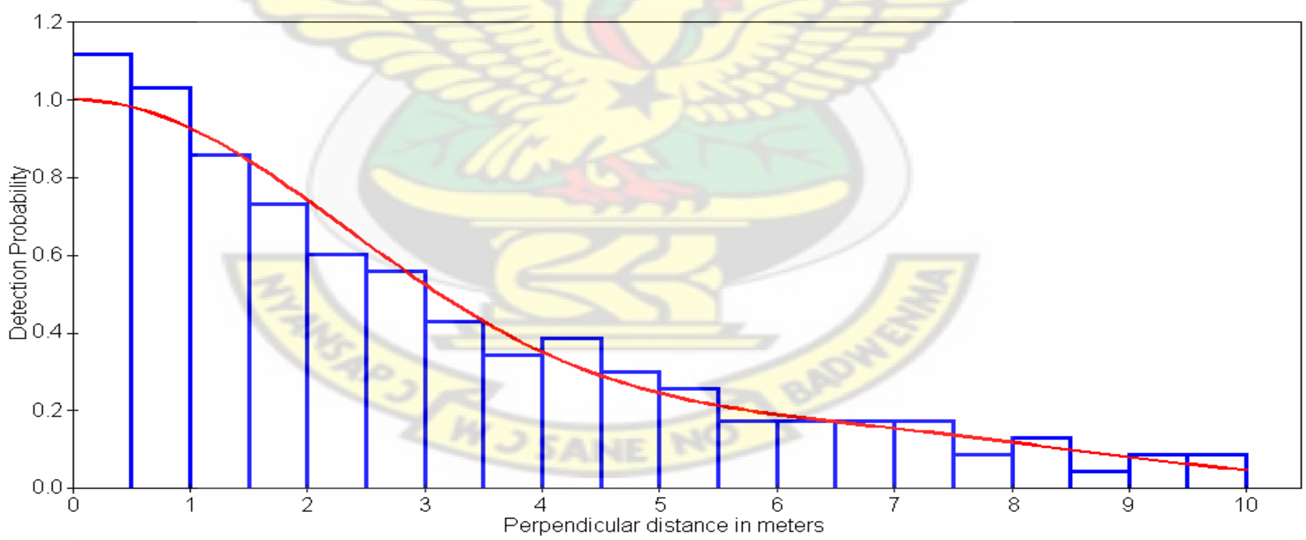


Figure 3.10: Histogram produced by DISTANCE showing the perpendicular distances and the fitted visibility curve (uniform + cosine) in the wet season survey.

Applying the six models of Buckland *et al.* (2001) to the dry season data without truncation gave an estimate of 452.15 dung-piles per sq km (confidence limits: 339.96 to 601.37), and a CV of 14.47%

through the half normal + cosine model. (Note that DISTANCE produces estimates with asymmetrical confidence limits). See Table 3.5.

In the dry season, the half normal + cosine model without truncation also gave an estimate of 463.324 dung-piles per sq km (confidence interval: 372.54 to 637.82) with a CV of 27.64%.

3.6.2.2 The Goaso Northern Forest Block

In the wet season, 65 dung-piles were recorded on a total of 53 transects laid in the 5 reserves of Mpameso, Bia Shelterbelt, Bia Tano, Asukese and Bonkoni FRs that constituted the Goaso northern forest block (970 sq km). However, in the dry season, 53 dung piles were recorded in only 3 of the reserves (Mpameso, Bia Shelterbelt and Bia Tano FRs). The encounter rate was 1.11 dung-piles per km with the number of dung piles per transect ranging between 0 and 5. No dung-piles were seen beyond 9.0 metres from the centre-line in both surveys.

Table 3.5: The parameters estimated by each of the six models fitted to the wet season line transect data.

Parameter	Uniform + cosine	Uniform + simple polynomial	Half-normal + cosine	Half-normal + hermite polynomial	Hazard rate + cosine	Hazard rate + simple Polynomial
f(0)	0.3000	0.2872	0.3014	0.2476	0.3216	0.3216
Density (km^{-2})	449.92	430.84	452.15	371.41	482.44	482.44
CV (%)	14.49	13.95	14.47	13.16	17.00	17.00
Upper CL	598.63	567.51	601.37	482.08	673.24	673.24
Lower CL	338.15	327.08	339.96	286.14	345.72	345.72
X^2	3.1764	4.1946	3.2907	13.0029	2.9477	2.9477
P(X^2)	0.9998	0.9970	0.9999	0.7914	0.9999	0.9999
AIC	668.85	671.31	667.10	673.00	667.34	667.34

- [Density is the number of dung-piles per sq km;
- Chi-square (X^2) compares the fit of the visibility curve to the histogram of the perpendicular distance data
- P(X^2) is the probability of X^2.
- AIC is the Akaike Information Criterion (Buckland *et al*, 2001)
- F(0) is the value of estimated probability density function (pdf) at zero for line transects.
- Percent (%) CV measures the precision of the estimate, and
- Upper and lower confidence limits (CL) describe the precision of the estimate.

The uniform + cosine model without truncation (Figure 3.11) gave the best fit with an estimate of 100.72 dung-piles per sq km (confidence interval: 67.74 to 149.76) and a CV of 20.18% for the wet season.

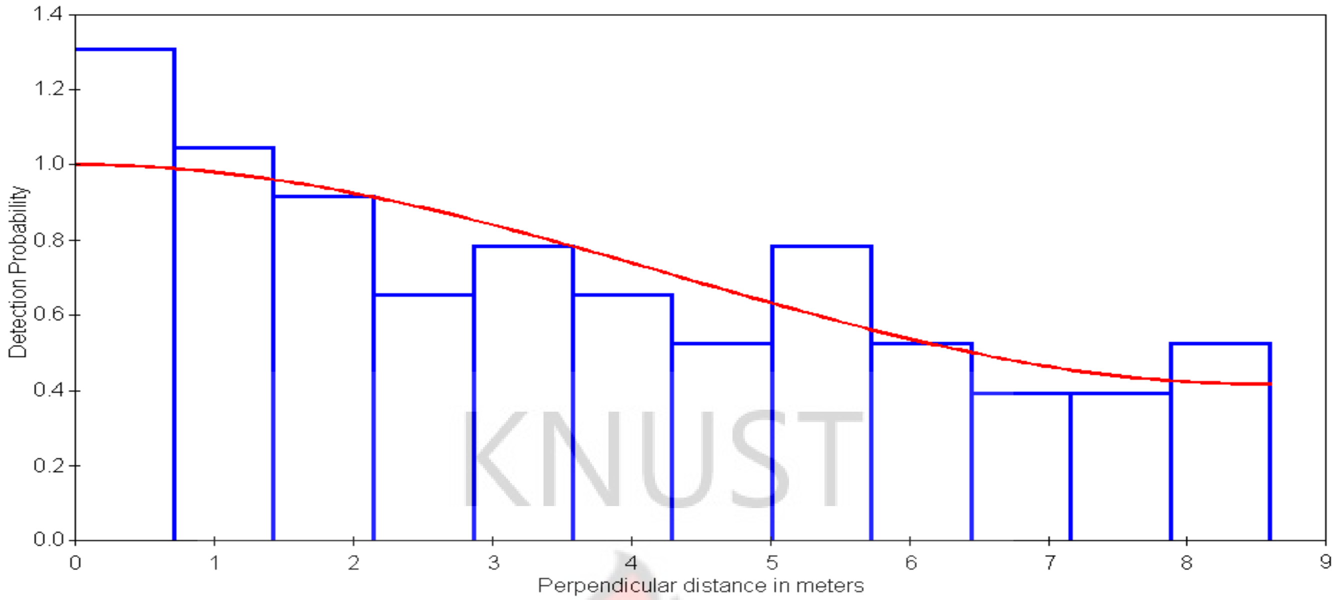


Figure 3.11: Histogram produced by DISTANCE showing the perpendicular distances and the fitted visibility curve (uniform + cosine).

While in the dry season survey, the uniform + cosine model without truncation also gave the best fit with an estimate of 92.65 dung-piles per sq km (confidence interval: 62.65 to 152.34) and a CV of 23.00%.

3.6.2.3 The Goaso Southern Forest Block

In both surveys, no dung pile was seen in the rest of the reserves (Goaso Southern Forest Block, namely Bia North, Subin, Ayum, Bonsam Bepo, Krokosua Hills, and Abonyere) that constituted the low-density stratum (Figure 3.9).

3.6.3 Estimation of dung decay rate for the 2007/8 study

Two hundred and sixty (260) and 282 dung-piles were recorded in BCA in the wet and dry seasons respectively, while for the Mpameso elephant range, 126 and 114 dung-piles were recorded in the respective seasons. While all dung-piles in the first cohort had completely decayed (stage S4) by the time they were re-inspected in middle of the respective surveys, all those in the sixth cohort were readily visible during the re-inspection.

Table 3.6: Numbers of dung-piles marked for each cohort during the dung decay experiment.

Cohort	Number of dungpiles marked				Median age of dungpiles at final inspection (days)				Percent still surviving at final inspection			
	Bia		Mpameso		Bia		Mpameso		Bia		Mpameso	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
1	46	67	23	26	95	95	98	98	0	0	0	0
2	48	50	18	16	79	79	76	76	0	8	0	3
3	56	43	25	16	60	60	64	64	0	28	0	18
4	32	38	14	22	48	48	50	50	14	42	22	56
5	42	44	22	16	33	33	35	35	76	86	82	78
6	36	40	24	18	18	18	18	18	100	100	100	100
Total	260	282	126	114	57	57	59	59	0.3	0.4	0.4	0.4

An estimated mean survival time of 52.46 days (estimated decay rate of 0.019 per day, SE = 2.221, CV = 4.23%) was calculated for the Bia range following Laing *et al*. (2006) and Hedge and Lawson (2006). Similarly, an estimate of 54.64 days (estimated decay rate of 0.018 per day, SE = 5.560, CV = 10.3%) was obtained for the Mpameso range.

3.6.4 Estimation of elephant numbers for 2007/8

Having estimated the number of dung-piles on the ground and the mean survival time in both surveys, Tchamba (1992) estimate of defaecation rate from Cameroon was used to calculate the number of elephants in the study area. Tchamba's defaecation rate was used because he studied defaecation with the largest sample ever used.

Using Tchamba's mean of 19.77 defaecations per day and a variance of 0.911, and the estimated number of dung-piles on the ground and the mean survival time in both surveys, elephant density and standard error gave a wet season estimate of 0.44 elephants per sq km (SE = 0.05, CV = 10.9%) for the Bia range and 0.09 elephants per sq km (SE = 0.02, CV = 23.2%) for the Mpameso range. The dry season estimate was 0.45 elephants per sq km (SE = 0.05, CV = 12.2%) for the Bia range and 0.09 elephants per sq km (SE = 0.02, CV = 25.7%) for the Mpameso range,

When multiplied by the area of the respective elephant ranges, estimates of 133 elephants (confidence interval from 104 to 162) and 137 elephants (confidence interval from 98 to 170) were obtained for Bia during the dry and wet season surveys respectively. Similarly, for the Mpameso elephant range, an estimate of 83 elephants (confidence interval from 41 to 125) and 90 elephants (confidence interval from 49 to 131) were obtained in the dry and wet seasons respectively. A merged estimate (Norton-Griffiths, 1978) for both seasons was 135 elephants (confidence interval from 114 to 156) for Bia and 87 elephants (confidence interval from 58 to 116). Precision of estimate improved in both cases (Table 3.7).

Table 3.7: Estimates of elephant numbers for the Bia and Mpameso elephant ranges in 2007/8

	Estimate	Variance	%CV	95% CL
Bia Elephant Range				
Wet season estimate	133	212.50	10.93	104 – 162
Dry season estimate	137	276.11	12.16	98 – 170
Merged estimate	135	120.08	8.13	114 – 156
Mpameso Elephant Range				
Wet season estimate	90	440.73	23.21	49 – 131
Dry season estimate	83	457.77	25.72	41- -125
Merged estimate	87	224.54	17.31	58 – 116

As there is no physical barrier between the reserves in the Goaso Northern and Southern Forest Blocks (altogether an area of about 2,035 km^2 with 80% of the low density stratum occurring here), it was assumed that the Mpameso elephants utilise both the Goaso Northern and Southern as their range. Consequently, a density of 0.043 elephant per sq km was calculated for the Goaso population.

3.6.5 Distribution of elephants in the study area in 2004

The Fig 3.12 below shows the distribution of elephants, as depicted by the number of elephant dung piles found on each transect in the entire study area in 2004.

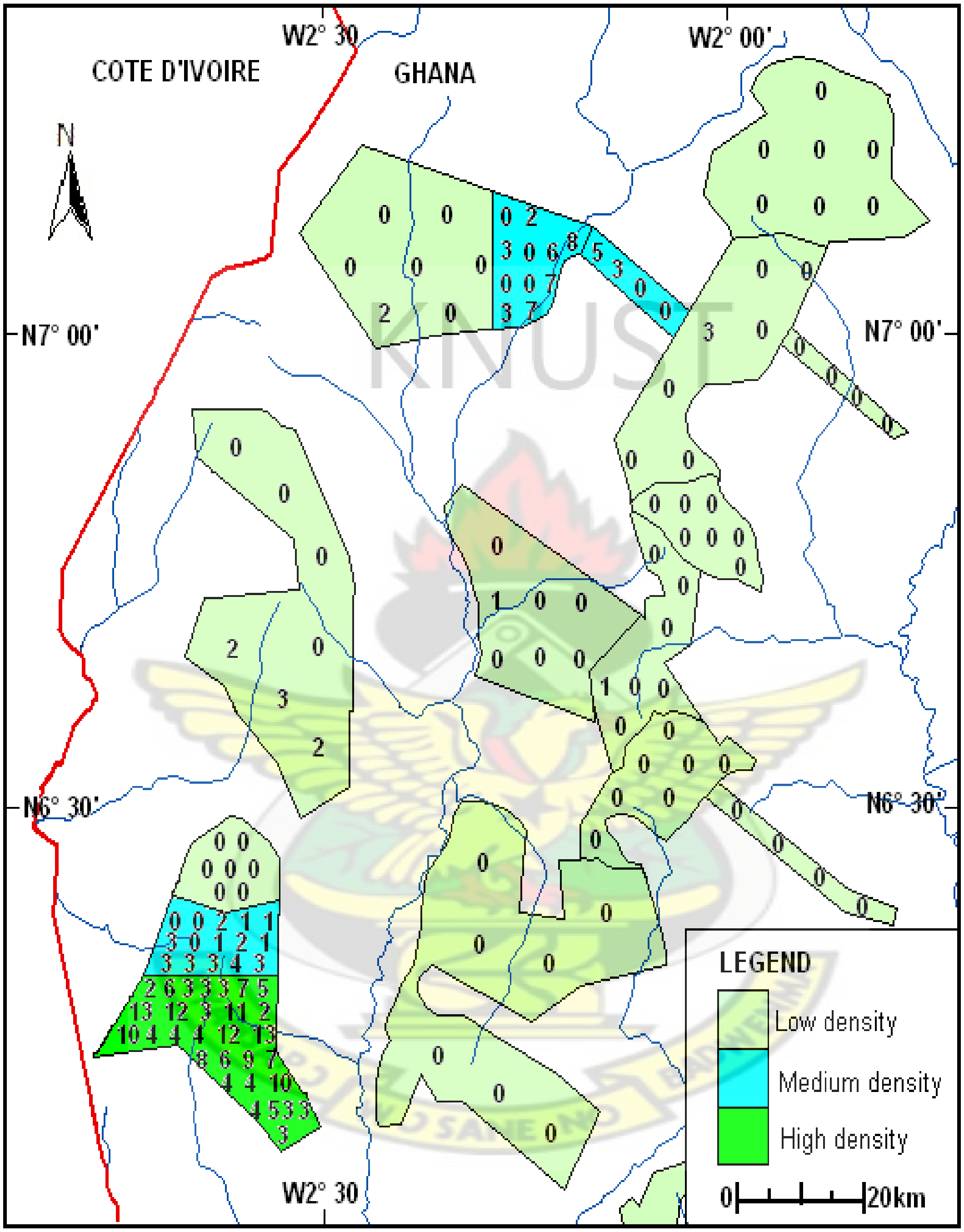


Figure 3.12 Dung distributions in the study area during the 2004 study

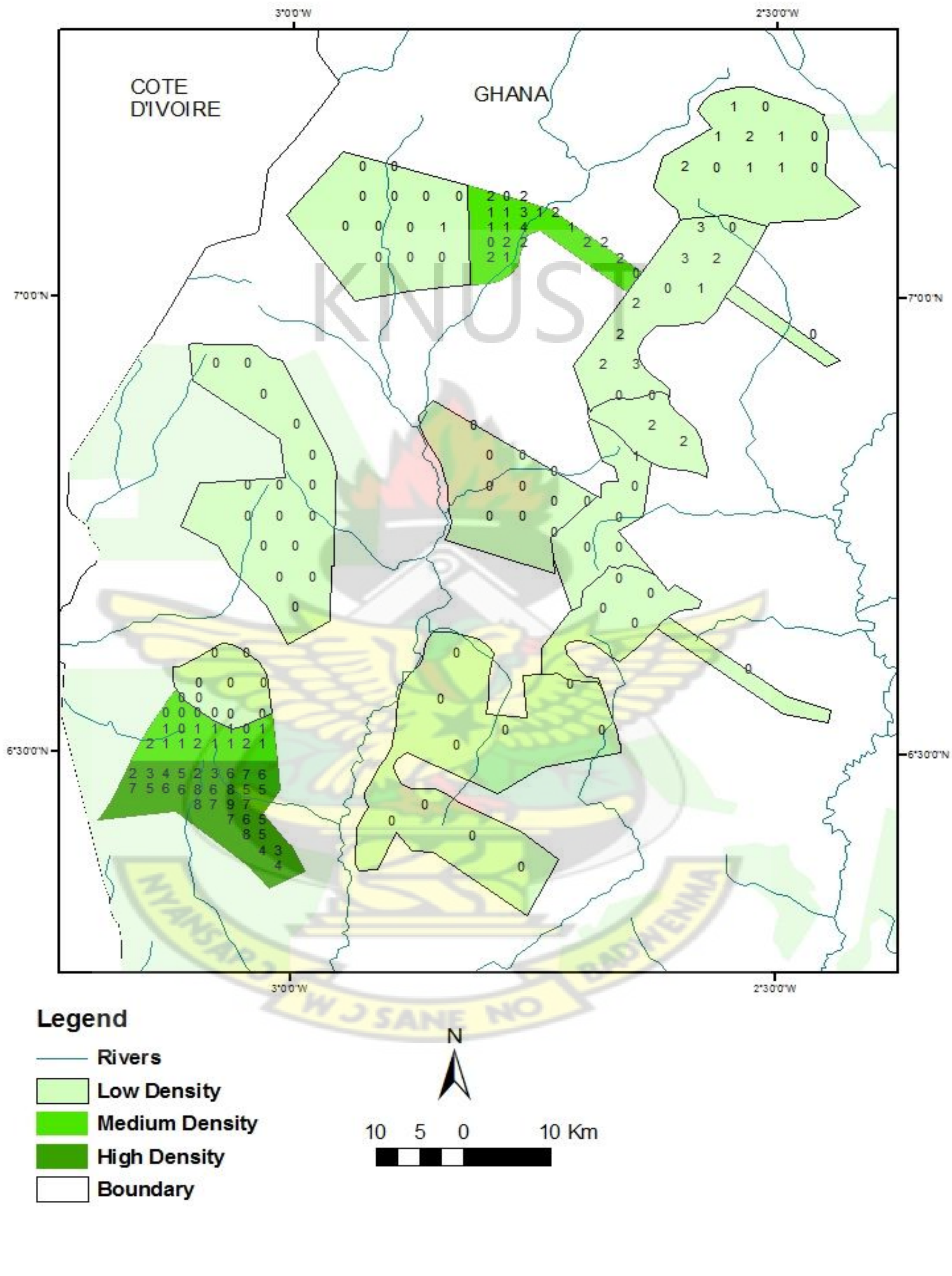


Fig. 3.13 Dung distribution in the study area during the 2007 wet season

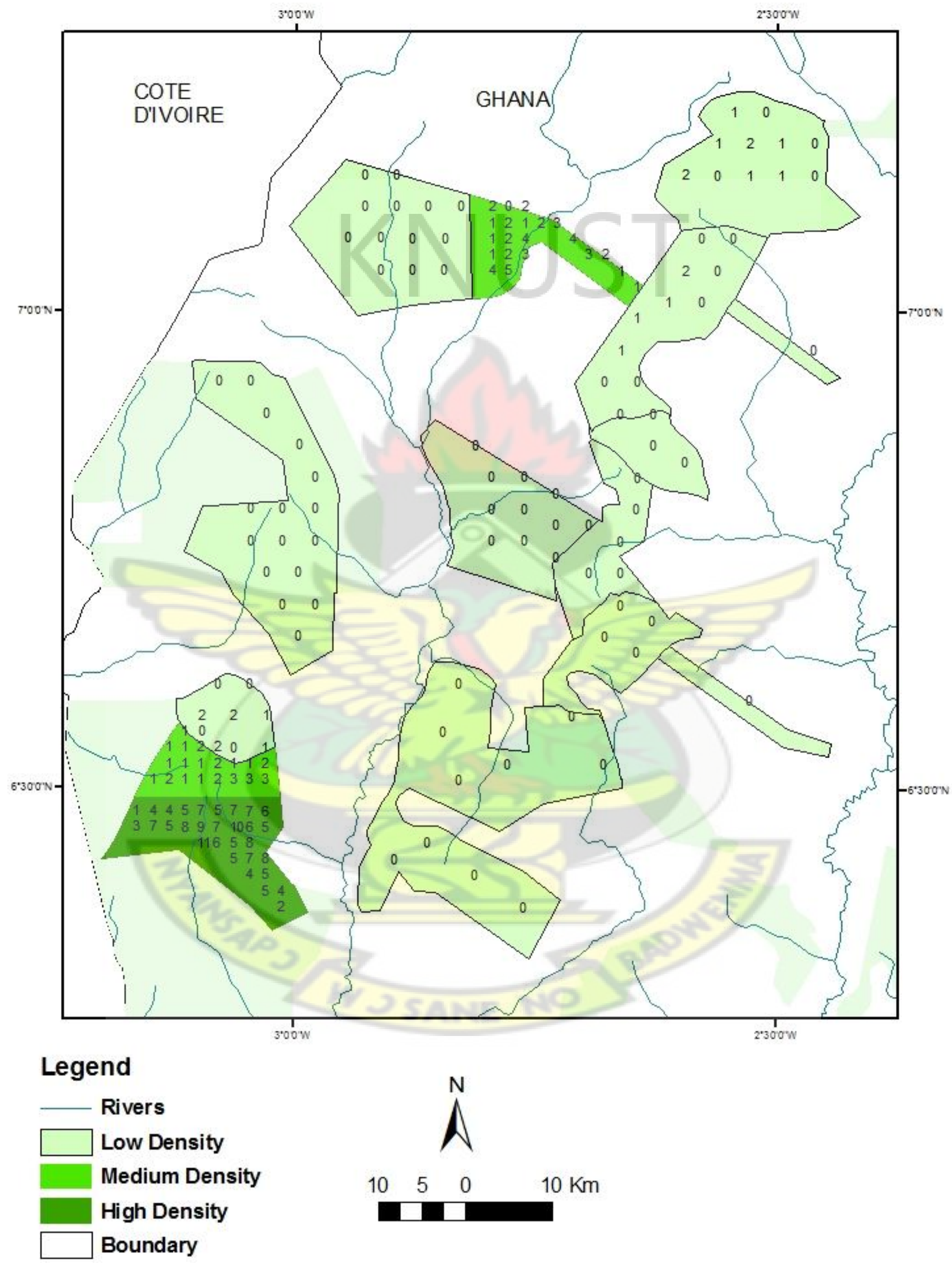


Fig. 3.14 Dung distribution in the study area during the 2008 dry season

Most elephants were found using the southern portion of the Bia Conservation Area. The eastern part of Mpameso and the adjoining Bia shelterbelt were also preferred areas. Most of the remaining sections of the study area were rarely used by elephants during the time of study.

3.6.6 Distribution of elephants in the study area in 2007/8

The distribution of elephants in the 2007/8 study had a similar pattern as that of the 2004 where the highest elephant activity was concentrated in the Bia RR, especially around the southeastern peripheries (Figures 3.12, 3.13 and 14), except for the fact that the current elephant activity seem to be more widespread with elephants using areas towards the national park.

Again, in the Goaso block of forest reserves, elephant activity was mainly encountered in Mpameso and the Bia Shelterbelt. Other reserves such as, Bia Tano, Asukese and Bonkoni FRs were also slightly more used than in 2004. Figures 13 and 14 show the wet and dry seasons' distribution of elephants in the study area. The distribution of dung piles in the Bia Conservation Area was significantly different (Kolmogorov-Smirnov Test: df=2, Dmax=0.467, $P<0.01$) from what pertained in the remaining Goaso block of forest reserves.

3.7 Discussion

3.7.1 Numbers of elephants in Bia Conservation Area

Rainfall varies from month to month, and in any one month it is unevenly distributed across days, and thus the steady state assumption is often invalid (Barnes *et al*. 1997). However, the rainfall model takes into account two months of rainfall preceding the dung count and makes no such assumptions as the steady states or normality hence it is probably the most accurate method for analysing data on dung-count (Barnes and Dunn, 2002). Moreover, calculations using the steady state assumption model gave a consistently higher (21%) estimate of elephant numbers than the rainfall model. This may mislead wildlife managers into taking irrational management decisions (e.g. culling) in their parks. Hence, in a case where rainfall data can be gathered the SSA model should not be applied in such environments.

Assuming that the Bia elephant population is an isolated one, then it is the largest elephant population in the study area. In a previous study, Sikes (1975) estimated the elephant population of Bia Conservation Area (BCA) as between 52 to 82 elephants based on track identification. Martin (1982) estimated between 200-250 individuals to inhabit the entire Bia forests. However, applying his density estimate to only BCA gave an estimate of between 89 and 113 elephants. Short (1983) on the other hand had an estimate of between 40 to 135 elephants. Furthermore, Heffernan *et al*. (1999) and Sam (2000) estimated the BCA population at 137 and 127 elephants respectively. The current estimate of 115 elephants (0.38 elephants per sq km) using the rainfall model is slightly lower than the 137 and 127 elephants estimated by Heffernan *et al*. (1999) and Sam (2000) respectively. Sam (2000) nonetheless has attributed his higher estimate to his inability to adequately stratify the study area. The apparent decline in the current study might be due to a superior sampling design used in this study.

It would appear from the above that elephant density has increased since Sikes (1975). However, this is because the original forest which was occupied by this elephant population has been reduced to only one-fifth of its original size making the density remain high still. That is, forest reserves such as Sukusuku and Bia Tawya which were part of the original range have all been reduced to farmlands.. Also, considering Martin's (1982) estimate of between 200 and 250 individuals, it can be realised that besides all the population recruitments that could be occurring, about 50% of the original elephant population have been lost through various means within the last two decades (up to 2004). If events are left to occur in this manner, such an isolated population runs the risk of extinction in case of demographic and environmental stochasticity (Sukumar, 1993; Barnes. 1999).

The Goaso population is one of the least surveyed in Ghana; Dickinson (1990) selected two of the forest reserves and surveyed the elephants inhabiting them while de Leede (1994) conducted interviews and made a presence or absence and guesstimate study. This study therefore represents the most comprehensive survey. Dickinson (1990) estimated a range of probable densities of 0.11 – 0.26 and 0.06 – 0.13 elephants per sq km for the Bia-Tano and Subin FRs respectively. This translated into an estimate of 200 – 250 elephants for the entire Goaso cluster of forests. DGW (1991) further estimated between 250 – 500 elephants to be present. The current total number of elephants occupying the Goaso forest reserves could not be adequately calculated due to very low elephant densities recorded in most of them. Nevertheless, elephant numbers estimated for the Mpameso-Bia Shelterbelt FRs (the only two reserves in the area with a significant elephant density) was estimated at 57 elephants at a density of 0.76 elephants per sq km. Since the Mpameso-Bia Shelterbelt FRs forms a continuum with all the other nine forest in the Goaso area and there is no apparent physical barrier to hinder movements, it can be argued that the same population uses the entire forests in that area. Based on these arguments, the current Mpameso-Bia Shelterbelt estimate of 57 elephants is assumed to represents the entire Goaso population (i.e. density of 0.03 elephants per sq km). This is significantly lower when compared with 200-250 individuals by Dickinson (1990), 200–500 elephants (DGW, 1991) and 500 elephants by Blanc *et al*. (2003).

Nevertheless, because of very low activities and the inability to record enough dung piles to estimate elephant numbers in the rest of the reserves in the study area, much cannot be said about population trends. Hence, the above comparisons are rather suggestive and should be treated with caution. One thing is certain though, that these reserves contain far fewer elephants than previously suggested.

3.7.2 Distribution of elephants

Elephants in the Bia RR and Bia North FR are isolated populations and do not move out of their respective ranges. In Bia North FR, a small population is possibly living in the central part of the reserve and seldom come out. However, in the Goaso population, elephants in the Mpameso FR use the Bia Shelter Belt (SB) to cross into the Bia Tano FR occasionally because of very fresh elephant activities recorded in the Bia SB and portions of the Bia Tano FR bordering the Bia SB. Old elephant signs (probably dating to the previous rainy season) recorded in some of the other reserves suggest a slightly more widespread elephant movement and distribution, possibly in relation to water availability. The us of existing shelterbelts to move from one reserve to another in the rainy season is likely to increase. This is important because, the use of these shelterbelts by elephants indicates that linear forest corridors have the potential to be used as passage by elephants to move around in the study area (Parren and Sam, 2003). Perhaps, it is only in the dry season that elephant movement and distribution may be restricted to just few areas within the reserves in response to patchily distributed water resources, and according to Barnes (1995) the availability of fruiting trees within the reserve.

3. 8 Conclusion

There are two (and a possible tiny third) elephant populations in the study area. The first is the Bia population (mainly found in BRR) which has a more stable elephant population, and could be increasing steadily. The original habitat has, however, shrunk considerably. The other population is the Goaso (Mpameso) population which appears to be decreasing at an alarming rate. These together make up about 172 elephants (CL; 123-264) in the study area. The 2004 survey indicated that there were a handful (probably less than 10) elephants in the heart of Bia North FR.

The elephants are clumped more to the BRR, especially the South-eastern portion and also the eastern part of Mpameso as well as Bia Shelterbelt FR. The population in BRR is gradually spreading northwards and beginning to make use of other parts of the BCA, making forays into the National Park portion. At the time of the study, it appeared that the other reserves (apart from the ones mentioned above) were rarely used by the elephants. Elephants were found to be more widely spread out in the wet season than in the dry season within BCA

CHAPTER FOUR

RELATIONSHIP BETWEEN ELEPHANT OCCUPANCY, ECOLOGICAL VARIABLES AND ILLEGAL ACTIVITIES IN THE BIA-GOASO FOREST ENCLAVE

4.1 Introduction

Environmental factors affect elephant home range, migration patterns, diet, group size and composition, all of which vary tremendously, in turn influencing the dynamics of elephants and their habitats (Poole, 1994).

In Ghana crop raiding reports show that elephant disturbances were frequent during the dry season (November-March) when elephants search for water and food. They empty waterholes and squeeze fruits and other crops such as plantains for their juice. Crop raiding is most frequent early in the rainy season (April-June) before the peak fruiting of trees when food is still scarce (Parren and Sam, 2003).

Forest elephants feed opportunistically on certain fleshy fruits when these are available and rely upon less nutritious foods during periods of fruit scarcity. Dudley *et al*. (1992) linked a sharp reduction in crop depredation to the fruiting of *T. heckelii* in the Kakum Conservation Area. Also, in the wet season, when few trees are fruiting within the forest, elephants move to the periphery of the reserve using the dense forest on the boundary as a base to raid neighbouring farms and to feed on the more accessible vegetation of the secondary forest (Danquah and Oppong, 2006).

From this account it is clear that the issue of elephant crop-raiding and more importantly elephant occupancy of an area will be better served if data on habitat variables such as areas of intact and disturbed forest, water sources, fruiting trees etc. in the study area were obtained. This is of the essence as distribution of elephants in an area could be influenced by these habitat variables among others. Such information will better facilitate the management of elephants and their habitats in the study area.

4.2 <u>Research Objectives and Questions</u>

a) Research objectives

This study was to:

i) ascertain the ecological and other variables that determine elephant distribution and numbers within the reserves in the study area.

ii) assess the human and other factors from outside the reserves that influence the distribution of elephants in the reserves.

b) Research questions

The primary research questions that this study sought to answer include the following:

- ✓ What are some of the environmental variables that affect elephant distribution and numbers in the study area? How does the different vegetation affect elephant distribution?
- ✓ How do elephants respond to the illegal human activities in the reserves?
- ✓ Is elephant distribution influenced by availability of fruiting trees?
- ✓ To what extent does water influence the way elephants use the reserves?
- ✓ How are elephant distributions in the reserves affected by the nearness of communities?

4.3 <u>Hypotheses</u>

- ◊ Ho = Vegetation type has no influence on elephant distribution
- ◊ Ho = Elephants avoid areas of higher concentration of illegal activities

◊ Ho = Fruiting trees determine the distribution of elephants

◊ Ho = Elephants tend to aggregate around water bodies

◊ Ho = The closer the major market centres to a reserve the lesser the presence of elephants

4.4 <u>Methods</u>

4.4.1 Habitat evaluation

Data collection was on the same transects established to assess signs of elephants as described in section 3.4.2.1

On each of the transects, 10 sampling points, each at every 100-metre mark was investigated. Whenever the observer arrived at the designated sample point, coordinates of the point was taken using a GPS. The vegetation type as well as canopy characteristics (presences of gaps in canopy, length of gap traversed by transect) were also recorded. The vegetation type include farm, fallow, secondary forest, *raphia* stand, riverbank vegetation and other vegetation types (which would then be specified).

4.4.2 Factors affecting elephant abundance within reserves

The presence of water, i.e. stream, river, pond, swamp without r*aphia (*sometimes dry during surveys conducted in the dry season) on the transect was noted. All fruiting trees on every transect were also recorded. Any man-made infrastructure or human signs such as hunting camps, empty bullet shells, wire snares, spent carbide, cane and wood cutting, and other such activities encountered on each transect were recorded. Other human influences such as the construction of trails or points associated with the haulage or loading of timber products, were recorded as logging roads.

4.4.3 Factors affecting elephant abundance outside reserves

Satellite images of the study area were acquired. The area is about 50 km (east to west) and 100 km (north to south). A grid of 5km by 5 km was laid over a map of the study area giving a total of 200 cells. Of these cells, 10% were systematically selected and using GIS approaches, the following human variables were gathered from them; size of built-up area, length of road, and length of forest reserve boundary, the distance between each transect and the nearest WD camp, the nearest park boundary line, the nearest main road and town. .

Again, ecological variables such as area of high forest, length of river (number of streams per km), proportion of primary forest, logged forest and farmlands were calculated for the same cells. The elephant dung data was then overlaid on images and compared with the human and spatial variables described above. Table 4.1 below shows the variables recorded for each transect at each study site.

Table 4.1: List of the variables recorded for each transect

Variable	Description of variable
X1	Date that the transect was walked
X2	Number of dung seen on the transect
X3	Number of signs of illegal human activities seen on the transect
X4	Number of water sources seen on the transect
X5	Number fruiting trees seen on transects
X6	Number of old logging roads crossed
X7	Distance to the nearest town (km)
X8	Distance to the nearest main road (km)
X9	Distance to the nearest WD/FD guard post (km)
X10	Distance to the nearest forest edge (km)
X11	Distance to the nearest international border (km)
X12	Length of secondary vegetation (km)
X13	Length of *raphia* stand (km)
X14	Altitude

4.5 *Data Analysis*

Single linear regression was used to investigate relationships between dung density and human and ecological variables found within and outside reserves. This was achieved by using the Stat View Computer Package 5.0.1 (2007). The above analyses described the variables that governed elephant abundance and\or their distribution during the time of the study. As the response variable, the number of dung piles recorded on transects are typical count data: they are not normally distributed and they consists of integers, positive numbers and sometimes there are many zeroes. Therefore variables were statistically normalised by a natural log transformation before analysing.

Following the transformations, each potential predictive variable was regressed against elephant dung densities. Another level of analysis was performed by pooling the dung density for all the reserves for both seasons and relating them to each of the potential predictive variables.

The data was further analysed using multiple regression (including multiple step-wise regression). In this case, several predictors were combined to examine how well they together fit the pattern seen in the response variable. One could have forced several variables in a model (e.g., water sources, canopy cover, logging roads, etc) and see if they produce a significant prediction of the response variable (e.g., dung/km^2). However, the step-wise regression was used as it adds and removes each variable in steps, and is a good and widely accepted way to look for a best model because it evaluates the strength of each of the predictors relative to each other. It is also more objective than methods where one "forces" variables into models (Dytham, 2003).

4.6 Results

4.6.1 Factors affecting elephant distribution/abundance within reserves (2004)

4.6.1.1 The Bia Resource Reserve (Bia RR)

Most elephant activities were concentrated at the south and southeastern sections of the RR and thinly spread northwards to reach the central portions. There was no activity in the Bia NP or the immediate adjoining northern fringes of the Bia RR.

Water availability was strongly influenced (r^2=0.654, P<0.05) by the number of logging roads constructed in an area (Figure 4.1).

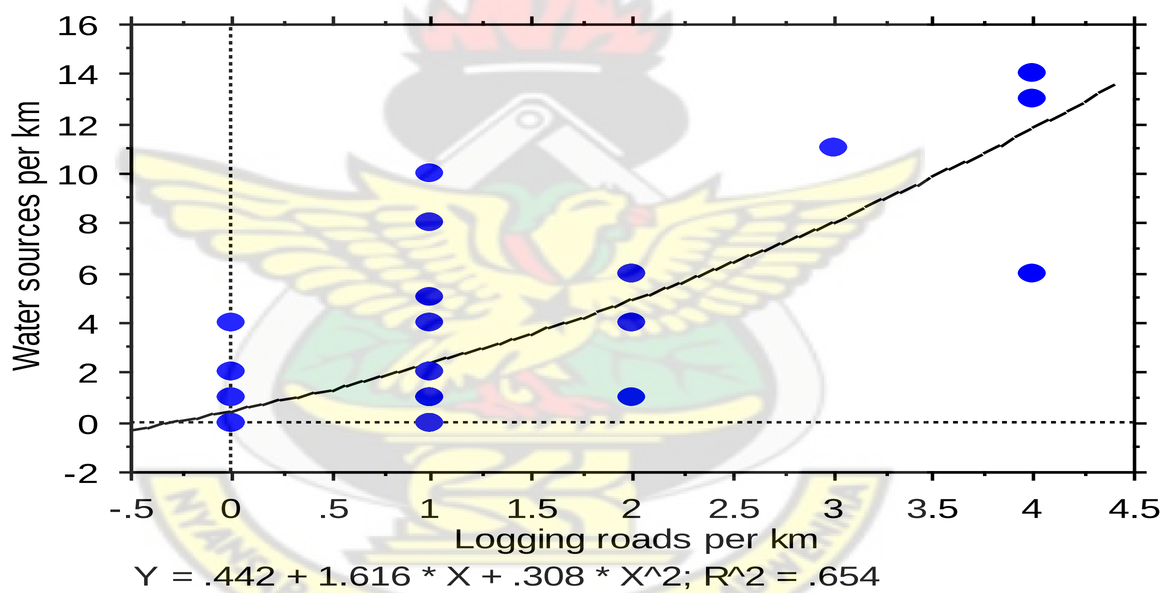


Figure 4.1: Relationship between logging roads and water sources per km

Elephant distribution was not strongly influenced (r^2=0.531, P<0.05, NS) by the number of logging roads (Figure 4.2).

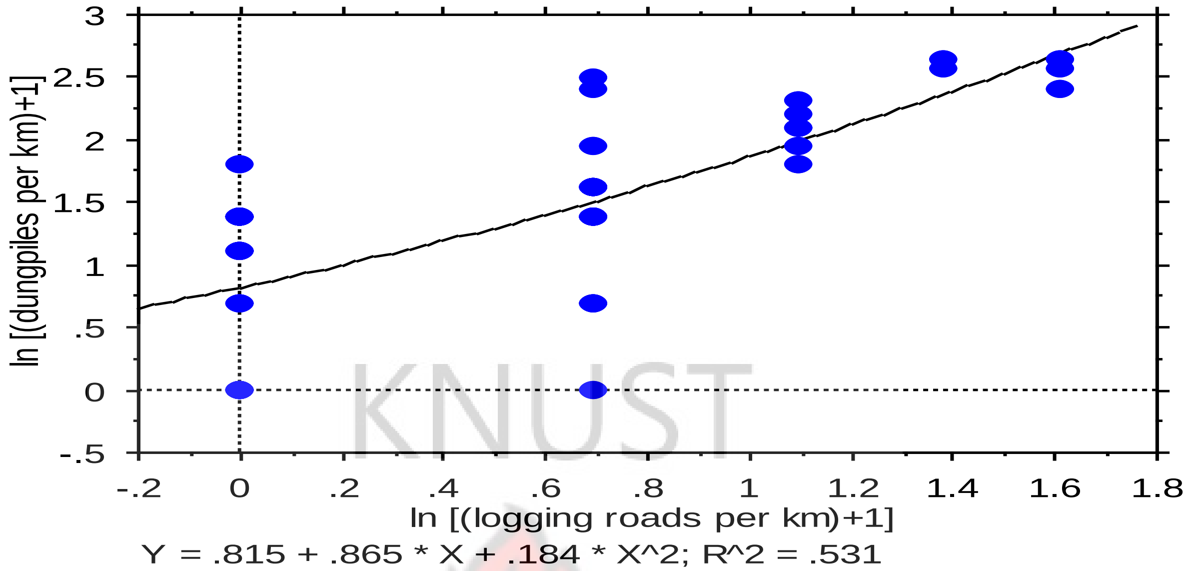


Figure 4.2: Relationship between logging roads and dung pile density

However, elephant distribution was clumped and significantly influenced (r^2=0.759, P<0.05) by the number of water sources (ponds and dams) associated with the logging roads (Figure 4.3).

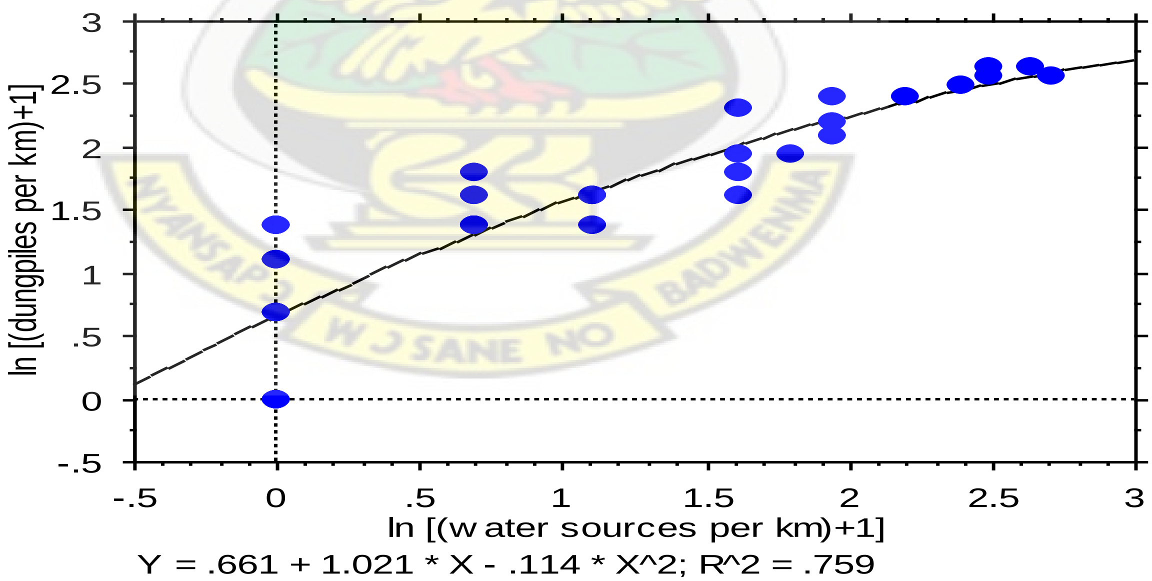


Figure 4.3: Relationship between water sources and dung pile density

Elephants were reported hunted but the team could not ascertain the intensity. At Adjoafia, a native community at north-eastern Bia NP for instance, an elephant was reportedly killed less than three months to the study. Yet, there was no direct correlation between illegal activity and elephant distribution (r^2=0.413, P>0.05, NS).

Nevertheless, the index of illegal activity per km dropped drastically when dung pile density exceeded 6 piles per km (Figure 4.4). Mean illegal activity throughout the Bia NP and Bia RR was 0.74 activity per km.

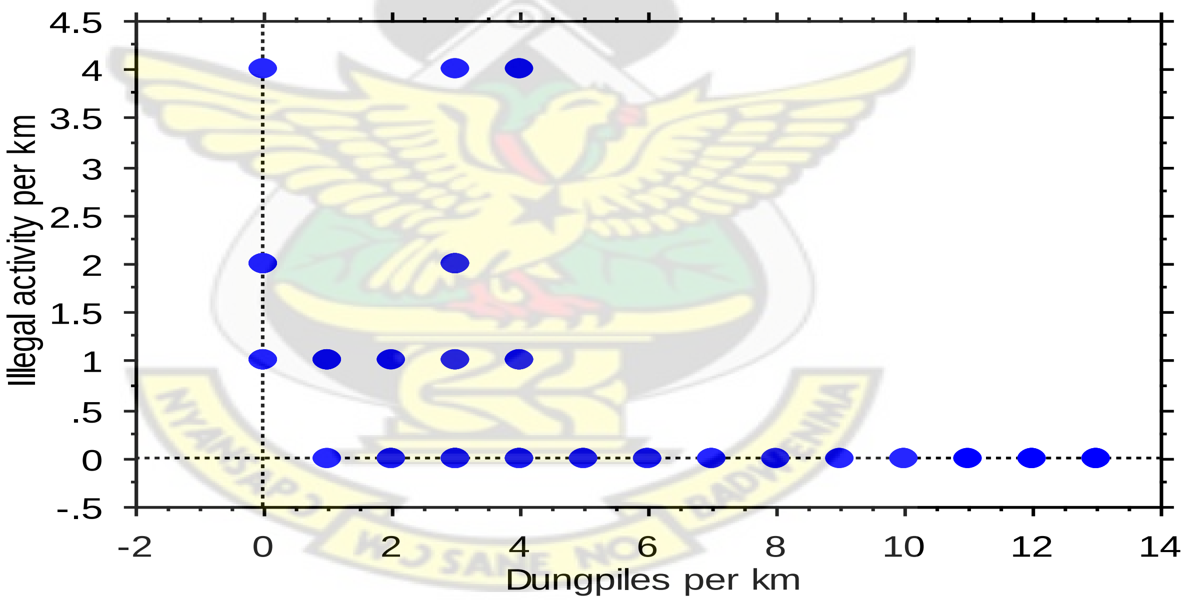


Figure 4.4: Scatter plot of dung piles in relation to illegal activity per km

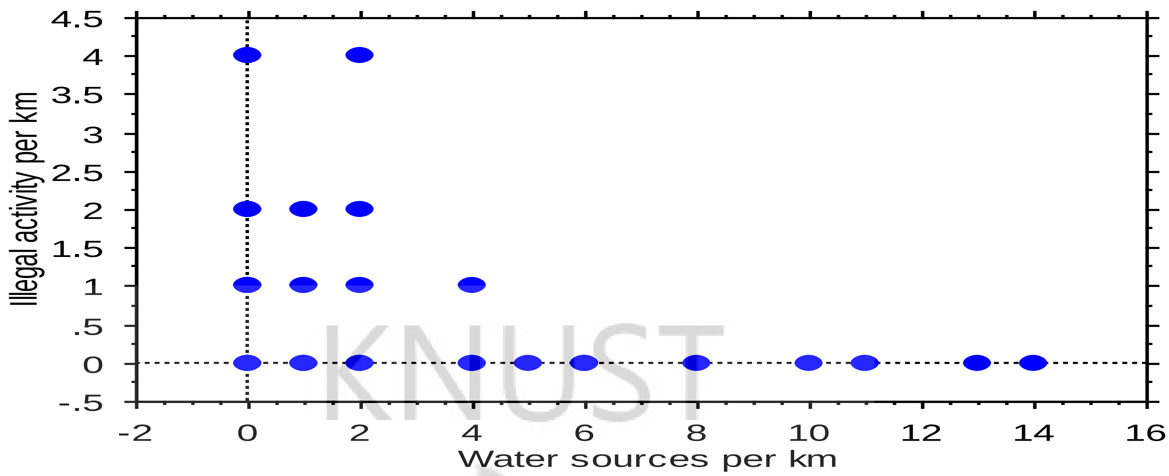


Figure 4.5: Scatter plot of water sources in relation to illegal activity per km

Poachers avoided areas of high water availability. No illegal activity was recorded in areas with more than 6 water sources per km (Figure 4.5).

Other variables assessed: raphia stand (r^2=0.005, P>0.05, NS), secondary vegetation (r^2=0.249, P>0.05, NS), gap length (r^2=0.079, P>0.05, NS), and fruiting trees per km (r^2=0.009, P>0.05, NS) did not account significantly for the distribution of elephants.

4.6.1.2 Mpameso and Bia Shelterbelt FR

The distribution of dung piles in the Bia RR and Mpameso-Bia Shelterbelt FR were not significantly different (Kolmogorov-Smirnov Test: df=2, Dmax=0.299, P>0.05, NS), i.e. elephant were found more often in areas which had high concentration of watering points. (Figure 4.6).

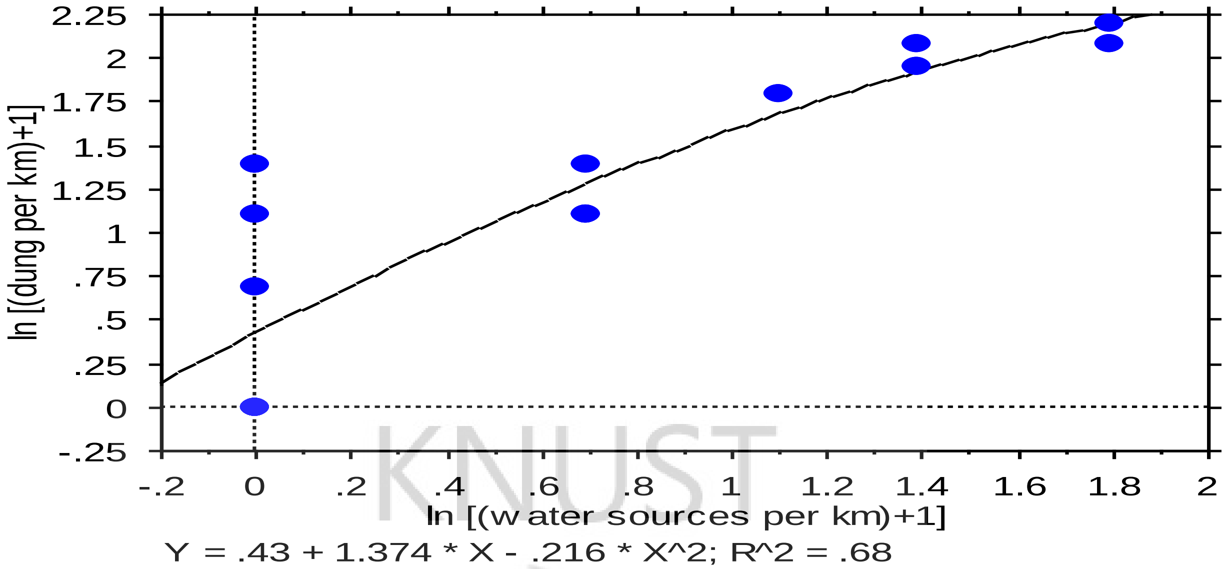


Figure 4.6: Relation between water sources and dung pile density

Distance to the nearest major river (Bia River) was inversely (r^2=0.650, P<0.05) correlated to the number of dung piles seen per km (Figure 4.7). Here, the distance from the centre point of the transects to the river was measured and the relationship assessed with its dung pile density.

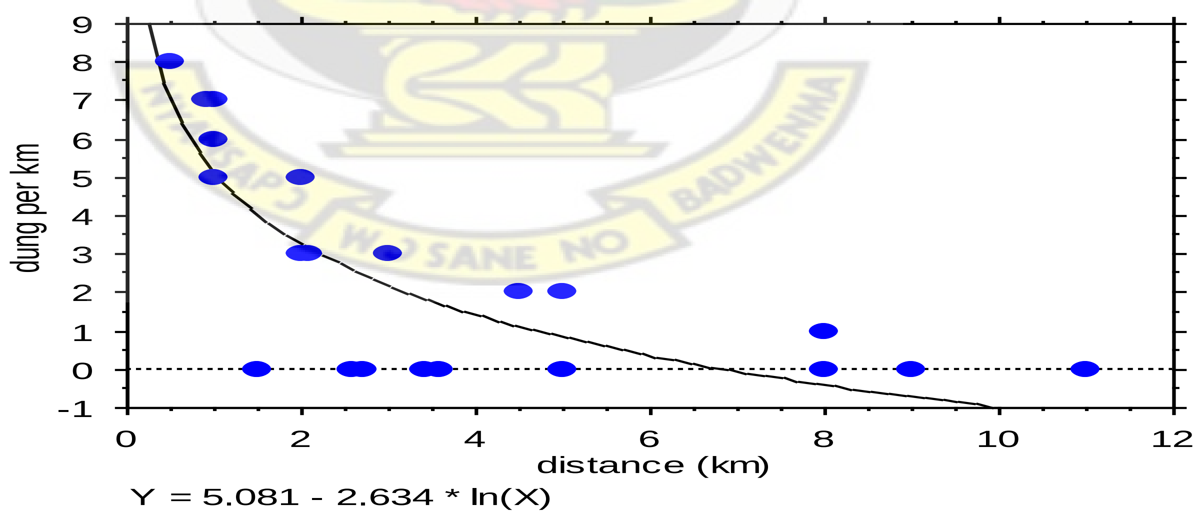


Figure 4.7: Number of dung piles seen per km with distance from the Bia River

In comparison to the Bia Conservation Area, illegal activity was twice higher in the Mpameso-Bia Shelterbelt area (1.48 illegal activity per km). This was largely made up of wire snares. Also, three gunshots were heard on a single day whilst walking on a transect. We could not tell whether they were the result of elephant killings or not. Nevertheless, illegal activity did not influence elephant distribution (r^2=0.277, P>0.05, NS).

The other variables: raphia stand (r^2=0.004, P>0.05, NS), secondary vegetation (r^2=0.059, P>0.05, NS), gap length (r^2=0.022, P>0.05, NS), number of logging roads (r^2=0.085, P>0.05, NS) and fruiting trees per km (r^2=0.035, P>0.05, NS) did not account significantly for the distribution of elephants. Hence, in the absence of these variables, elephants may spread and move into other reserves during the rainy seasons when water becomes available and widespread.

4.6.1.3 Rest of Reserves

On the average, illegal activity was highest (1.52 illegal activity per km) in the low-density stratum, which constituted the rest of the reserves in the Goaso region. Elephant activity was low hence this study was unable to adequately relate elephant distribution to ecological variables including illegal activity.

4.6.2 Factors outside reserves affecting elephant abundance (2004)

The distance to the nearest major road significantly influenced (r^2=0.710, P<0.05) elephant abundance in the reserves. Elephant density increased steeply in reserves beyond 8 km distance from the main Bibiani-Dormaa Ahenkro road.

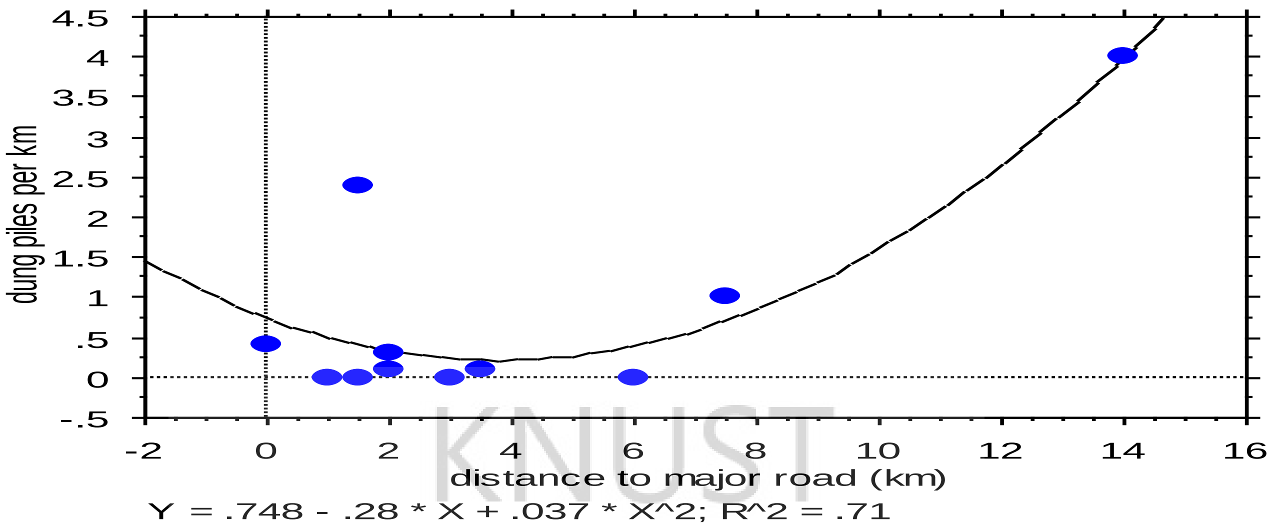


Figure 4.8: Changes in dung pile density with distance from the nearest major road

The distance to the nearest major towns significantly influenced (r^2=0.728, $P<0.05$) elephant abundance in the reserves. Elephant density increased steeply in reserves beyond 8 km distance from the nearest major town.

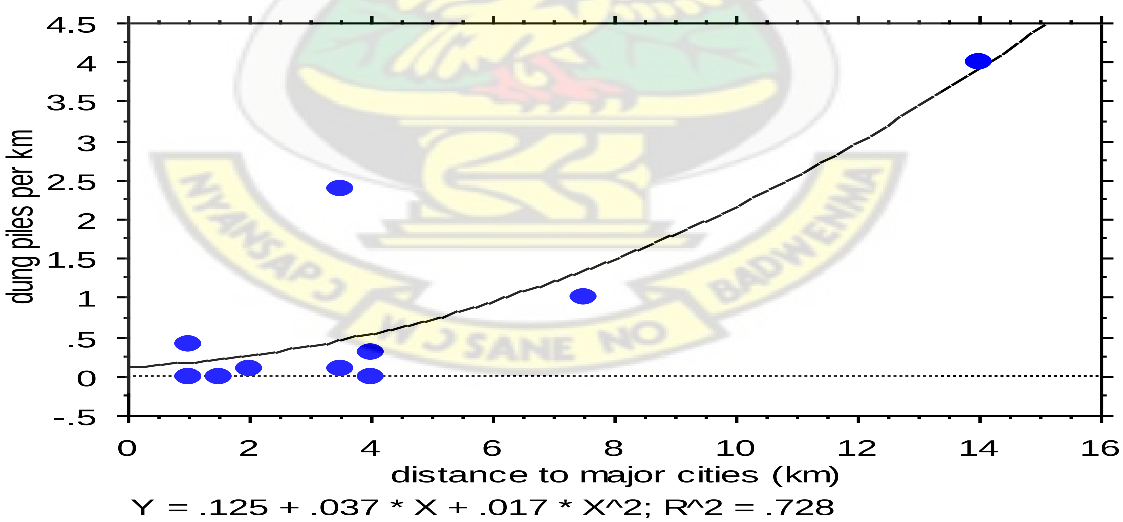


Figure 4.9: Changes in dung pile density with distance from the nearest major town

4.6.3 Factors affecting elephant distribution (outside/inside) reserves during the 2007/8 study period

The effect of water had the most significant effect on the distribution of elephants in the dry season whilst proximity to the edge of reserves was prominent in the wet season (Table 4.2).

Table 4.2: Spearman rank correlation coefficients (r_s) between dung per km (pooled data) and a suite of ecological variables recorded on transects.

	Wet season		**Dry season**		**Combined data**	
Description of variable	r_s	**P**	r_s	**P**	r_s	**P**
Number of water sources	0.566	< 0.05	0.910	< 0.01	0.720	< 0.01
Distance to forest edge (km)	- 0.740	< 0.01	- 0.699	< 0.05	- 0.719	< 0.01
Index of illegal human activities	- 0.410	> 0.05	- 0.465	> 0.05	- 0.438	> 0.05
Number of logging signs	- 0.080	> 0.05	- 0.042	> 0.05	- 0.058	> 0.05
Number of fruiting trees	- 0.193	> 0.05	- 0.476	> 0.05	- 0.324	> 0.05
Distance to WD/FD guard post (km)	0.010	> 0.05	0.114	> 0.05	0.057	> 0.05
Distance to the nearest town (km)	0.306	> 0.05	0.313	> 0.05	0.309	> 0.05
Distance to the nearest road (km)	0.268	> 0.05	0.145	> 0.05	0.205	> 0.05
Distance to Ivory Coast border (km)	- 0.071	> 0.05	- 0.006	> 0.05	- 0.047	> 0.05
Length of secondary vegetation (km)	0.180	> 0.05	0.230	> 0.05	0.210	> 0.05
Length of *raphia* stand (km)	0.036	> 0.05	0.044	> 0.05	0.041	> 0.05
Altitude	0.196	> 0.05	0.112	> 0.05	0.148	> 0.05

The variable that greatly explained (r^2=0.855, P<0.01) elephant distribution, especially in the dry season when dung density for all the reserves for both seasons were pooled was number of water sources in an area when expressed as a polynomial (Figure 4.10).

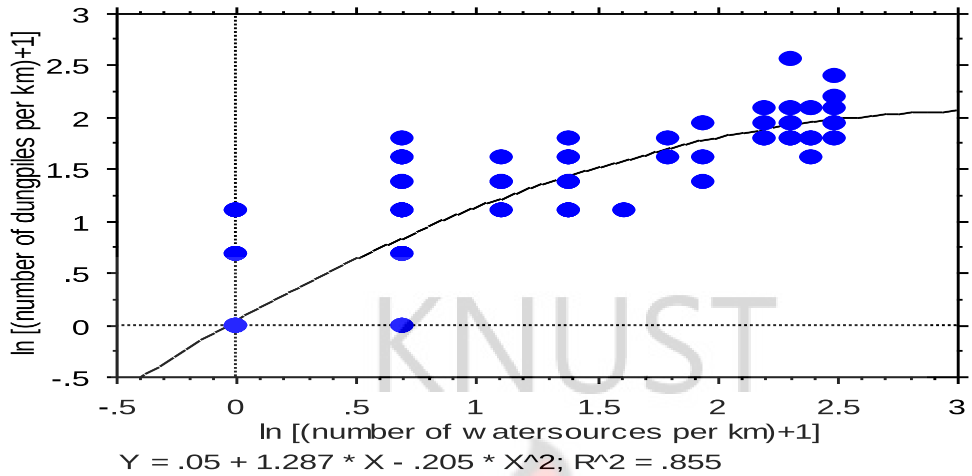


Figure 4.10: Relationship between pooled dung density and number of water sources

The distance to the nearest forest edge emerged as the second most important variable in the wet season (r^2=-0.598, P<0.01), again in polynomial model (Figure 4.11).

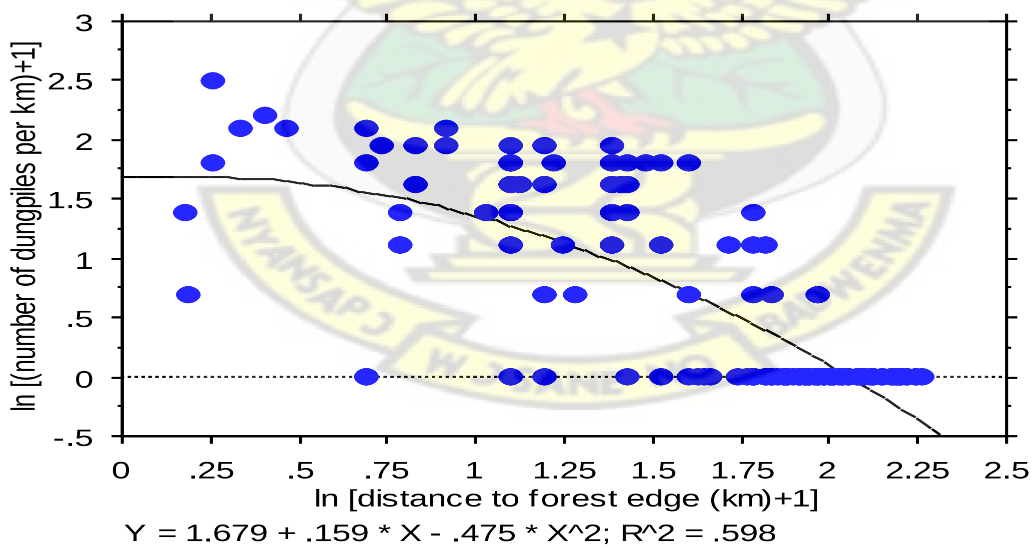


Figure 4.11: Relationship between pooled dung density and distance to forest edge

These models allow us to predict the number of dung expected in an area for specific seasons given the number of water sources in an area or distance to the forest edge.

4.6.4 *Illegal activity*

Elephants were reported hunted but the intensity could not be ascertained during the study. There was no direct correlation between illegal activities recorded and elephant distribution. Four hundred and fifty-five (455) signs of illegal activity were encountered in both surveys: 180 in the wet season (encounter rate = 1.07 per km) and 275 in the dry season (encounter rate = 1.63 per km). Eighty-one (81) illegal activities were recorded in the Bia range in both surveys (encounter rate = 0.68 per km), 183 in the Mpameso range (encounter rate = 1.73 per km) and 191 (encounter rate = 1.71 per km) in the forests south of Goaso.

Illegal activities in the study area consisted mostly of wire snares (84%, n = 455). Other activities were empty cartridges cases (9%), carbide spots (4%) and poacher camps (3%). Twelve (12) gunshots were heard in the night during the entire survey. Illegal activities per km was significantly higher in the Goaso block of reserves than in the Bia CA (Mann-Whitney U test: $U=4175$, $P<0.01$).

4.7 Discussion

4.7.1 *Factors within reserves*

Formerly, elephants were found both in the Bia NP and the Bia RR (Martin, 1982; Short, 1982). However, the 2004 study showed that the distribution of elephants on the ground had changed considerably. Since timber companies started logging in Bia RR in the early 80s (de Leede, 1994) elephants have left the Bia NP and moved downwards into the south eastern portions of the RR. Both Barnes (1996) and de Leede (1994) also observed this pattern. Meanwhile, it had been suggested that the absence of elephants in the Bia NP was temporarily as a reaction to different and more palatable secondary vegetation conditions created by logging within the Bia RR (Short, 1981 and Martin, 1982).

Both the 2004 and 2007/8 studies confirmed the above pattern of elephant distribution where elephants concentrated more in the south (especially southeast) of the CA. However elephants were found to be more widespread than formerly observed. The 2004 study showed a medium elephant density stratum, which extends above this southern high density to the limits of the Bia NP. Indeed, even during the 2004 study old elephant activities, probably dating to the previous rainy season were recorded in the NP. The 2007 distribution showed an even more thinly spread into the Bia NP. According to Sam (2000), the question that needs to be asked and investigated is why elephants seem to be gradually moving back into the National Park after a long period of absence. There is every indication that close to a decade of the stoppage of logging in the southern portion of the BRR, the vegetation is maturing and becoming like elsewhere in the CA so making elephants spread out the more. The widespread distribution of elephants in the wet season as compared to dry might be in response to the lack of fruiting trees during this time (Dudley *et al*., 1992; Barnes, 1996). Elephants make up by moving out of reserve to crop-raid. The spread can also be attributed to the availability of water all over.

Analysis of dung pile distribution indicated that water sources accounted for a large proportion of this variation in the Bia Conservation Area. Barnes (1996) and Sam (2000) also reported of a positive correlation between elephant abundance and number of water sources per km. These pools or water sources, which were more abundant in the south and southeastern sections of the reserve, were created as a result of the logging activities of Mim Timber Company. In the construction of their logging and hauling roads which were larger than those specified in Ghana's Logging Manual (PADP, 1998), many streams have been blocked forming several pools along the sides of sections of the roads. Apart from their swampy nature, the areas around these pools were surrounded by very thick thorny vegetation which is very difficult to traverse and hence likely to be avoided by hunters (Sam, 2000). Therefore whilst the pools provided water for the elephants, the vegetation at their banks also gave protection to the elephants, by warding off poachers.

Sam (2000) stressed that water availability in the reserve is not a problem because of many artificial pools in the reserve. However, elephants may be avoiding the northern half of the Bia RR and Bia NP due to unavailability of water in most elephant pools especially in the dry season when the survey was conducted. Also as those areas have not been logged for over three decades there are limited man-induced pools. Consequently, elephant movement and distribution in the dry season may largely be restricted by water unavailability than any other single factor. Elephants spread out a little more to the northern parts during the wet season when water becomes more available in most parts of the conservation area.

In the Goaso area, de Leede (1994) observed that lack of water appeared to be the main reason for elephants moving out of the forests. Similarly, this study showed a positive correlation between dung density and number of water sources per km in the Mpameso-Bia Shelterbelt area.

The distribution of elephants along rivers in the dry season is well documented (Danquah *et al*., 2001, Sam *et al*., 1997). This study has shown that scarcity of water in the reserves and elephants affinity to water becomes the central theme for such distribution. At the Mpameso-Bia Shelterbelt area, the main Bia River, may be serving as a major source of water for most of its elephants; dung density per km was inversely related to distance from the Bia River. Elephant distribution during the time of all the studies was concentrated in the eastern section of the reserve along the Bia River where a few elephant ponds were observed to still contain water in the case of two dry season periods. It is possible that most of the elephants residing in this area might have migrated to live close to the River Bia due to unavailability of water in the other parts.

Barnes (1996) and Sam (2000) further reported significant correlations between dung density and variables such as fruiting trees and illegal activity respectively. However, this study found no such correlation. It is possible that as the logging in the Southeastern portion of the reserve has ceased since about a decade ago, that area no longer has the highest concentration of available fruiting trees hence elephants are gradually dispersing to other areas of the reserve.

Elephants were reported hunted but the team could not ascertain the intensity. In 1999, there were at least four official elephant-poaching cases in BCA alone (Sam, 2000). At Adwuofia (a native community at north-eastern edge of Bia NP) for instance, an elephant was reportedly killed less than three months to the 2004 study. In addition, park rangers expressed fears and concern about an alleged presence of a group of poachers lurking in the vicinity of the reserve but there were no evidence to suggest that they operated in the park.

Despite the above, illegal human activity within the park did not influence elephant density. Even though there was a difference in the level of illegal activity between Bia RR and the Mpameso-Bia SB area, the use of wire snares dominated the signs of illegal activity in comparison to hunting with guns. Hunting with guns posses a greater threat to the elephant population than wire snares (Sam, 2000). However, no poacher was encountered even though three gunshots were heard during the day whilst walking transects in the Bia RR during the 2004 study, and 12 were heard in the night in the study area during the 2007/8 study. Poachers may have been active in the night than daytime. Available information tends to suggest that poachers also avoided areas of high concentration of watering points possibly because these areas had the highest concentration of elephants and they feared encountering them. These observation implies that most of the illegal activity seen on the transects were those of small game poachers and were not targeted at elephants.

4.7.2 ***Factors outside reserves***

The 2004 study supports the assertion that to a large extent, man determines the distribution of elephants (Barnes *et al*., 1991). For example, elephant density was found to be inversely correlated with human activity/disturbance, as both the distance to the nearest major road and town inversely influenced elephant abundance within the reserves.

Eighty percent (80%) of the reserves constituting the low-density stratum form a contiguous block and are aligned in a north-south manner. This block of forests lie parallel to and within 8 km of the main Bibiani-Dormaa Ahenkro road, hence can be easily and quickly assessed by poachers from the road. Some major commercial towns and district capitals, which are linked by the road and consequently, very close (not more than 8 km) to these reserves, are Bibiani, Goaso, Mim and Dormaa Ahenkro.

Moreover, because these are only forest reserves and not protected by strict wildlife laws, they are vulnerable to professional elephant poachers from the major towns. A lot of forest products including bush meat are carted along this road to various destinations. This could also be the reason for the striking difference in the intensity of illegal activities between the Bia range and the Goaso range in all the three independent studies as Bia is well protected by armed wildlife guards as against the Goaso range that has only a few unarmed forest guards.

4.8 Conclusion

Density of water sources (i.e. watering sources, natural or artificial notwithstanding) is a very good predictor of elephant distribution. In fact, it is an unusually strong predictor that explains almost 90% of the variance or the manner in which elephants were distributed, throughout 2004, in the Bia-Goaso area and confirmed in the 2007/8 study. In Bia CA and Mpameso-Bia Shelter Belt, logging roads and raphia length respectively also entered the model as significant variables in the 2007/8 study. However, they really did not add much power to the simple models. No correlation has been observed between illegal activities and elephant distribution in the reserves. However, the nearness of the reserves to a major highway as well as major towns were observed to have a negative influence on the abundance and distribution of elephants in the study area.

CHAPTER FIVE

POTENTIAL CORRIDORS FOR ELEPHANT MOVEMENT BETWEEN BIA AND GOASO FOREST ENCLAVES AND BORDERING FORESTS IN IVORY COAST

5.1 Introduction

Naturally, elephants are wide ranging animals, but they have become isolated in fragmented habitats because of human activities. Small patches of habitats may not have the resources necessary to support an elephant population year round, hence the need to facilitate unobstructed movement of elephants for their conservation by creating linear features of vegetation that connects isolated habitat fragments that were once connected (Saunders and Hobbs, 1991).This is the situation of the forest elephant (*Loxodonta africana cyclotis*) populations in the Upper Guinea forest block of West Africa which are currently small, scattered and isolated within relict patches of rainforest habitat (Dudley *et al*. 1992). This has been further exacerbated by growth of the population, going hand in hand with deforestation and expanding agricultural activities, resulting in drastic reduction of the habitat of the forest elephant, thereby requiring urgent attention.

In response to this situation, one of the most significant issues of the West African Elephant Strategy has been the recognition of "shared" elephants among range states (IUCN/AfESG, 1999). In reality, cross border elephant populations account for more than half of the elephant populations in West Africa (Blanc *et al*., 2002). Cross border elephant conservation programs are therefore necessary for the conservation of forest (as well as savanna) elephants and the trans-boundary biological processes that sustain the ecosystem they depend on.

The Bia-Goaso elephant range in Ghana together with that of Diabarakrou in Ivory Coast has been cited as one of the 5 key trans-boundary corridor areas harbouring the largest remaining cross-border elephant populations in West Africa (IUCN/AfESG, 2003). A project ensuring that the two populations are linked through the establishment of a corridor will enhance the conservation of these populations.

However, corridor options that are feasible need to be determined to inform the preparation of the actual corridor establishment project, i.e. this study can determine and prioritize the most feasible corridors and the sections of the corridor that should be tackled first when the implementation project commences.

Due to their wide-ranging habits, elephant conservation initiatives in the corridor will largely benefit other wildlife species sharing the habitat. Consequently, the development of the corridor though targeted at the elephant will ensure the conservation of biodiversity in general within the corridor area.

Urgent investigations are required now as continued rapid growth of human populations and their impact on what could be the corridor habitat indicate that in the next few decades, the possibility of developing these corridors to conserve the habitat and the wildlife within will be much more challenging.

It is important to be able to design corridors that can attract forest elephants into them. Hence factors such as the presence of food plants, availability of water, and the size and structure of the corridors needed to be investigated.

5.2 Research Objectives and Questions

a) Research Objectives

This study is designed to:

i) establish whether elephants actually move along the Bia River from Ghana into Ivory Coast and vice versa

ii) determine whether there has been any changes in the extent and structure of habitat of the elephants between 1989 and 2003

iii) elucidate which areas could be used as corridors to facilitate movement of elephants between populations

iv) determine whether people living in the potential corridor areas will agree and be willing to participate in the establishment of the corridors

b) Research questions

The primary research questions that this study sought to answer were the following:

- ✓ Do elephant populations in the study area actually interact with each other?
- ✓ Do elephants use the Bia River as a migratory corridor?
- ✓ Which parts of the elephant habitat are being lost and at what pace?
- ✓ What are the possible areas with the necessary conditions for the establishment and promotion of a transboundary elephant conservation corridor(s) between Ivory Coast and Ghana?
- ✓ What is the perception of the local communities' on the establishment of corridors in their area?

5.3 Hypotheses

- ◊ Ho = Elephants populations in the Bia and Goaso interact with one another
- ◊ Ho = Elephant habitat in the study area is being drastically degraded in extent and structure
- ◊ Ho = There are favourable ecological and social conditions for linking elephant populations in the study area.
- ◊ Ho = There is a north-south movement of elephants along the Bia river linking populations in Ghana to those in Ivory Coast
- ◊ Ho = Local communities are willing to share space with elephants

5.4 Methods

5.4.1 Elephant movements along the Bia River

Most of the reserves comprising the Goaso complex are contiguous to each other in a north-south manner. It was important to determine whether elephants actually moved southwards towards Ivory Coast. This was to help determine whether in the eventual management of the area, elephants needed to be "baited" to utilise a possible/proposed corridors, or that they were likely to do that naturally on their own. From the Asukese FR to the point where the Bia river enters Ivory Coast border is about 100 km. To ascertain the north-south (and vice versa) movements of elephants within the study area, five east-west transects going across the Bia River were established and studied. The first was laid randomly and the others spaced 20 km to each other in relation to the first (Fig. 5.1). The idea was to understand the utilisation of the spaces in between the reserves along the Bia river. Any transect reaching the boundary of a reserve was extended for two more km into that reserve. On the other hand, where there was no reserve, a 10 km transect (five km on each side of the river) was laid.

These transects were walked once every three months on six different occasions to determine whether elephants have crossed them, and in which direction. This experiment would have been best achieved through radio/satellite collaring of elephants, however, this technology could not be used because of lack of funds. With the above information, it was possible to graphically present which time of the year elephants cross a particular transect, (and so were likely to be found).

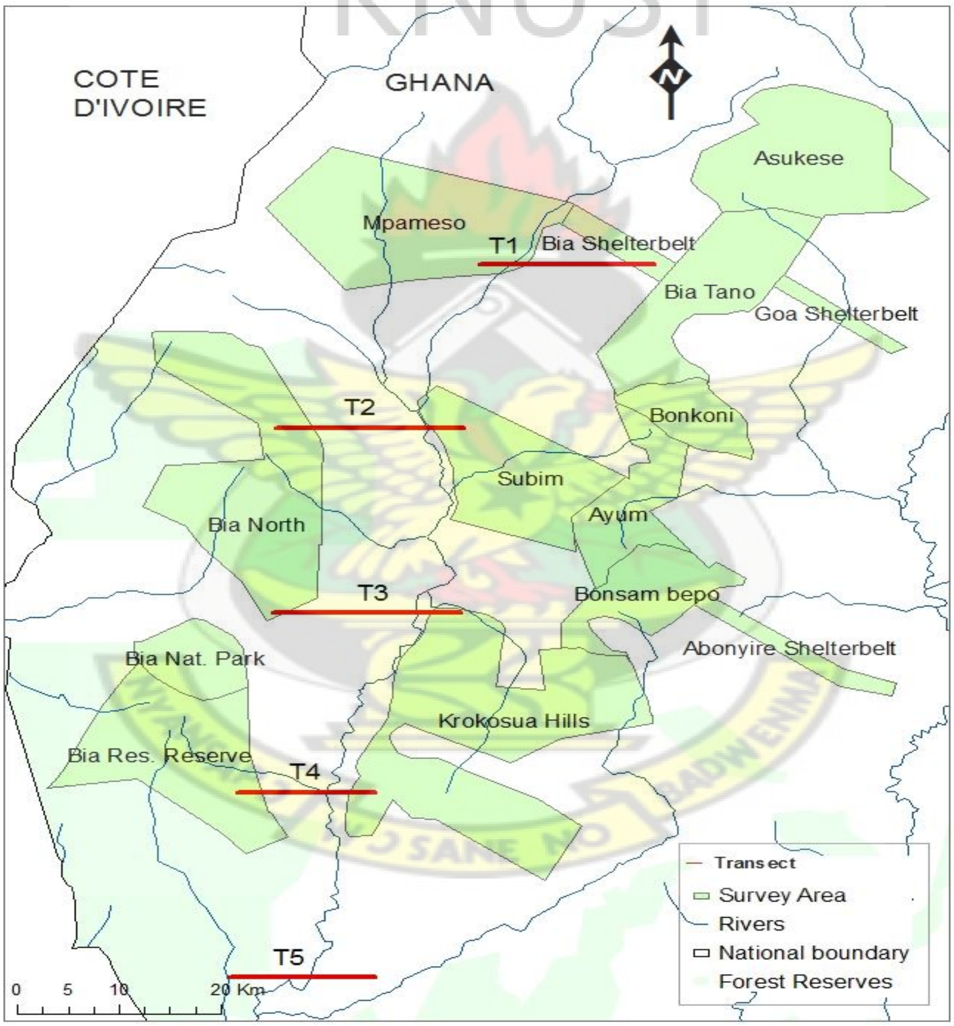


Figure 5.1: Distribution of transects for monitoring the north-south movements of elephants from the Goaso area into Ivory Coast

5.4.2 Change detection using Post classification

Change detection using post classification method (Lunetta *et al*., 2002) was undertaken to detect the type, geographic location and amount of changes (Im and Jensen, 2005) that had occurred in the study area from 1989 to 2003. To do this, a preliminary land cover map of the study area was produced by undertaking an unsupervised classification of the 2003 image. Landsat TM satellite image of 1989 that had been already georeferenced to the coordinate system of the study area (Transverse Mercator / Clarke 1880) was used as a master image for georeferencing and image to image co-registration of the 2003 Landsat ETM image in ERDAS Imagine 8.7. At crossroads and river junctions control points were taken. The image was then projected to the common coordinate system and re-sampled to the same spatial resolution of 1989 image and classified using unsupervised classification. This aided in selecting training samples of land cover for field data collection.

Six (6) land cover types were identified and areas within them which had not undergone change in both images were identified. Relying on expert knowledge and field observation, image classification was carried out in ERDAS Imagine using supervised classification technique with Maximum likelihood algorithm (Kerle *et al*., 2004). This involved defining the spectral characteristics of classes by identifying sample areas (training areas) and using pixels assigned to an informational class to classify pixels that were not identified.

During the classification overlaps in spectral reflectance among land cover classes were dealt with by masking out the forest and classifying them separately from the off-reserve areas and mosaicing them later. Each of the classified maps was then smoothened to remove individual pixels.

Change detection using NDVI (Sellers, 1985) which is strongly related with the extent of vegetation cover (Murwira and Skidmore, 2005) was employed to validate changes observed in the post classified land cover maps as there was no ground truth data for both 1989 and 2003 years and classification was done based on back classification and ground data collected in 2007.

After the NDVI maps were generated from the 1989 TM and 2003 ETM images, radiometric correction was done using relative radiometric normalisation correction (Lillesand and Kiefer, 1994) which minimised differences between the two images resulting from atmospheric differences between the dates of acquisition and consequently, detecting genuine changes in the maps.

5.4.3 Using satellite images and ground truthing to determine potential corridors

The use of shelterbelts set up in the 1940s by elephants in the Goaso area, indicates that linear forest corridors have the potential to be used as passages by elephants (Parren *et al*., 2002). Thus, it was intended to determine the potential for the creation of corridors between forest reserves by examining and analysing the locations and physical conditions of the vegetation between the reserves using satellite images and maps, and confirming through ground truthing. Information gathered included the following aspects: distance and width of a possible/proposed corridor, population pressure (number and distribution of villages within), land-use types, NTFP gathering activities, presence of rivers and streams, as well as remaining forest cover.

5.4.4 ***Questionnaire survey for determining socio-economic feasibility for corridor creation***

A questionnaire survey was used to collect information on elephant numbers, distribution and movement’s patterns over the past decade of years, other information gathered included land-use practices, human-elephant interaction. Appendix 1 outlines information that was obtained through the questionnaires which were administered in 36 randomly selected communities within the study area. A combination of Participatory Rapid Appraisal and Rural Rapid Appraisal techniques (Warren, 1998) were employed to determine the socio-economic feasibilities for creating elephant corridors in communities which fell within potential corridor areas within the study area. These included determining attitudes of the local population towards the possible establishment of corridors and investigating local people's views and knowledge about issues such as tree planting. The people's willingness to share or offer up lands for the establishment of corridors and whether they required some additional and/or alternative livelihood ventures were also determined.

An initial visit was undertaken to each selected community to see the chief/elders and to ask for an appointment. On the agreed day, the whole community was met and interacted with. Care was taken to ensure that a few individuals did not dominate the discussions. Community consensuses were sometimes through breaking the community up into various stakeholder groups and using negotiations and lobbying techniques among interest groups.

5.4.5 A reconnaissance trip to the Ivory Coast side of the border adjacent to the study area

To understand the elephant situation on the Ivorian side, a trip was undertaken between September and October 2010 to Abengorou areas in Ivory Coast (ARG, 2010). This was primarily, to obtain a current on-the-ground insight into perceived elephant movements towards Ghana and to obtain a snap-shot perception of the feasibility of corridors from that end. The forestry and wildlife officials from *Société de Developpement des Forêts* (SODEFOR), *Office Ivoirien des Parcs et Réserves* (OIPR) and *Direction de la Protecttion de la Nature* (DPN) as well as from some community people were interacted with.

5.5 Data Analysis

The final selection of potential corridor(s) was influenced by, *inter alia*, the north-south movements of elephants along the Bia river, the attitudes of the local people and geographical/ecological conditions within an area.

5.5.1 Elephant movements along the Bia River

The activities of elephants across each transect was used as an indication of elephants moving across that transects. Hence each transect was divided into 1 km bands and the index of the activities calculated to show ‘hot spot’ for movements across the transects. The number of occasions out of the six monitoring periods when elephants crossed transect was calculated to show whether movement was a regular thing or just a coincidence. These information were then showed graphically.

5.5.2 Geographical/ecological feasibility

To determine the geographical possibility for the creation of corridors between forest reserves, maps of the study area depicting the location and physical conditions of the vegetation between the reserves and width of proposed corridors was developed. Also, aspects such as distance and, population pressure (number and distribution of villages), land use practices, NTFP gathering activities were considered and scored. These were then used to undertake a suitability analysis for the establishment of corridors in the study area.

In developing the Habitat Suitability Index (HSI) model, existing data, literature, and expert opinions were combined to develop an equation or alogorithm using a small number of selected habitat variables in predicting the suitability of an identified corridor for elephants (Parren *et al*, 2002). The habitat variables included were vegetation cover, food trees cover, and availability of water (Parren and Sam, 2003). Line transects were used for assessing most of the habitat variables used in developing the model (See Chapter 4). The suitability was determined through an aggregation of Suitability Index (SI) scores for the requisite components such as food and shelter. This was then combined with the social issues in the corridor to determined its overall suitability

5.5.3 Socio-economic feasibility

The perception of the population was made clear based on answers they provided during the questionnaire administration.

Community perception was broadly classified as, importance of forest animals (e.g. elephants), benefits derive from forest reserves (sustainable utilisation), willingness to improve forest condition (e.g. tree planting), management of HECs (co-existence) and local support for elephant corridors (e.g. enthusiasm to give up land). Willingness to embrace additional and alternative livelihood ventures was also ascertained (and equated to commitment). The data were analysed using averages, percentiles, rankings and ordinary logistic regression techniques. Based on the responses (negative or positive) of the communities, scores were awarded for each perception to symbolise the importance of that particular perception in a community and the effort that would have to go into effecting a change if so required.

5.6 Results

5.6.1 Movement of elephants along the Bia River

The six monitoring trips to the study area along the transects which were laid revealed that elephants crossed both legs of the first transect (Figure 5.2). There were only some scanty activities on the eastern portion of Transect 2 which passed through the Subim FR. It was very clear that elephants did not cross the last transect towards Ivory Coast as well as those which passed through Krokosua Hills FR and Bia North FR. A more detailed presentation of each of the six monitoring visits is found in Appendix 2.

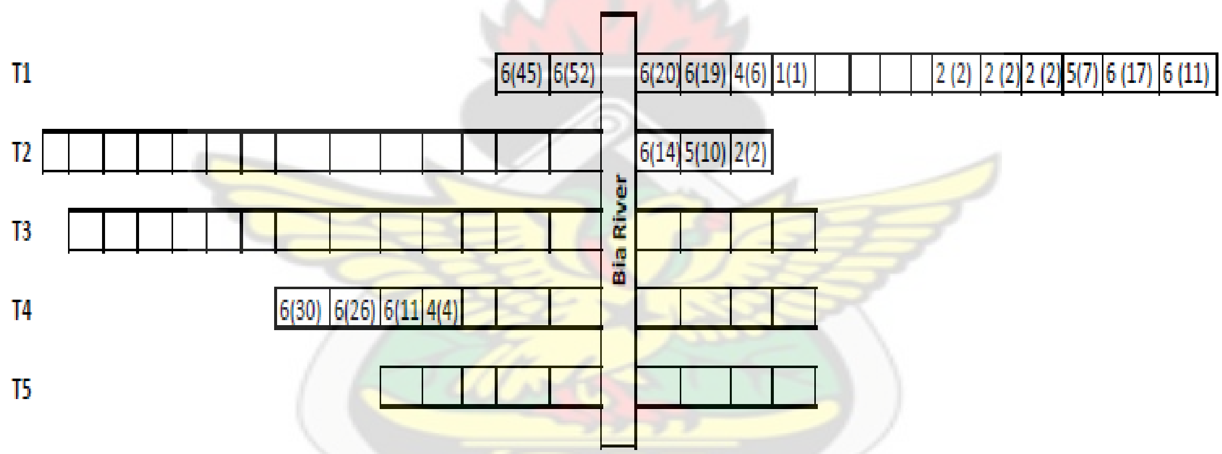


Figure 5.2 Elephant activities per km as an indication of elephant movements recorded on transects along the Bia river from the Goaso area into Ivory Coast. *Each box represents one km (The numbers outside the brackets indicate how many occasions out of six monitoring periods elephant activities were observed, while those in brackets represent the total number of activities recorded on all six occasions in that segment of the transect. Empty box means no activity was observed).*

5.6.2 Land cover changes from 1989-2003

All land cover types, with the exception of intact forest, increased in size between 1989 and 2003 (Figure 5.3). By 2003, class Intact Forest had decreased by over 60% of the original size as at 1989.

Classes open forest increased by 17%, Croplands by over 30% and Cocoa farms by about 22%. While class Built-up areas increased by about 35%, class shrubs/matured fallow increased sharply by about 290% (See Table 5.1).

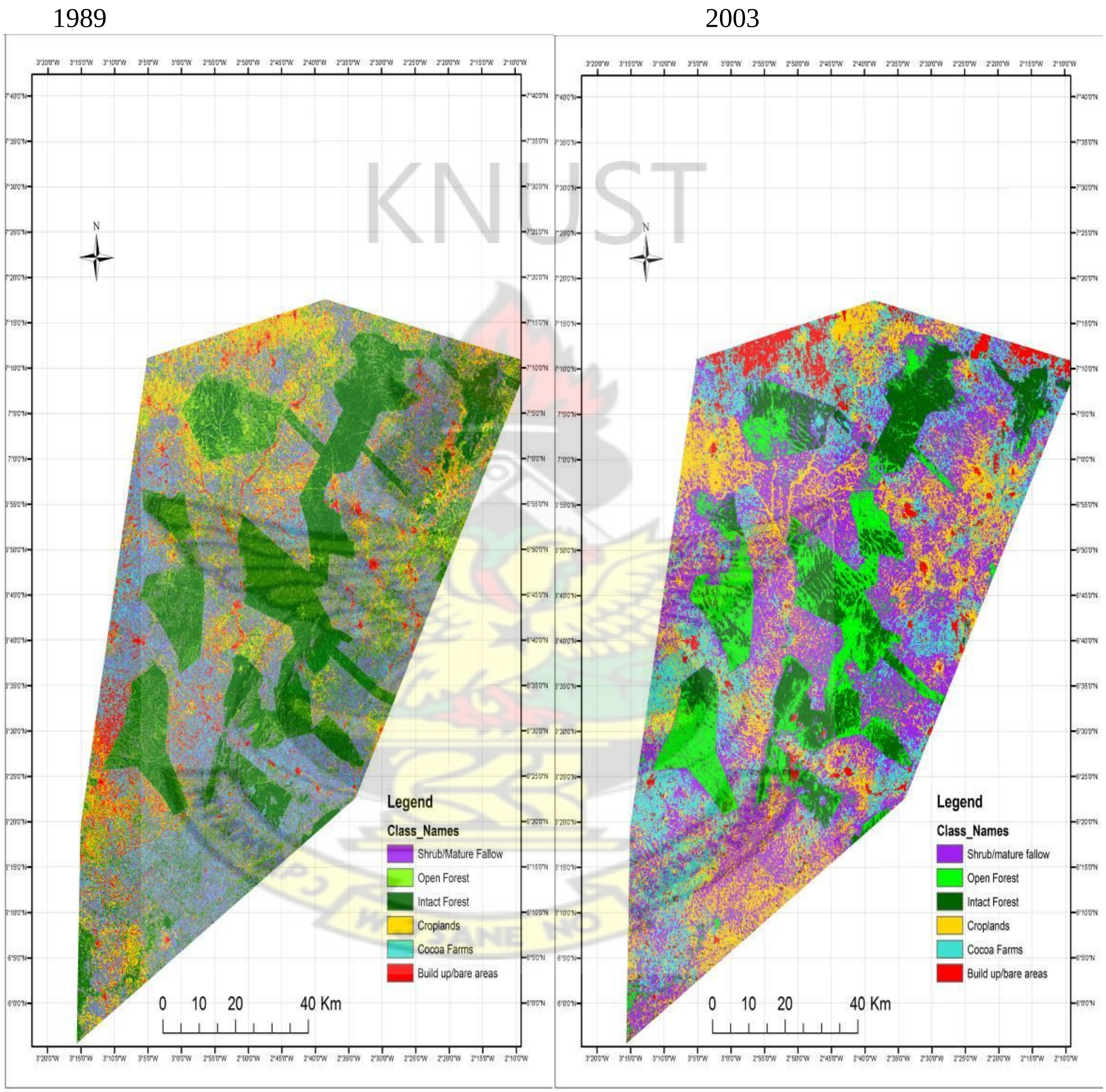


Figure 5.3 Land cover maps (a) 1989 and (b) 2003

Table 5.1 Land cover changes in the study area between 1989 and 2003

Land cover type	1989		2003	
	Area (ha)	%	Area (ha)	%
Intact Forest	205,184.60	41.3	80,980.85	16.3
Open (Degraded) Forest	83,464.92	16.8	97,375.74	19.6
Cocoa Farms	101,847.08	20.5	124,700.57	25.1
Croplands	74,025.44	14.9	96,878.93	19.5
Shrubs/ Matured Fallow	20,866.23	4.2	81477.66	16.4
Built-up/ Bare Areas	11,426.75	2.3	15,401.27	3.1

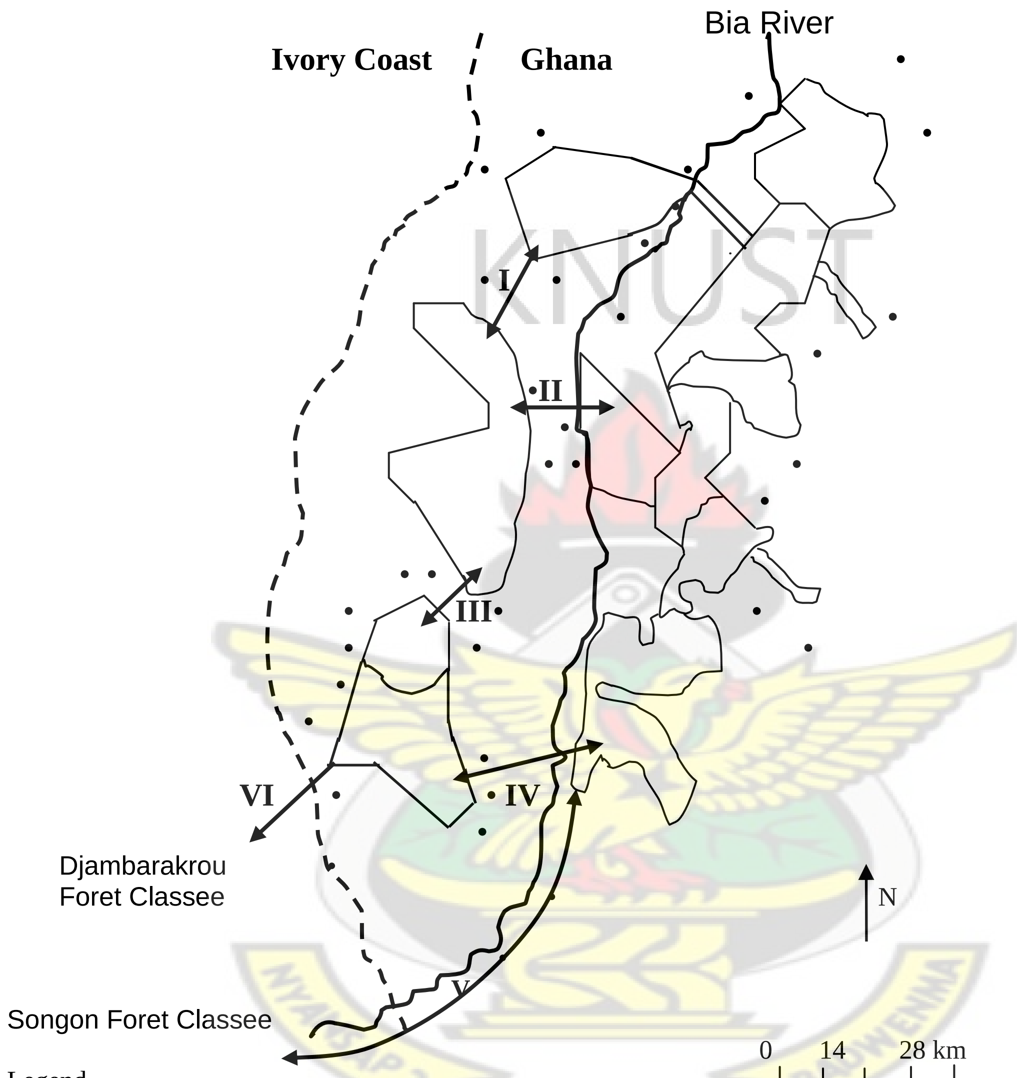
5.6.3 *Geographical/biological feasibility of corridors*

A preliminary examination of maps on the locations and physical conditions of the vegetation between reserves in the study area shows that the Bia Conservation Area and the Bia North FR are separate or isolated populations in the study area. However, the rest of the reserves are contiguous to each other and aligned in a north south manner, in the same direction as the Bia River, the only river directly connecting the forest reserves. Outside reserves, the river has virtually no forests left along its banks, as existing forest areas have been converted to agricultural fields. Extensive cultivation of cocoa along the banks of the Alafaso and Abranko streams also prevents them from being developed into corridors that might have linked Bia North to Subin FR. The boundary between forest reserves and agricultural fields is very sharp and most lands not under reservation have been cleared. Only some relic forests are left with scattered trees. The population pressure seems high (Agyare, 2010) as many villages and hamlets lay scattered throughout the whole area, especially along the Bia River. Based on the above geographical limitations, and a preliminary socio-economic feasibility analyses (see below) six possible corridors have been proposed to link specific reserves in Ghana and to the Djambarakrou Foret Classee and Songon Foret Classee in Ivory Coast (Figure 5.4).

5.6.4 Socio-economic feasibility of corridors

Views were solicited from 36 randomly selected communities (Figure 5.4, Appendix 3) within the study area. The main occupation in these communities was farming i.e. all of those interviewed were cultivators. Farms were positioned within 6 km of reserves. The major food crops are maize, cassava, plantain, cocoyam, yam, rice and vegetables with the main cash crop being cocoa. In addition to their farming, some communities near the Bia River practiced fishing as a means of subsistence. Other minor activities include hunting, gathering of NTFPs, informal trading, domestic poultry and livestock rearing. Pastoralism on the other hand was an uncommon occupation.

The major land use practice was farming (100%) and the general opinion (95%) of community members confirmed a decrease in land especially lands surrounding the reserves. Though a few communities (8%) could not give any reason for this observation, the majority (92%) of them attributed the situation to the system of farming (shifting cultivation) practiced in the communities. This practice, they explained, has caused greater pressure on the land as a result of acceleration of migrants from other regions into the Western Region in recent years (Sam, 2000). This perhaps has resulted in severe encroachment on the forest reserves resulting in a hard edge between the reserves and the surrounding farmlands. Some community members (around Bia North FR) even requested that the reserve boundary be redefined to make more farmlands available.



Legend

= Int. boundary
= Communities
= Proposed corridors

I. Mpameso FR to Bia North FR
II. Bia North to Subin FR
III. Bia North to Bia NP
IV. Bia RR to Krokosua Hills FR
V. Krokosua Hills FR, along the Bia River to Songon Foret Classee in Ivory Coast
VI. Bia RR to Djambarakrou Foret Classee in Ivory Coast

Figure 5.4: Study area showing proposed corridors to link the Goaso and Bia elephant populations with those in eastern Ivory Coast and locations of fringe communities where questionnaires were administered.

Most (75%) community members had no idea on how to improve the forest situation even though a few (25%) suggested putting a stop to uncontrolled logging practices around the reserves. Furthermore, only a small section (11%) of the entire sample of people interviewed had ever been involved in any conservation work including tree planting as a way of improving the forest condition. Nevertheless, there was a general level of awareness concerning the conservation and protection status of the reserves especially the Bia RR and Bia NP. Even though some interviewees denied the knowledge of poachers in their communities, others were ready to expose poachers if the need arose. Similarly, most of the respondents admitted to the prevalence of bush meat on the local market especially in the nearby big towns such as Goaso, Mim and Bibiani.

The general opinion among the communities (77%) showed that the existence of the reserves did not benefit them much, though a few admitted relying on it for medicines (15%) and water (8%) especially in the dry season. However, everyone agreed to the importance of wild animals in the reserves, mostly because of their value as bush meat. Furthermore, the continuous existence of the reserves was required since they believed that it represented a national heritage to be passed on to future generations and also that their existence were important for the survival of animals and as a source of revenue from tourists in the case of the Bia RR and NP. Altogether, Table 5.2 represents the perception ranking for individuals interviewed from communities that fall within various proposed corridors.

Table 5.2: Priority ranking based on community perception in 2004 for the establishment of proposed corridors

Corridor	Rank for animal / elephant importance (percentage)	Rank for benefits from reserves (percentage)	Rank for improving forest conditions (percentage)	Rank for managing crop raids (percentage)	Rank for enthusiasm to support corridors (percentage)	Average priority rank (whole number)	Corridor priority settings*
I	4 (100)	3 (56)	1 (11)	3 (67)	1 (11)	2.4	Medium
II	4 (100)	4 (100)	2 (29)	2 (29)	1 (0)	2.6	Medium
III	4 (100)	4 (90)	1 (0)	1 (0)	1 (0)	2.2	Medium
IV	4 (100)	4 (100)	3 (63)	3 (50)	3 (50)	3.4	High
V	4 (100)	4 (83)	4 (83)	4 (83)	3 (67)	3.8	V. High
VI	4 (100)	3 (50)	2 (25)	3 (56)	1 (0)	2.6	Medium

* Corridor priority settings

1. Very High (Average priority rank 3.6 – 4.0): Feasible within one year of community awareness and sensitisation
2. High (Average priority rank 3.1 – 3.5): Feasible within one year of community awareness and sensitisation
3. Medium (Average priority rank 2.1 – 3.0): Feasible after two years of community awareness and sensitisation
4. Low (Average priority rank 1.1 – 2.0): Feasible after four years of community awareness and sensitisation
5. Very Low (Average priority rank 1.0): No corridor. Probably corridors might never work except with complete evacuation of people

5.7 Discussions

5.7.1 Human dimension considerations in corridor creation

5.7.1.1 *Human pressure*

Intensive agriculture, involving an intercropping of food crops with cash crops under traditional shifting cultivation seem profitable and is the bedrock of the economy. This has resulted in an acceleration of migrants from other regions into the Western Region in recent years (Agyare, 2010), further leading to greater pressure on the land as a result of increasing human populations in the communities. This serious degradation of surrounding forest vegetation and occasional encroachment on forest reserves by farmers has culminated in a hard edge between the reserves and the surrounding farmlands (Sam, 2000). Indeed, the land pressure is so high that most lands outside the forest reserves have been converted to agriculture and many villages are scattered over the whole area (de Leede, 1994). With agriculture creeping forward, forests shrinking and migration routes becoming blocked, the elephant habitat is becoming more restricted and isolated from each other than before.

The above situation is further exacerbated by the fact that bush meat is an important source of protein in the area (Holbeck, 1998). Most of the respondents admitted to the prevalence of bush meat on the local markets, especially in the nearby big towns surrounding the reserves. It is estimated that the daily bush meat consumption per capita is about 0.18 kg, while the annual catch per hunter is about 1,050 kg worth US$1,240 (Sam, 2000). Hence, the level of poaching in the reserves is high.

Ongoing destruction and felling of trees by logging firms in most of these reserves is likely to expose more elephants to poaching pressures (Laryea, 2006) since logging roads created not only provide easy access to elephants but also reduces most of the habitat used by elephants.

5.7.1.2 *Socio-economic feasibility*

The success and sustainability of any conservation work largely depends on the communities affected, hence possibilities (feasibility) for establishing elephant corridors will be affected by how surrounding communities perceive the efforts. However, under earlier discussed conditions (extent of HECs, high human pressure on land), it is difficult to expect local communities (especially victims of persistent elephant attacks) to have a positive attitude towards elephants, the reserves or conservation authorities (Laryea, 2006). The friction between nature conservation and farmers keeps increasing. Most farmers did not see the advantage of conserving elephants by creating corridors between reserves. They saw this idea as a way of claiming their lands from them which will in turn provide more lands to elephants to further aggravate the crop raiding situation in the area. However, it has also been established that a good sensitization programme would to some extent erase this notion (PADP, 2009).

5.7.2 Biological and spatial considerations in corridor creation

The Goaso population resides in a large area formed by eleven reserves. The density of elephants seems to have been negatively impacted by the close proximity of human presence since de Leede's work in 1994. However, the Bia population live in a smaller and isolated habitat. For the benefit of the entire Goaso – Bia elephant population and their long-term viability, it is better to promote the exchange of genetic material between them and the neighbouring population in Ivory Coast. However, taking into consideration factors such as elephant distribution, distance to be covered by corridor, population pressure, land use intensity, areas of forest cover and general perception of local communities, the need to reclaim land and establish corridors to link these reserves, as proposed by Parren *et al*. (2002) will be challenging. Farmers may be adamant in contributing to the execution of such a corridor network area, possibly because of the fear of loosing their entire lands or the possibility of having to deal with escalating HECs in the future. Another restriction is the unavailability of many major rivers, which could have served as natural corridors in linking several reserves. However, if these reserves are secured, they could provide a link to some populations like the Songon Foret Classee in eastern Ivory Coast. The Dadieso FR, which probably forms a suitable habitat for elephants (Sam *et. al*., 2003) could be included.

Parren *et. al*. (2002) have suggested the payment of compensation for loss of land required for the establishment of corridors. For instance, compensation would need to cover at least three production years for cocoa since cocoa produces a crop only at three years of age. Perhaps if this was suggested to farmers who were interviewed, some would have been more amenable to the idea.

Corridors should be designed to attract forest elephants into them, and important characteristics to take into consideration are the presence of food plants, availability of water, and the size and structure of the corridors (Parren *et al*., 2002). An overview of the rather gloomy conditions pertaining in the various proposed corridors is presented below.

1. Mpameso FR to Bia North FR

The presence of elephants in both the Mpameso and Bia North FRs provides an opportunity to link these reserves. The shortest distance between them is approximately 9 km. Since the Bia North population seems very small and isolated, a potential corridor linking them to the Mpameso population will promote genetic viability. Bia North is also important in joining the northern Goaso reserves to the Bia NP. However, the region between Mpameso and Bia North is intensively being used for agriculture and the population pressure is very high. The absence of major watercourses in the area makes linking the two reserves along waterways also difficult. As the land pressure is very high in this region, the enthusiasm of farmers to forfeit part of their land to support the creation of elephant corridors was very low making the general potential for creating a corridor here very low.

II. Bia North to Subin FR

The distance between Bia North and Subin FRs is approximately 11 km. The presence of elephants in both reserves also provides a good reason to link these reserves, though both populations may consist of a few elephants. Because of the not too distant Bia River and a number of streams, land pressure in this area is very high and has been used extensively for farming purposes. Notable among these streams are the Alafaso and Abranko whose riverbanks would have promoted the establishment of corridors. However, almost all trees along their banks have been cut and the land used for farming, especially, cocoa. With over 20,000 ha of intact forest being degraded annually it was not surprising to observe why the enthusiasm of farmers to forfeit part of their already overburdened land to support the creation of elephant corridors was very low. The overall potential of a possible corridor here is low especially when no elephant activities were noticed on six monitoring trips on two transects that connected the Bia North FR with the Bia river.

III. Bia North to Bia NP

A corridor between Bia North and Bia NP would have been the shortest (about 4 km long) and hence the most feasible in terms of distance. However, there is a very high pressure on land and there are no major rivers or streams that link up these two reserves. Furthermore, until very recently, there has been no presence of elephants in the Bia NP making the establishment of this corridor unattractive. The potential for a successful corridor here was therefore low. However, it must be noted that though at the initial stages of the study, farmers expressed their unwillingness to re-forest or sacrifice part of their lands for corridor establishments, after a sensitization programme between 2007 and 2009, this has changed dramatically and a (River Asuopri) CREMA has been established in a section of this corridor. Again, gradual movements of elephants into the Bia NP are being observed, consequently boosting the potential success of the corridor. This corridor therefore requires further examination.

IV. Bia RR to Krokosua Hills FR

The least distance between Bia RR and Krokosua Hills FR is approximately 6 km. De Leede (1994) mentioned some WD staff to have reported of elephants crossing from Bia RR to Krokosua Hills FR. This would have provided a good opportunity to connect these two reserves. However, all the surveys as well as transects which were monitored showed no elephants presence in Krokosua Hills Forest Reserve,making one wonder whether such a corridor would be useful. However, it must be noted that in the midst of the high land pressure, majority of interviewees (farmers) in the area were willing to cooperate with a future corridors establishment programme; the perception of farmers within the region ranked high (second) in the corridor priority settings. Relying on this quality, the Wildlife Division through its Community Forest Biodiversity Programme, funded by the French Government has within two years mobilised several communities in the area to sustainably manage their natural resources through the CREMA process (this concept will be discussed later in this document). There are therefore two CREMAs currently operating within this corridor. These therefore urgently need to be supported to eventually serve the purpose of contributing to an elephant corridor. As there are a lot of elephants in the southeastern part of the Bia CA, some intensive management intervention in the landscape could be employed to 'bait' elephants into Krokosua from the former.

V. Krokosua Hills, along the Bia River to Songon Foret Classee in Ivory Coast

The creation of an elephant corridor along the Bia River was most favoured by farmers in this region. They were prepared to plant trees along the riverbanks in an effort to widen the river belt (corridor). It is worth stating that, the farmers living along the vicinity of the river expressed their readiness to help protect river, possibly because it is their most reliable means of water supply. They admitted having noticed a significant consistent reduction in the volume of water in the river as well as the deterioration of its quality. Support of farmers within this corridor ranked highest in the corridor priority settings. This positive attitude of farmers, the relatively lower population pressure and according to Parren *et al*. (2002), the riverbanks on the Ivory Coast side is already better forested making this corridor an important option. The greatest setback, however, was that no signs of elephant use of this whole area was detected; hence one could have a well vegetated landscape as a corridor, but with no elephants using it. As in the case of Corridor IV, elephants would have to be "baited" from both the Mpameso (Goaso) population and/or the Bia population for a successful corridor. Furthermore, ARG (2010) suggest that the elephants in the Sogan-Yaya-Mabi complex in Ivory Coast (See Appendix 4) probably forage up to the frontier.

VI. Bia RR to Diabarakrou Foret Classee in Ivory Coast

There are a lot of elephants in BRR which are usually undertaking crop-raiding in nearby fields. Hence a corridor between Bia RR in Ghana and Djambarakrou Foret Classee in Ivory Coast would have provided the shortest means of connecting the Ghanaian elephant populations with their Ivorian counterparts, hence the most feasible in terms of distance. However, there are no major rivers or streams in the area and the pressure on land is also high. A lot of the people here are migrants who only care about their farms. Thus, community support for re-afforestation or corridor establishments is low. If there was a lot of will-power in the forestry sector, this corridor could be established, as part of it is an encroached forest reserve (Sukusuku FR) and will only require ejecting the illegal settlers or letting them leave over a period of time (ARG, 2010). The Djambarakrou FC on the Ivorian side is also heavily encroached and has not been used by elephants for more than a decade. However, the forestry authorities of Ivory Coast have a plan for rehabilitation and are ensuring that no new buildings are constructed nor farms established in the reserve anymore (ARG, 2010). Indeed, the 2003 satellite imagery showed some improvements in the habitat there. A landscape approach (AfESG/IUCN, 2003) to corridors will be more appropriate here than a migratory corridor. However, this would only succeed after that reserve is restored and the space on the Ghana side (i.e. the area immediately next to the western boundary of Bia RR) is secured.

5.8 Conclusions

The extermination probability of a given species depends on the available habitat and its population size (Caspary, 1999). For the under 200 elephants recorded in this study and spread across their discontinuous range in Bia and Goaso, one can rehash Barnes's (1999) question as to whether there is a future for elephants in West Africa, and for that matter the Bia-Goaso area. No matter the answer one may give, one faces the grim reality that the elephant population and for that matter the over two-third others found throughout West Africa, have little chance of long-term survival if immediate efforts are not made to reconnect their fragmented landscapes and ensure gene flow.

Although, Sukumar (1993) mentioned that about 200 elephants are needed to avoid the risks of demographic and environmental stochasticity and to ensure a high probability of survival over the next century, Barnes (1999) noted that the fragmentation of West African elephant populations has occurred quickly, within the last few generations, implying that they may not have lost much genetic variation yet. It may therefore be possible to prevent such loss through the establishment of wildlife corridors which have been widely advocated in conservation planning as a way to help reduce effects of habitat fragmentation and counter the current tendency for population isolation (Bennett, 1990; Saunders and Hobbs, 1991; Laurance and Laurance, 1999).

In applying this, a combination of migratory corridors and landscape-level corridors (e.g. Community Resource Management Areas (CREMAs)), can be used as a means for increasing the size of the habitat and ultimately help reduce habitat fragmentation. This study has shown that there are two elephant populations in the study area which are not interacting with each other anymore. Also, the north-south movement of elephants between Ghana and Ivory Coast is ceasing as there is close to 40 km gap between the elephants across the two frontiers. However, of the six corridors identified and analysed in the study area, corridors IV and V appear to be most potentially feasible, requiring immediate attention with VI and to a lesser extent III, being possible in a medium to long term. It must also be noted that these conclusions are only based on community perceptions and general geographical analysis and that some more information may be needed before undertaking any corridor implementation programme.

CHAPTER SIX

KINDS OF HUMAN-ELEPHANT CONFLICTS AND LEVEL OF CROP DAMAGE BY ELEPHANTS IN BIA-GOASO FOREST ENCLAVE

6.1 Introduction

Human-elephant conflict is a problem that many parks and reserves across Africa experience. However, this problem is especially severe in West Africa where isolated populations of elephants often live adjacent to areas of dense Agriculture (AfESG, 1999, Sukumar, 1990). As human populations increase and elephant populations become more concentrated in isolated protected areas and remnant forest habitats, these conflicts are almost certain to escalate (Barnes *et. al.*, 1995), making this problem one of Africa's most challenging problems (Hoare and Du Toit, 1999).

Crop damage by elephants is one of the serious multifaceted management problems that the wildlife Division faces in Ghana (Sam, 2000). Although crop damage by elephant populations around the study area is serious, there has not been much systematic data gathering attempts to appreciate the issue including understanding the elephants requirements (and preferences) around the area. The study therefore aims to undertake a social survey and also utilize the measurements taken on ravaged farms to gather data to contribute to the understanding of the characteristics of human/elephants conflicts (HEC) in the study area. This will help park management to effectively tackle the problem.

6.2 Research Objectives and Questions

a) Objectives

The specific objectives of this study are to:

i) determine the types of human-elephant conflict that occur in the study area

ii) estimate key crop-raiding areas and the severity of the damage around Bia Conservation Area

iii) ascertain which crops and crop-parts are mostly destroyed by elephants around BCA

iv) establish the factors that promote crop depredation by elephants around BCA

v) determine which elephant groups indulge in crop-raiding

b) Research questions

The study therefore sought to answer the following research questions among others

- ✓ What plants or crops are mostly damaged by elephants?
- ✓ Which parts of the plants are damaged by elephants?
- ✓ At what stage of the plants growth do they get damaged by elephants?
- ✓ Why are some farms raided and others not?
- ✓ How far do elephants travel to raid farms?
- ✓ What kinds of elephants (family groups, bull groups or individuals) raid crops?

6.3 <u>Hypotheses</u>

- ◊ Ho = Human-elephant conflicts occurred all around the conservation area.
- ◊ Ho = Distance from farm to the reserve is a predictor of crop raiding
- ◊ Ho = A significant proportion of farmers in the area are affected by damages.
- ◊ Ho = For those who suffer crop damage the risk to an individual farm is high
- ◊ Ho = Elephants preferred crops in their matured stages.
- ◊ Ho = The risk of crop raiding increased as the number of different crops on the farm increases.
- ◊ Ho = Only bull groups undertake crop-raiding
- ◊ Ho = the distribution of elephants immediately inside the reserve is a predictor of crop-raiding outside the reserve

6.4 Methods

To understand the Human-elephant situation around the study area, both the historical and current crop raiding situations were determined

6.4.1 Social survey of human-elephant conflicts

A social survey of human-elephant conflicts was undertaken through the administration of questionnaires by interviewing 10 randomly selected members of 36 communities within 5 km of the reserve boundaries. Issues investigated included the type of conflicts, how long it had been occurring, the frequency as well as extent (spatial) of damage. For crop-raiding, other information gathered included crops usually raided, crops spared and the time of the year raid occur. Thus, with this approach, qualitative historical and current information on the distribution and frequency of crop raids around the study area were gathered (Sam *et. al.*, 2003).

6.4.2 Field assessment of elephant damage

An elephant damage report form developed by the African Elephant Specialist Group was used to assess current crop raiding activities (Appendix 5). The geographical coordinates of raided farms were recorded with a handheld Geographical Positioning System (GPS; Garmin 12XL). By plotting relative positions on a map of the study area, we determined distance of raided farms from the nearest forest boundary.

There are several villages within 5 km from the boundary of the CA. There are also 15 designated camps manned by wildlife personnel for the protection of the CA. Farmers whose fields are damaged report the incidence to the nearest wildlife camp.

Every damaged farm was visited for verification. The following information most of which are found in an elephant damage report form developed by the African Elephant Specialist Group and used to assess current crop raiding activities (Appendix 5) were gathered at the site of damage: the name of the farmer, date of raid, location of field, crop types on fields, those damaged and their stage of maturity.

Other types of damage, such as barns, stored water as well as heaped harvest and also, the crops in the neighbouring fields were also noted. The size of the fields as well as the proportion of field damaged was then measured. A stem count of each damaged crop was conducted. If there was a mixture of crops the distribution of the different crops within the field was noted. If the farmer saw the elephants, the number was noted. The period of the day that the raid occurred was also reported.

6.4.3 Determining elephants involved in crop-raiding

Whenever any clear hind footprints of elephants were found on fields, the length of each footprint was measured with a tape measure. Also, the circumference of any intact elephant boli found on ravaged farmland was measured. These measurements were used to determine the age and sex groups of problem elephants.

6.4.4 Comparing dung-pile density immediately inside and outside the Bia Conservation Area

Twenty transects were randomly placed around the edge of the Bia Conservation Area in 2004. Each transect was 4 km long and perpendicular to the forest boundary. Half of each transect lay inside the forest and half lay outside. The number of elephant dung-piles was recorded on the 2 km segment inside the park and in the 2 km segment outside, using the distance method. The experiment was repeated in 2007. The essence of this experiment was to determine whether the distribution of elephants immediately within the conservation area affected their utilization of area and therefore resources outside it.

6.5 <u>Data Analysis</u>

Regression models were used to determine the significance of the relation between number of raids and sizes of farms, frequency of raid and the nearness of farm to park boundary. The crop raiding incidents for a particular area were also examined, at the village level. For this level of analysis, the data for all raids within a common village were combined and related to the total area of land under cultivation. Hence the number of raids that a village suffered was evaluated in relation to the total area of land under cultivation in that village.

By plotting relative positions on a map of the study area, distances of raided farms from the nearest forest boundary were determined. The data was then analysed by relating the total number of raids in a particular village to the mean distance of the raided farms from the nearest reserve boundary line. A further examination was undertaken on the crop raiding incidents for a particular area i.e. at the village level. For this level of analysis, the data for all raids around a common village from which farmers reside were combined and related to the total area of land under cultivation. Hence, the probability of suffering a raid was evaluated in relation to the proportion of land under cultivation in that area. Secondly, the data was analysed by relating the total number of raids in a particular area to the mean distance of farms to the nearest reserve boundary line.

The data was further analysed at two more levels. First, the crop raiding incidents for a particular area was examined in relation to the total number of crop species planted, and secondly, the total number of raids recorded for a given area was related to the type of crop species planted.

Extent of damage was scored for raided crops based on index of damage developed by Hoare (1999). The damage score is the sum of the age score of crop (1 = seedling, 2 = intermediate, 3 = mature), the quality score (1 = poor, 2 = medium, 3 = good) and the damage category (1 = <5% of farm area damaged, 2 = 6 – 10 %, 3 = 11 – 20%, 4 = 21 – 50%, 5 = 51 – 80%, and 6 = >80% of farm damaged).

6.6 Results

Destruction of water sources and farm barns were not reported as serious human-elephant conflict issues. However, most of the interviewees (ca. 86%) mentioned farm damage as the major conflict issue within the study area so the results presented in this section are all based on this.

6.6.1 Severity of crop raiding

Crop raiding in the entire study area is a serious problem and it occurs throughout the year. However, majority (68%, n=360) of community members interviewed (except around the Bia RR and Mpameso FR during the rainy seasons) had not seen or had any physical encounters with elephants within the past six years. They also had no idea whether elephant numbers had increased or not. About half (n=360) of the farmers interviewed were employing different kinds of traditional deterrent methods of driving away elephants from their farms of which noise making (beating of metallic objects) and firing of guns and carbide bombs were most prominent. However, noise making alone was not very effective unless combined with other minor methods like fencing options, burning of car tyres and setting up fires in the night. It must be noted that in the wake of all these traditional ways of deterring elephants, the majority of farmers (72%) were afraid for their lives and had usually relied on the WD guards to drive raiding elephants back to the reserves.

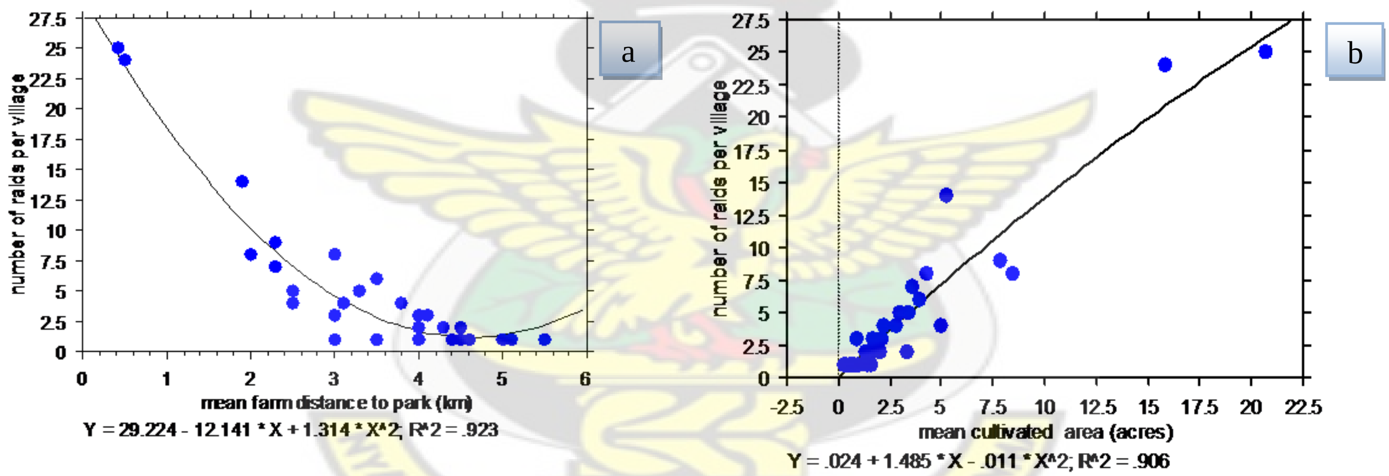
A Kruskal-Wallis one-way analysis of variance showed a distinct yearly difference in the distribution of raids ($H=7.914$, $DF=2$, $P<0.05$). Generally, elephant crop damage is low in November and by December has reached minimal levels. However, crop damage may start from April and become severe in June, and may continue steadily till September.

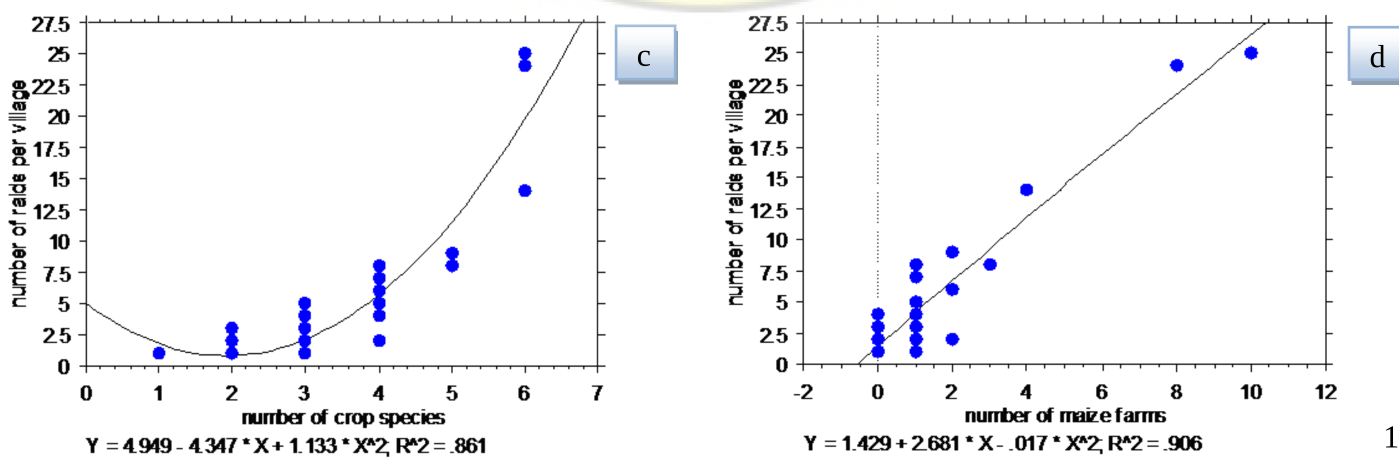
Within the study period, 131 farmers (from 32 villages) had their farms experiencing a total of 152 raids around the Bia Conservation Area alone. Some detail information on farms of 36 selected farmers is presented in Appendix 6. Mean distances of cluster of farms in villages to reserve boundary ranged from 0.41 km to 5.1 km, with the average being 3.5 km. The mean size of cluster of farms at village level was 3.4 acres with the range between 0.3 to 20.7 hectares. Of the total land under cultivation 0.006% was destroyed through crop-raiding. The mean farm damage to a farmer was about 46%, with the range between 14 – 93%. There was about 14% chance that when a farm was raided it would be visited again.

There was no significant relationship between number of raids and sizes of farms ($r^2=0.057$, $P>0.05$, NS) or the nearness of farm to reserve boundary line ($r^2=0.102$, $P>0.05$, NS). However, the number of raids registered in an area was inversely influenced ($r^2=0.923$, $P<0.0001$) by the mean of their distances to the nearest reserve boundary line (Figure 6.1a).

In Figures 6.1b, a significant relationship is observed between number of raids and mean cultivated area (acres) ($r^2=0.906$, $P<0.0001$). That is, the larger the area cultivated, the more damage is inflicted on it. Also, figure 6.1c indicates that the more the combination of species on a farm the more it attracts elephants ($r^2=0.861$, $P<0.0001$), There was no significant interaction between number of raids per village and number of pineapple farms (r^2=0.022, P>0.0001) or number of banana farms (r^2=0.001, P>0.0001). Similar patterns were observed between number of raids and number of sugarcane farms (r^2=0.001, P>0.0001) and number of vegetable farms (r^2=0.020, P>0.0001).

In contrast, Figures 6.1d, 6.1e, 6.1f, 6.1g and 6.1h show significant relationships between number of raids per village and numbers of farms of five other crop species. These are numbers of plantain farms (r^2=0.911, P<0.0001), maize farms (r^2=0.906, P<0.0001), cassava farms (r^2=0.820, P<0.0001), cocoa farms (r^2=0.782, P<0.0001) and yam farms (r^2=0.653, P<0.0001) (Figure 6.1a-h).





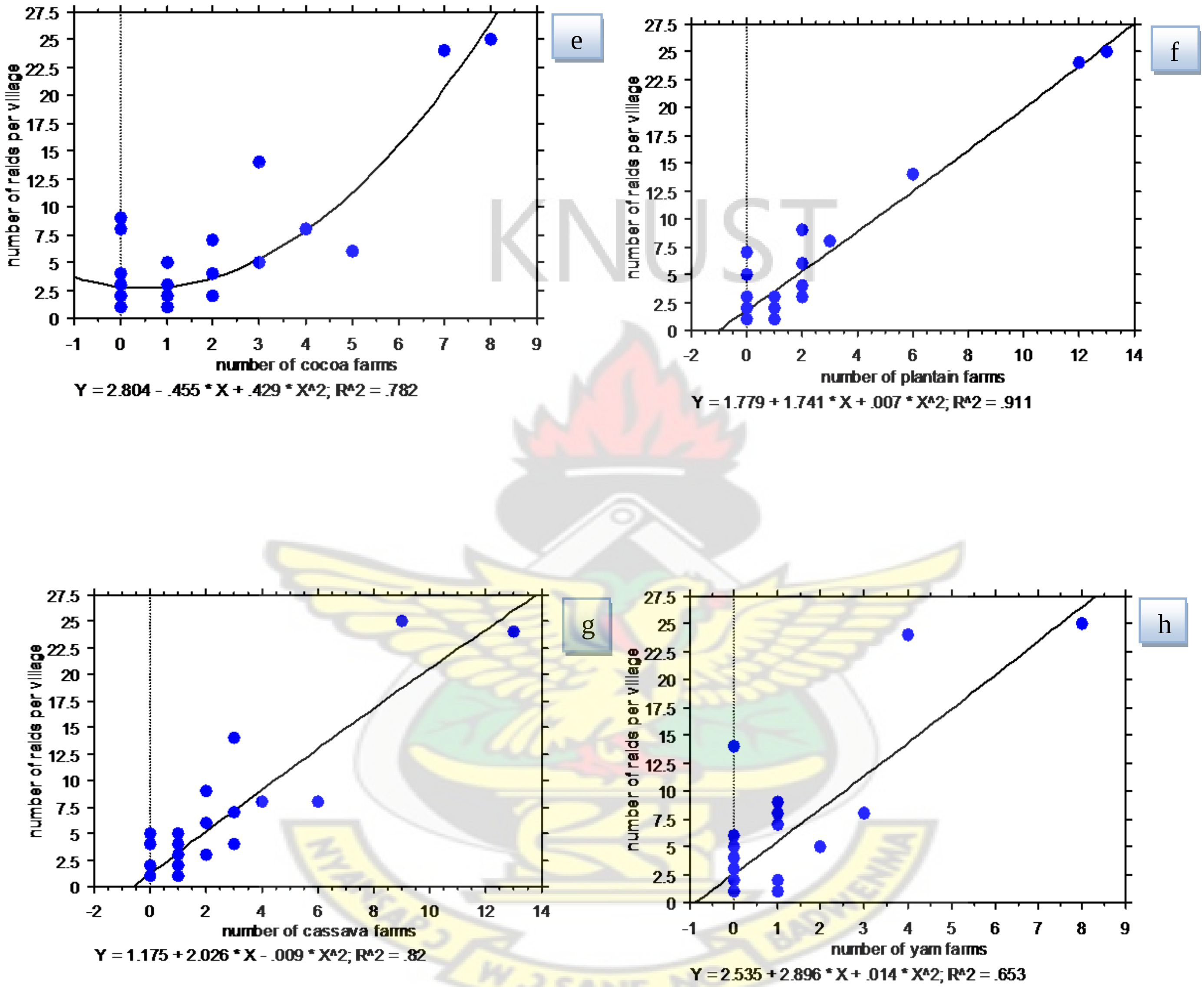


Figure 6 1a-h: Relationship between number of raids registered per village and the mean of their distances to the nearest reserve boundary line, the mean cultivated area, and the food crops that were significantly correlated (P<0.00001).

Farming in the study area involved seasonal, rain-fed subsistence agriculture. Cassava, closely followed by Plantain and Cocoa were the most raided crops (24%, 23%, and 21% of crops raided respectively). Maize and yam followed in the proportions of 14% and 11% of raided crops. Other crops which were eaten by elephants included cocoyam, pineapple and vegetables. Crop raiding was largely targeted at crops that were mostly matured (ca. 82% of total number of times crops were raided) (Table 6.2).

Table 6.2: Stages of growth of raided crops by elephants in BCA

Crop	Frequency of crops raided	Frequency in mature stage	Frequency in intermediate stage	Frequency in seedling stage
Maize	44 (15)	43 (19)	1 (2)	0 (0)
Yam	29 (10)	14 (6)	15 (27)	0 (0)
Cocoa	62 (21)	56 (23)	6 (11)	0 (0)
Cassava	73 (24)	57 (23)	16 (29)	0 (0)
Plantain	70 (23)	62 (26)	8 (15)	0 (0)
Cocoyam	8 (3)	0 (0)	8 (15)	0 (0)
Banana	6 (2)	5 (2)	1 92)	0 (0)
Vegetables	2 (1)	2 (1)	0 (0)	0 (0)
Pineapple	3 (1)	3 (1)	0 (0)	0 (0)
Sugarcane	1 (0)	1 (0)	0 (0)	0 (0)
Total	**298**	**243**	**55**	**0**

Numbers in brackets are percentages………………………………

Table 6.3: Quality of damaged crops in farms raided by elephants

Crop	Number of raids (Percent)	Number of raids (Percent) of crops of good quality	Number of raids (Percent) of crops of medium quality	Number of raids (Percent) of crops of poor quality
Maize	44(15)	41(20)	3(6)	0(0)
Yam	29(10)	24(11)	5(10)	0(0)
Cocoa	62(21)	45(21)	8(16)	9(23)
Cassava	73(24)	32(15)	21(43)	20(49)
Plantain	70(23)	53(25)	7(15)	10(25)
Cocoyam	8(3)	2 (1)	5(9)	1(3)
Banana	6(2)	6(3)	0 (0)	0 (0)
Vegetables	2(1)	2(1)	0 (0)	0 (0)
Pineapple	3(1)	3(1)	0 (0)	0 (0)
Sugar Cane	1(0)	1 (0)	0 (0)	0 (0)
Total	**298**	**209(70.1)**	**49(16.5)**	**40(13.4)**

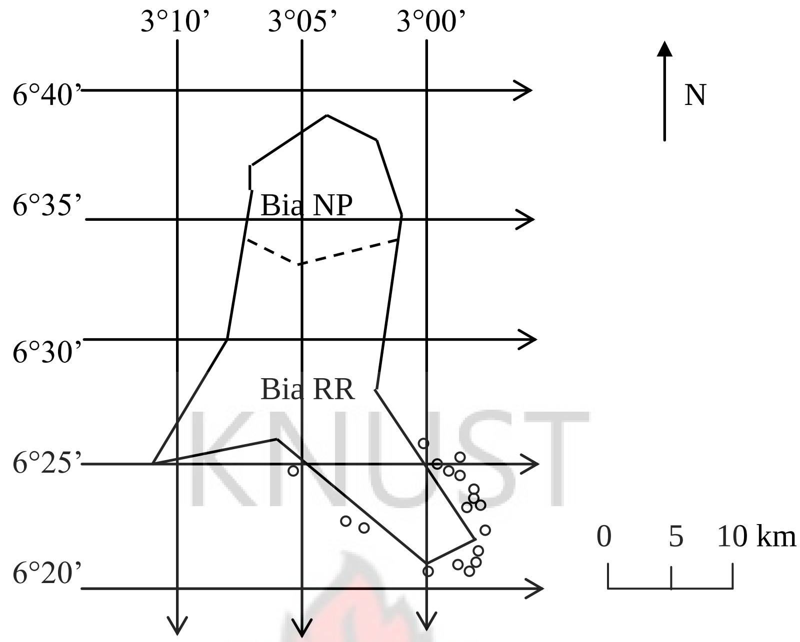
Numbers in brackets are percentages………………………….

Table 6.4: Damage score for crops raided by elephants

Crop	Age score	Quality score	Damage category	Damage score*	Interpretation
Cocoa	3	3	4	10	High and severe
Plantain	3	3	5	11	High and severe
Maize	3	3	5	11	High and severe
Cassava	3	2	5	10	High and severe
Yam	2	3	4	9	High and severe
Cocoyam	2	2	1	5	low and non-severe
Pineapple	3	2	2	7	Medium
Banana	3	3	2	8	Medium
Vegetable	3	3	1	7	Medium

Damage score was scaled from 0 to >9 (integers only). Scores ≤5 were interpreted as low and non-severe, scores from 6 – 8 were medium damage and scores ≥9 were interpreted as being high and severe.

Raiding was largely targeted at crops that were of good quality (ca. 70% of total frequency of crops raided) (Table 6.3). It seems that total crop loss by farmers whose farms border the south and south-eastern boundary line of the Bia RR, may be the greatest because of the highest (72%) reported cases of crop raids (Figure 6.2) and highest density recorded for elephants in the whole study area.



Legend

o = **Crop raiding sites**

Figure 6.2: Distribution of crop raiding incidences around the Bia Conservation Area. *A spot could be more than one farm.*

6.6.2 Elephants involved in crop raiding

6.6.2.1 Actual sightings

A bull elephant was found in farms between Boundary Pillars (BP) 81-82, 70-71 as well as 64-65 in 2004. On all occasions, it was not clear whether or not it was the same elephant. Similarly, single bull elephants were found either thrice or twice in each of 2005, 2006 and 2007 (Table 6.5). A family group of 6 elephants with 2 calves was seen four times in various farms in 2005. This group could be identified because one was injured in the leg. Also, one had a broken tusk so the group was easy to identify. On five occasions, bull groups of four (4) were recorded in 2006, but only once in 2007. A bull group of three was reported between BPs 34-35 in 2004. A similar group was observed twice between BP 19-20 and also 24-25. It could not be determined whether it was the same group. In each of the four years, another bull group of four was also encountered up to four occasions in farms between Pillars 349-50. Table 6.5 provides details of elephant groups observed in crop raiding in each year between 2004 and 2007.

Table 6.5 Groups of elephants and the number of occasions seen in farms per year.

Year	**Type of Elephants group**					**Total Number of elephants involved**
	1 Bull	**3 Bulls**	**4 Bulls**	**Family of 6**	**Family of 7**	
2004	3	1	4	0	1	15 – 29
2005	3	2	3	4	0	14 – 27
2006	2	5	1	0	2	15 – 35
2007	3	1	2	1	1	21 - 27

Based on the above Table 6.5, it is estimated that at the least, between 14 and 35 elephants were involved in crop damage in each year around BCA from 2004 to 2007. This is likely to be lower than the actual figure since not all raids were witnessed by people.

6.6.2.2 Elephant footprints and dung measurements

In all the four years, clear hind foot prints and intact dung boli were found and measured in the farms. On the whole 41 hind footprints were measured in 2004. Twelve footprints were below 25 cm, representing infants. The largest footprints were between 35 to 39 cm, forming over 40% of all the footprints measured in that year (Table 6.6).

Table 6.6 Footprints and dung measurements of crop-raiding elephants

Footprints					Dung Boli				
Footprint	**No. of Footprints**				**Dung Bolus**	**No. of Boli**			
Length (cm)	**2004**	**2005**	**2006**	**2007**	**Circumference (cm)**	**2004**	**2005**	**2006**	**2007**
<20	6	3	8	2	<20	5	8	8	6
20 – 24	6	9	12	17	20 – 24	4	8	10	12
25 – 29	8	5	10	9	25 – 29	7	7	11	9
30 – 34	2	7	12	7	30 – 34	17	12	10	9
35 – 39	17	11	23	21	35 – 39	6	8	12	6
40 – 44	2	1	1	2	40 – 44	5	12	12	0
45 – 49					45 – 49				
>50					>50				
Total	**41**	**36**	**66**	**58**	**Total**	**44**	**55**	**63**	**42**

In each year, between 21% and 43% of dung boli measured were less than 25 cm in circumference, representing elephant calves less than three years old as detailed in Table 6.6 above.

6.6.3 Elephant distribution versus crop-raiding

In 2004, the number of dung-piles recorded outside the forest (y) was significantly related to the number recorded on the transect segments inside the forest (x):

$$y = -0.07065 + 0.03351x + 0.04801x^2$$

$$r^2 = 0.9333,\ F = 118.88,\ df = 2{,}17,\ p < 0.0001$$

This relationship was rather a curvilinear one (Fig. 6.3).

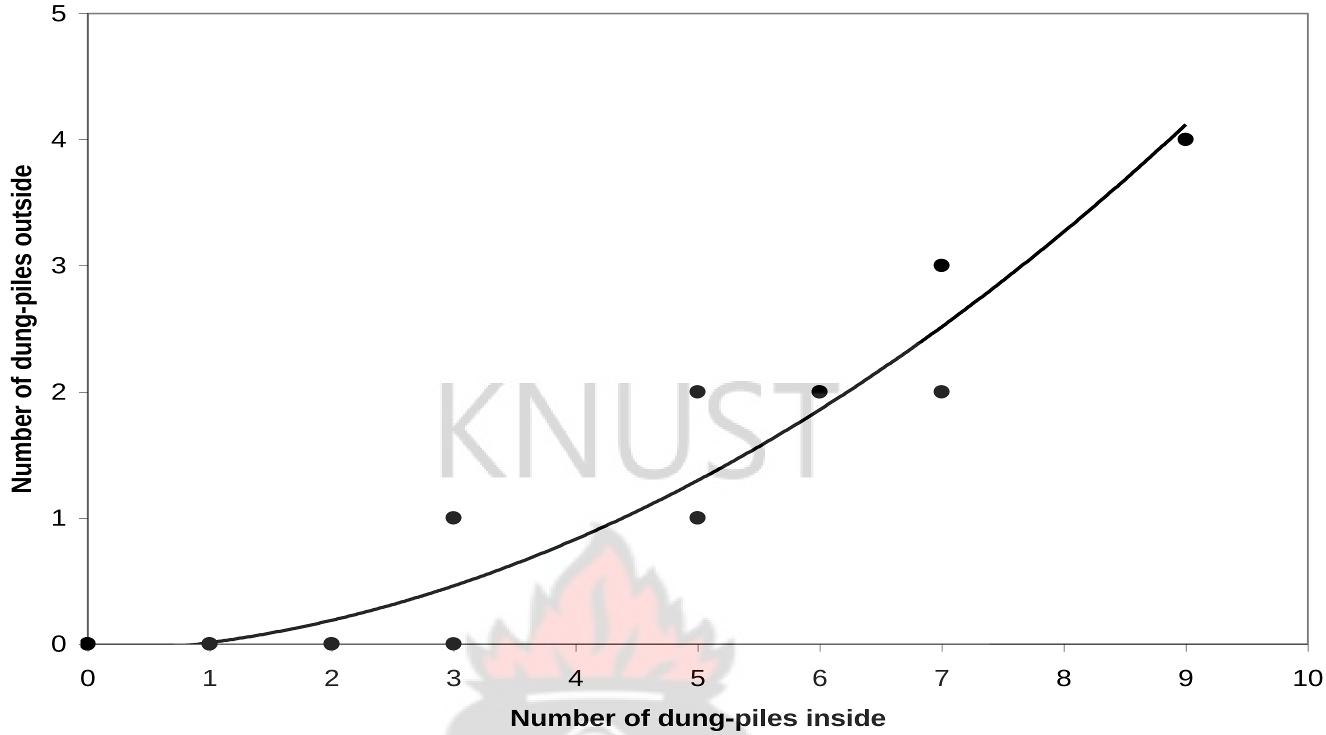


Fig. 6.3: The relationship between number of dung-piles outside (vertical axis) against number of dung-piles recorded on the transect segment inside the forest (horizontal axis) in 2004. $y = -0.07065 + 0.03351x + 0.04801x^2$ *($p < 0.0001$).*

Similarly, in 2007 the relationship is described by the equation:

$$y = 0.04844 - 0.16887x + 0.07265x^2$$

$$r^2 = 0.7761,\ F = 29.46,\ df = 2,17,\ p < 0.0001$$

This too is a curvilinear relationship (Fig. 6.4).

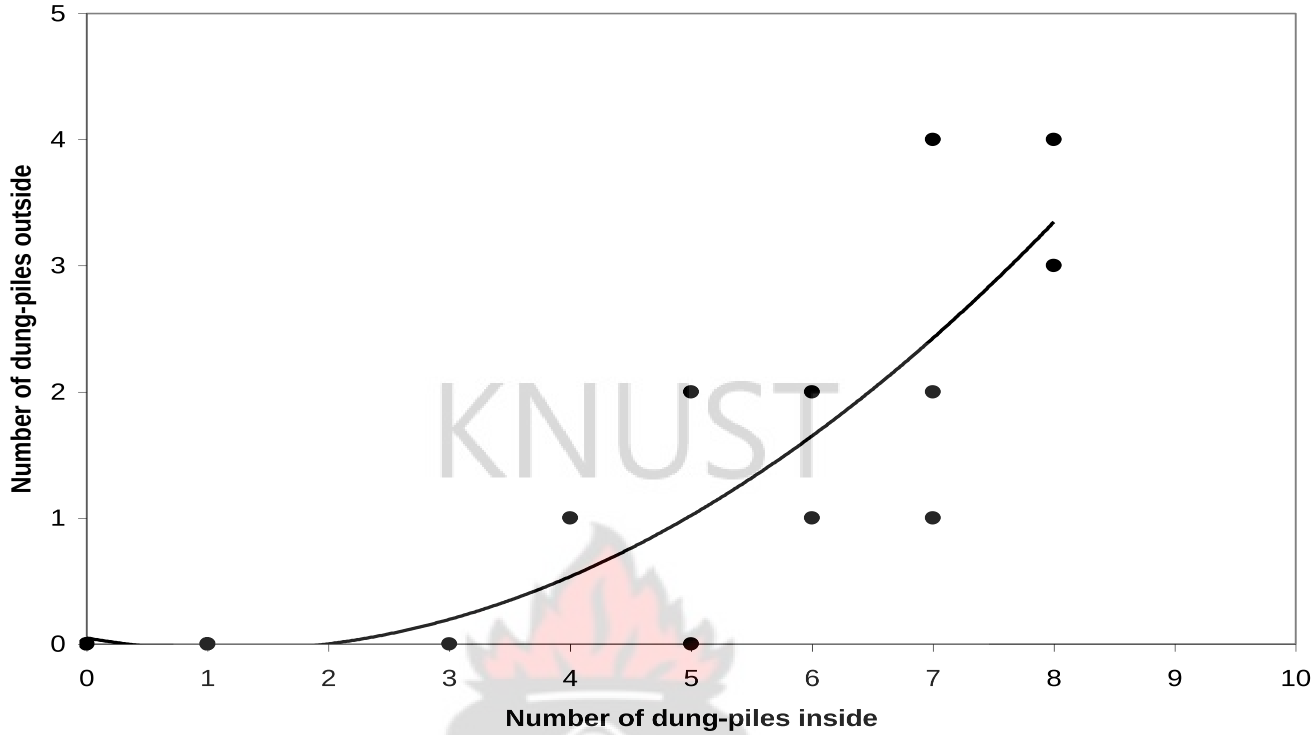


Fig. 6.4: The relationship between number of dung-piles outside (vertical axis) against number of dung-piles recorded on the transect segment inside the forest (horizontal axis) in 2007. $y = 0.04844 - 0.16887x + 0.07265x^2$ $(p < 0.0001)$.

6.7 Discussion

6.7.1 Nature and extent of HECs

In the 1970s, the Bia elephant ranged over 1450 km^2, 79% of which fell outside BCA. The Bia population became separated from the nearby Goaso population after a heavy farming activity on the western bank of the upper Bia River (Martin, 1982) though some contacts were believed to have been maintained (de Leede, 1994). Since then, there has been a steady increase in migrants from other regions into the study area (Sam, 2000). As the number of people increased around the reserves, the cultivated area also increased, so the landscape has become more attractive to elephants (Dudley *et al*., 1992; Barnes *et al*., 1991). As the high forest was cleared, elephant range shrunk and many elephants might have been killed but others might have moved into the remaining blocks of forests in the vicinity (current reserves in the study area). Thus, these reserves may harbour larger numbers of elephants than would otherwise have been the case. However, at present, the Goaso forest reserves may contain fewer elephants due to higher human influence (illegal activity) coupled with recent alleged heavier elephant poaching incidences as compared to the better-protected Bia population. In any case, it is possible that, many of the forest fragments in the study area have become too small for a species whose range used to be more extensive in the past and has evolved a large body size that confers low locomotion costs (Barnes, 2010). Elephants have evolved to range widely, and if they were restricted in small reserves, one should not be surprised why they wander outside to areas where they used to range for food.

Accordingly, elephant crop raiding activities in the Bia-Goaso region is a serious problem and it occurs throughout the year. It dates far back into the 1970s when immigrant farmers started cultivating between reserves (Phillip Mensah, Camp 9 Leader, personal communication, 2004) and has been growing from year to year with continuous influx of migrants. Progressively, the problem has developed into a big issue and the Wildlife Division is constantly under pressure from local communities to curb the problem, especially around the BCA. Within limits of data gathered, the risk of crop raids depends largely upon the proportion of land under cultivation in an area, number of crop species on the farm and the number of farms with maize, yam, cassava, cocoa, but especially plantain present. The nearest distance between an area under cultivation and the reserve boundary is one of the strongest predictors of risk, and the same was true for the Kakum CA in Ghana (Barnes *et al*., 2003) and Kibale NP in Uganda (Naughton-Treves, 1998).

Given that people must eat, and the current policy of the Government of Ghana is to conserve the country's last remaining elephants, then there is the need to search for a form of agriculture that reduces the risks of attracting elephants. Cultivation of food crops should be discouraged within the immediate environs of the reserves. Hence, the most effective action a farmer can take is to move further away from the park boundary, reduce the number of farms within that band, or change to planting of crops that elephants do not usually cherish (Barnes *et al*, 2003; Sam *et al*, 2005), for example, pepper.

There are no data to show the trend in crop raiding frequency over the last two or three decades, but there is much anecdotal evidence for an increasing trend. The farmers blame the elephants. It is clear that the behaviour of the elephants have changed. In the past it was only males that raided, and then only at night (according to farmers). Nowadays, as shown in this study, family groups consisting of adult females, males and especially sub adults are often the culprits, and sometimes elephants have been more daring and showed up in the fields in daylight. Sitati *et al.* (2005) also reported of female-led crop raiding patterns in their study area.

Though crop damage has been reported to peak in the wettest part of the year (Sam, 2000), this study recorded most damage from September, coinciding with the minor rainy season. In the Kakum Conservation Area, severe damage rather occurs in June, coinciding with the major rainy season (Barnes *et al.*, 2003). Damage in the Red Volta Area is severest in October and November, when the single raining season would be ending and harvesting of most crops would be occurring (Sam, 2000). According to Martin (1982), within the elephant range of the Bia population, elephants confine their movement, usually to the same, often traditional routes. Opoku (1988) also reported the occurrence of crop raids especially along the eastern borderline of the BRR mainly in the wet season. A similar pattern was observed during the study period, where most raided farms were centred along the Anwiafutu and Ntosue streams, south of Adjuofia and south east of the reserve.

Confirmatory reports from wildlife staff and interviews in the local communities suggest that elephant crop raiding spreads to the south-west and northern sections including the boundary of Bia NP during the peak rainy or crop growing season in June when water sources throughout both reserves become filled with water and the density of food crops like maize farms increase along the boundary line of both reserves. These two factors may be the most important determinants of dispersing elephant distribution in the wet season.

In the Red Volta areas, Sam *et al*. (1997) have recorded two types of crop damage: damages caused by elephants moving through farmlands without eating extensively and damages caused by elephants actually raiding farms and feeding on crops. The nature of the damages in Bia falls under only the second category, where elephants move out of reserve mainly to feed on farms (with high quality harvestable crops) and back into 'hiding'. This type and its associated high level of damage is of major economic disadvantage to the individual farmer; it means a serious disaster for him/her, as farming is the only source of income for most of them. Furthermore, the fear of elephants destroying their crops at any time is a nasty burden for a family to carry through the growing season (Sam *et al*., 1997).

Farmers should be encouraged to protect their crops. Protection falls into two stages: detection and repulsion (Barnes *et al*., 2003). Improving methods of detecting the approach of elephants considerably reduce the chance of damage (Osborn and Parker, 2002). Elephants quickly habituate to single repulsive methods, hence a combination of a number of methods is recommended to effectively drive elephants away. Farmers had to resort to noise making in combination with other scare tactics to achieve a minimal level of success in driving elephants away from their fields. As much time, resources and funds were required to mitigate these conflicts, villagers often responded to these conflicts with violence, sometimes killed elephants. However, HECs may not contribute significantly to the illegal killing of elephants in the study area. From interviews, it appears the quest for ivory may be the principal driving force behind these elephant deaths.

6.7.2 Elephants involved in crop-raiding and their movement around boundary of BCA

Considering actual sightings of elephants found on farms as well as dung boli and footprint measurements give an indication that crop raiding is done by both bulls and cow-calves groups. There is of course considerable variation in growth rates between the elephants in Ghana and those in the countries where the growth curve were calculated. Therefore, the growth curves in Jachmann and Bell (1984) can only give a very rough indication of the ages of the animals in BCA. However, it is clear through the footprint and dung measurements data curve that there were signs of many very young elephants in the field. Both of these measurements and actual sightings show that families with very young elephants participate in crop-raiding in BCA.

Sam *et. al.* (1997) noted that this is typical of situations where farms are seen as attractive feeding sources without much risk for all sectors of the elephant population. Sam (1998) reported a similar situation for the Red Volta area and attributed it not only to farmers doing little to protect their crops, but also farms being close to FRs as well as far from the communities. In the case of Bia the farms are up to the boundary of the CA and the structure of cocoa farms reduces the sighting of the animals to a large extent. Hence by the time they are sighted, they would have done much damage already.

Elephants' perception of crop-raiding as low risk-free activity will need to be changed by employing a combination of tactical and strategic approaches. If one could frighten family groups enough, so they learn that approaching farms puts their calves at risk, then a large sector of the elephant population would refrain from crop-raiding. However, according to Sam *et. al.* (1997) it must be noted, that if elephants are harassed or associate certain places with risk, they would become aggressive when they do come in to contact with people (Sam *et. al.* , 1997) thus, if these tactics are successful, one might have fewer but more aggressive elephants indulging in crop-raiding.

On movements of elephant along the edges of the park one might have expected a straight line relationship, but it seems that the more there were elephants just inside the forest, the greater the propensity to move outside.

Elephant behaviour is often so unpredictable that relationships one observes in one year are often not seen in a subsequent year. Hence, the striking feature of these two graphs is that, despite the fact that they are separated by three years in time, they are very similar. So the behaviour of the elephants on the edge of the forest, in terms of moving out into the surrounding area, was the same in 2004 and 2007.

Elephants are said to be unpredictable. However, Sam (2000) mentioned how his study of the movement patterns of elephants around BCA was similar to that of Martin (1982). Though this study was not meant to repeat their study, it to a large extent confirms the predictability of the movement of the elephants of the park. Again, while Sam *et al.* (2005), estimated that at least some 24 males and 12 females were involved in crop-raiding at eight different settings or occasions around BCA this study suggests that up to about 35 elephants could be involved.

6.8 Conclusions

The main human-elephant conflict issue in the study area is farm destructions by elephants. These occurred mainly at the southern portion of the Bia Conservation Area. It was realised that a relative small number of farmers in the area were affected by crop-raiding. However, though the extent of damages within the bigger district economy was not significant, the suffering to the individual farmer was found to be high as damage was estimated to be between 14% to over 90% of a farm. The most cherished crops were found to be plantain, maize, cassava, cocoa, and yam. These were usually eaten in their matured stages of growth and especially when the quality was excellent. It was observed that elephants were attracted by cluster of farms that were nearest to the reserve. Also, cluster of farms with large sizes and a higher combination of crops were more preferred by the elephants. It was noticed that both family groups as well as bull groups participated in crop-raiding around the park and that the phenomenon involved about 25% of the elephant population. It was realised that one could use the distribution of elephants immediately within the reserve to predict their movement into the adjacent farms.

CHAPTER SEVEN

COMPARISON OF CONSERVATION STATUS OF THE ELEPHANT POPULATIONS IN THE BIA-GOASO FOREST ENCLAVE AND OTHER FOREST ELEPHANT POPULATIONS IN WEST AFRICA

7.1 Introduction

West Africa lost more than 90% of its elephant range during the 20th century (Roth and Douglas-Hamilton, 1991). As a result, the remaining elephant populations in the sub-region are small and fragmented. In recent times, about 75 separate elephant populations exist (Figure 7.1); 41 in the forest zone and 27 in the savanna and 7 in the Sahel region (IUCN/AfESG, 1999). These occupy about 5% of the land area of West Africa while elephants occur on 17%, 29% and 52% of lands of East Africa, South Africa and Central Africa respectively. Due to the intense fragmentation and the consequent smaller populations, it has been argued that most of the West African populations are not viable and therefore important for the overall conservation of the species (Barnes, 1999). The proponents of this line of argument further propose that Development Partners spend their funds in other sub-regions to conserve the elephants there. It is therefore becoming important to establish a way of prioritising these populations so that conservation efforts could be more focussed and made more effective.

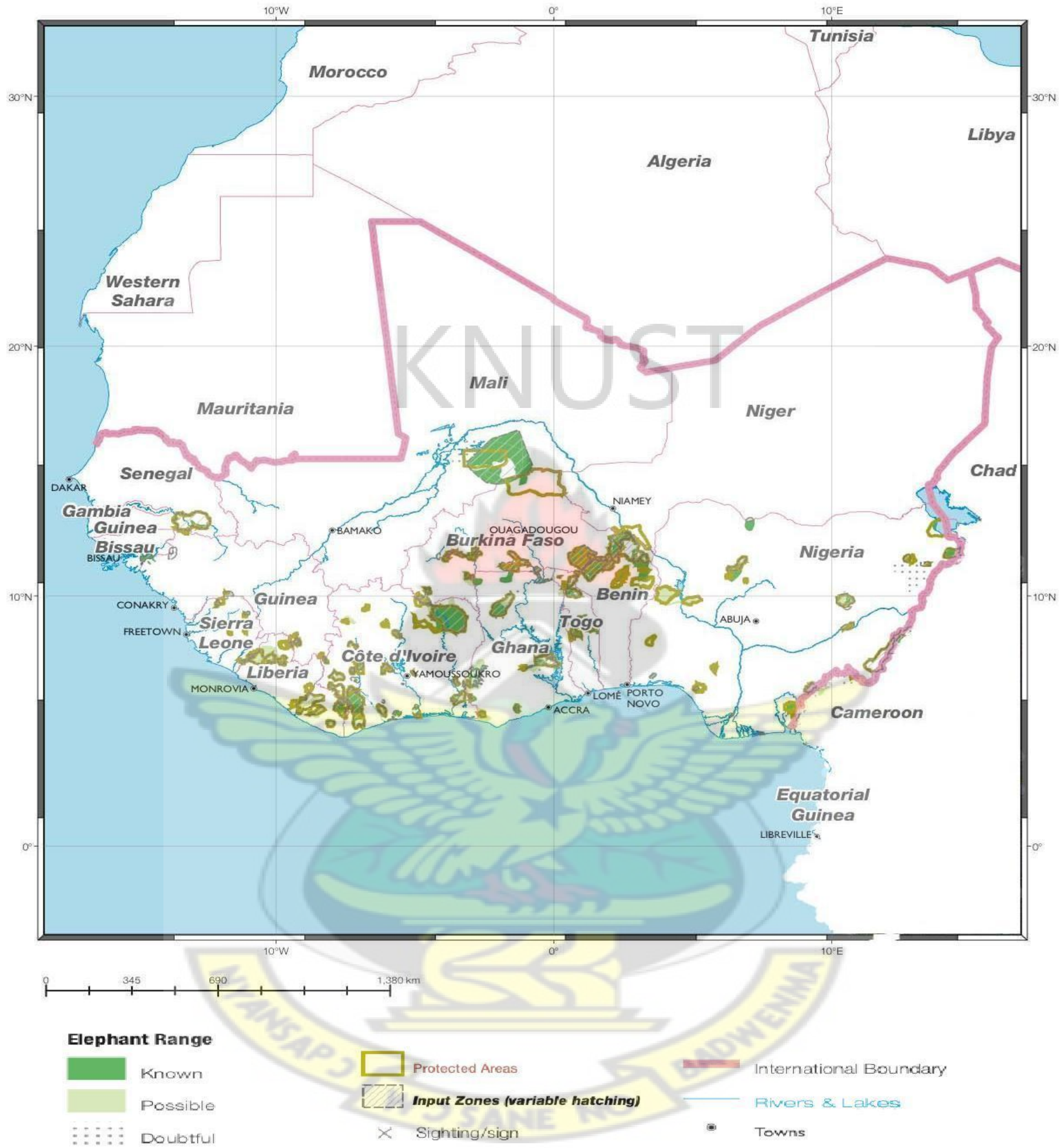


Figure 7.1 Elephant ranges within West Africa. Adapted from AfESG (2007)

According to Blanc *et al*., (2003), the average population size in the West African savanna is 100 elephants, and only 40 for forest populations. In both forest and savanna areas, one-fourth of West

African elephant populations consist of 20 or less individual elephants. Small populations are less likely to be viable in the long term, (say the next 100 years) because they could be genetically isolated (Barnes, 1999). As a result of serious habitat fragmentation, encroachment on elephant habitat and poaching, many elephant populations in the region may probably not be viable and may be genetically isolated.

The West African Elephant Conservation Strategy (2003) encourages that, conservation priority is foremost given to all populations above 100 elephants within the first five years of its implementation, to be followed by populations that are 50 and above in next five years following that. Furthermore, if there is any chance to choose between conserving an isolated population and populations that have the opportunity to inter-breed with those in other ranges, the obvious choice would be the interbreeding populations.

On the basis of the estimated population size for the study area, a comparison was made with that of the average population size (40 in this case) for forest elephants in the sub-region to establish their importance. Again, a comparison of elephant estimates for the study area with populations in other West African countries as this study seeks to do, will establish the conservation importance of populations in the study area relative to the other populations in the sub-region.

In trying to establish a criteria for prioritizing elephant populations in the sub-region a preliminary attempt was made to determine which site-level and national-level variables were important in explaining elephant abundance in West Africa.

7.2 <u>Research Objectives and Questions</u>

a) <u>Research Objectives</u>

This study was undertaken primarily to:

i) Develop a set of criteria for prioritising elephant populations in West Africa

ii) Establish the conservation importance of the elephant populations in the Bia-Goaso forest enclave in the West African context

iii) Determine which world-level economic, political and development indicators affect elephant abundance in West Africa

b) <u>Research questions</u>

The study was designed to answer the following research questions:

- ✓ What factors can be used to prioritise elephant populations in the sub-region?
- ✓ What is the current status of elephants in the study area?
- ✓ What is the conservation status of elephants in different elephant populations in the West African sub-region
- ✓ Which elephant populations have others close by that can ensure gene-flow?
- ✓ How are elephant populations being conserved amidst increasing human population in the sub-region?
- ✓ How secured is the habitat of the elephants in the study area relative to those in the sub-region?
- ✓ Are there any governance indicators that influence elephant numbers or densities at the sub-regional level?

7.3 <u>Hypotheses</u>

◊ Ho = Elephant density in the study areas is among the top 10% in West Africa

- ◊ Ho = Conservation status of elephants in the study area is high compared to those in the other countries in West Africa.
- ◊ Ho = Elephant population in the study area has a better chance of survival over the long-term than half the populations in the sub-region.
- ◊ Ho = the quality of governance in a West African country affects elephant abundance in that country

7.4 Method

7.4.1 Prioritising elephant populations in West Africa

This was basically a desk study. Some of the site-level information were obtained through contacting authorities in the range states. Key documented studies on elephant populations in the West African sub-region were reviewed. Data on elephant densities in the sub-region were compared with that obtained for the study area to ascertain the conservation importance of the Bia and Goaso elephant populations in the entire West Africa.

Some of the key documents consulted include the following:

- ➢ African Elephant Status Report 2002: An update from the African Elephant Database (2003). By Julian Blanc *et. al*. of IUCN/SSC AfESG, Gland, Switzerland and Cambridge, UK.
- ➢ West African Elephant Conservation Strategy. Unpublished report (1999) by IUCN/SSC African Elephant Specialist Group, Nairobi Kenya.
- ➢ Strategy for the conservation of West African elephants (Update). Unpublished report (2003). By IUCN/SSC African Elephant Specialist Group/WWF Int., Nairobi Kenya.

- Strategy for the Conservation of Elephants in Ghana (2000). By Wildlife Division (Forestry Commission), Accra-Ghana.

7.4.2 *Governance Indicators that determine elephant population sizes in West Africa*

Based on a detailed internet search and publication reviewing, a suite of 11 country-level governance indicators were compiled to ascertain their individual or combined relation with elephant numbers and/or densities in the 13 West African elephant range states. The indicators, and the underlying data behind them, are 1) World Banks' Worldwide Governance Indicators (WGI) which capture six key dimensions of governance (Voice and Accountability, Political Stability and Lack of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption); 2) Mo Ibrahim Foundations' Ibrahim Index (MI) of African Governance: a governance assessment and ranking of 48 sub-Saharan African countries according to five general criteria as proxies for the quality of the processes and outcomes of governance (safety and security, rule of law, transparency and corruption, participation and human rights, sustainable economic opportunity, and human development); and 3) Transparency Internationals' Corruption Perception Index (CPI). Available data for the immediate past years were used. Compilations for WGI were for the years 2005 to 2008, MI for 2007 to 2008 and CPI for 2005 to 2008 (See Table 7.1). The mean of the different governance suites in respect to the years were also used for analysis (Appendix 8).

Table 7.1 Governance indicators used to compare elephant densities in West Africa

Source of Indicator	Type of Indicator	Abbreviation	Year of Data

Transparency International	Corruption Perception Index	CPI	2005 - 2008
World Bank (Worldwide Governance Indicators)	Voice and Accountability Political Stability and Absence of Violence Government Effectiveness Regulatory Quality Rule of Law Control of Corruption	VA est. . PS est. Ge est RQ est. RL est. CC est.	2005 - 2008
United Nations Development Programme	Human Development Index	HDI	2005-2008
Mo Ibrahim Index	Safety and Rule of Law Participation and Human Rights Sustainable Economic Opportunity Human Development	SRL PHR SEO HD	2007 - 2008

These were combined and analysed together with data on the following covariates: geology (categorical with 4 classes, park-specific), mean annual rainfall (continuous, mostly park-specific), protected (categorical with 2 classes, park-specific) human population size (continuous, country-level), and elephant range size (continuous, park-specific).

7.5 <u>Data Analysis</u>

7.5.1 Prioritisation of elephant populations

In order to assess the importance of the study area for elephant conservation in the sub region, elephant numbers for known populations in West Africa (Blanc *et al*., 2003) were converted into densities based on size of the respective elephant habitats. The analysis was done on two levels.

On one level, the densities that were obtained for the current Bia and Goaso populations were compared with the densities of the remaining West African elephant populations. However, since the two Ghanaian elephant populations are forest elephants, on another level, their numbers and density were compared to other forest elephant populations in the West African sub-region. Since mere numbers or densities are not enough justification for prioritising populations other factors which have been enumerated below were considered.

The population estimate data recorded in the African Elephant Database (Blanc *et al*., 2003) has reliability ranging from A (highest) to E (lowest). Hence, analysing such data of varying quality on national, regional or continental levels is most confusing and may produce misleading results. In order to minimise this problem, a further ranking was done based on the reliability of the survey results for the forest elephant populations.

Survey reliability A refers to when Individual registration (IR) was applied as survey type; B refers to Dung counts (DC) with 95% confidence limits and dung decay rate measured on site; C refers to Dung counts with 95% confidence limits but no on-site measurement of dung decay rate, or Genetic Dung counts (GD); D refers to Dung counts without 95% confidence limits, or Informed guesses (IG); and E is any Other guess (OG), or any of the above survey types in which the estimate is over 10 years old

(Blanc *et al*., 2003. For the purposes of this study, only surveys that fell within an acceptable range of reliability from A (highest) to C (medium) were considered.

Another criterion that was used for ranking was limited to the degree of protection that is accorded to the range (habitat) of a population. For example, all things being equal, a range that falls within a National Park is more likely to survive pressures for a longer time than one that falls within non-community protected land, as the probability of these lands being converted for farming or other such purposes are higher.

The last criterion used for ranking is the degree to which a population has the chance of interacting with other populations as this will increase the survival of such a population.

7.5.2 Governance indicators that are determinants of elephant numbers/densities

Regression models (and correlations) were constructed using either abundance (or density) as response variable, and at either a park or country level. Governance indicators are the main predictor variables of interest, and one would not want to include highly correlated predictors in a regression model, so the first step was to test for collinearity (at the country level). The next step was to check correlations between country mean elephant abundance or density and the governance indicators. This was to identify which were the most promising indicators to include in regression model.

To test multiple regression models at the country level, an exploratory linear model was run using the R-software with mean abundance at country level as the response variable and the following 5 predictors: mean range area, mean rainfall, human population, “va” and “hd” (2 less correlated governance indicators). Human population was converted to density (accounting for country size). Geological type and protected status were not included since a country average couldn't be calculated.

Multiple regression models were further explored at the site level. It must be noted that there is the problem of pseudoreplication (non-independence) of predictor variables at the site level, since site are clustered within countries which share the same values for several variables (i.e., governance, human population size). Nevertheless, if there were stronger patterns in analysis at the site level, it might justify trying to build a mixed model that deals with the hierarchical nature of the data (Littell, Milliken *et al*. 2006; Bickel 2007).

There are several variables that might explain elephant density of particular sites: rainfall, soil/geology (Bell, 1982) and human density around the study area (Barnes, 1999).

A simple model that explains elephant abundance (E) in terms of area of site (A), rainfall (R), geology (G) and human density (H) was developed:

E = A + R + R2 + G + H

The hypothesis was then tested by adding each of the governance variables e.g. corruption (CPI) to the model:

E = A + R + P + G + H + CPI

There is very wide variation in elephant density within each country. For example, in Burkina Faso the density varies from 0.03 to 0.407 per km2. This is a wide difference. The mean corruption index for the whole country is 3.2. So a comparison of E against CPI (or any of the other country-level indices) is probably not going to reveal anything.

There are several variables that might explain elephant density of particular sites: rainfall, soil/geology (Bell, 1982) and human density around the study area (Barnes, 1999).

A simple model that explains elephant abundance (E) in terms of area of site (A), rainfall (R), geology (G) and human density (H) was developed:

$$E = A + R + R2 + G + H$$

The hypothesis was then tested by adding each of the governance variables e.g. corruption (CPI) to the model:

$$E = A + R + R2 + G + H \quad + CPI$$

The list of governance variables that were significant were then added together.

7.6 Results

7.6.1 *Importance of the Bia-Goaso elephant populations and their range for elephant conservation in West Africa*

With an average elephant density of 0.441 elephants per sq km, the Bia CA ranks 6th in order of density in the sub region (for both forest and savannah populations). Furthermore, it has the fourth highest density for all forest populations in West Africa besides being the eighth largest forest elephant population. The Bia population is also one of the few forest elephant populations with the most reliable survey estimates (A – C) for the sub-region (Blanc *et al*., 2007). Its current range is a government protected area, that is, a National Park and a Resource Reserve. All these rankings (Table 7.2) stress the importance of the Bia elephants and their range for elephant conservation in West Africa.

Table 7.2: The Bia and Goaso Elephant Populations in the West African context

Country	**Elephant Range**	**No. of Elephants**	**Size of Range (km^2)**	**Elephants Density**	**All Popn Rank**	**Forest Popn Rank**	**Survey Reliability Rank**	**Forest /Savanna Popn**	Protected/ Unpro-Tected
Cote d`Ivoire	Tene forest	5	4	1.250	1st	1st	D	F	U
Mali	Gourma Range	322	387	0.832	2nd			S	
Burkina Faso	Nazinga Game Ranch	630	940	0.670	3rd			S	P
Guinea	Ziama Strict Nature Reserve	214	455	0.470	4th	2nd	D	F	P
Ghana	Kakum Conservation Area	164	366	0.448	5th	3rd	C	F	P
Ghana	**Bia Conservation Area**	**135**	**306**	**0.441**	**6th**	**4th**	**C**	**F**	**P**
Burkina Faso	Konkombouri Hunting Zone	490	1300	0.377	7th			S	U
Burkina Faso	Arly National Park	422	1224	0.345	8th			S	P
Burkina Faso	Singou Partial Faunal Reserve	618	1920	0.322	9th			S	P
Nigeria	Cross River National Park	74	239	0.310	10th	5th	D	F	P
Burkina Faso	W du Burkina NP	740	2412	0.307	11th			S	P
Cote d`Ivoire	Azagny National Park	65	218	0.298	12th	6th	E	F	P
Liberia	North East National Forest	33	130	0.254	13th	7th	E	F	U
Benin	Atakora Hunting Zone	343	1356	0.253	14th			S	P
Benin	Pendjari Biosphere Reserve	713	2827	0.252	15th			S	P
Burkina Faso	Zabre Department	150	600	0.250	16th			S	U
Liberia	Gola, Kpelle and	500	2071	0.241	17th	8th	E	F	P

	Lorma NF								
Sierra Leone	Outamba-Kilimi	80	358	0.223	18th	9th	E	F	P
Sierra Leone	Gola East FR	60	295	0.203	19th	10th	E	F	P
Nigeria	Taylor Creek	25	145	0.172	20th	11th	D	F	U
Burkina Faso	Mohoun Protected Area	541	3296	0.164	21st			S	P
Cote d`Ivoire	Davo forest	20	126	0.159	22nd	12th	E	F	U
Cote d`Ivoire	Marahoue National Park	159	1010	0.157	23rd	13th	E	F	P
Liberia	Barrobo National Forest	100	640	0.156	24th	14th	E	F	P
Cote d`Ivoire	Keregbo forest	30	213	0.141	25th	15th	E	F	U
Burkina Faso	Bontioli Partial & Total FR	50	422	0.118	26th			S	P
Cote d`Ivoire	Mont Peko National Park	40	340	0.118	27th	16th	E	F	P
Burkina Faso	Ouamou Hunting Zone	73	644	0.113	28th			S	U
Cote d`Ivoire	Djambamakro Forest	30	274	0.109	29th	17th	E	F	U
Nigeria	Yankari National Park	348	3224	0.108	30th			S	P
Guinea Bissau	Binase Area	35	330	0.106	31st	18th	E	F	U
Sierra Leone	Gola North FR	50	480	0.104	32nd	19th	E	F	P
Ghana	Digya National Park	357	3478	0.103	33rd			S	P
Liberia	Krahn Bassa National Forest	500	5142	0.097	34th	20th	E	F	P
Liberia	Sapo National Park	124	1292	0.096	35th	21st	C	F	P
Cote d`Ivoire	Beki-Bossematie Foret Classee	35	389	0.090	36th	22nd	D	F	P
Burkina Faso	Pama Partial Faunal Reserve	200	2230	0.090	37th			S	P
Ghana	Mole National Park	401	4504	0.089	38th			S	P
Liberia	Grebo National Forest	230	2604	0.088	39th	23rd	E	F	P
Guinea	Oure Kaba and Sansale	57	691	0.082	40th	24th	E	F	U
Cote d`Ivoire	Abokoamekro Faunal Reserve	11	135	0.081	41st	25th	A	F	P
Ghana	Ankasa Conservation Area	41	509	0.081	42nd	26th	C	F	P
Cote d`Ivoire	Bolo forest	5	88	0.057	43rd	27th	E	F	U
Cote d`Ivoire	Tai ecosystem	189	3500	0.054	44th	28th	C	F	P

Cote d`Ivoire	Okromodou forest	50	945	0.053	45th	29th	E	F	U
Cote d`Ivoire	Mont Sangbe National Park	47	950	0.049	46th			S	P
Cote d`Ivoire	Niegre Foret Classee	50	1056	0.047	47th	30th	E	F	P
Nigeria	Kwiambana Game Reserve	80	1715	0.047	48th			S	P
Nigeria	Chad Basin	100	2300	0.043	49th			S	P
Ghana	**Goaso forest**	**87**	**2035**	**0.043**	**50th**	**31st**	**C**	**F**	**P**
Ghana	Chichiban Corridor	12	290	0.041	51st			S	U
Niger	Baba N`Rafi forest	17	430	0.040	52nd			S	U
Niger	W du Niger National Park	85	2294	0.037	53rd			S	P
Cote d`Ivoire	Goin-Cayally Foret Classee	70	1890	0.037	54th	32nd	E	F	P
Nigeria	Okomu Game Sanctuary	40	1082	0.037	55th	33rd	E	F	P
Cote d`Ivoire	Tiapleu forest	10	280	0.036	56th	34th	E	F	U
Ghana	Red & White Ecosystem	46	1370	0.034	57th			S	P
Cote d`Ivoire	Go-Bodienou forest	20	600	0.033	58th	35th	E	F	U
Togo	Fazao-Malfakassa NP	61	1920	0.032	59th			S	P
Benin	Djona Hunting Zone	36	1216	0.030	60th			S	U
Burkina Faso	Diefoula Foret Classee	26	880	0.030	61st			S	P
Cote d`Ivoire	Haut Sassandra Foret Classee	30	1024	0.029	62nd	36th	D	F	P
Nigeria	Andoni Island	6	215	0.028	63rd	37th	D	F	U
Cote d`Ivoire	Fresko forest	60	2229	0.027	64th	38th	E	F	U
Cote d`Ivoire	Scio Foret Classee	30	1338	0.022	65th	39th	E	F	P
Cote d`Ivoire	Haut Bandama Forest Reserve	20	1230	0.016	66th			S	P
Sierra Leone	Bagbe River forest	5	349	0.014	67th	40th	D	F	P
Togo	Abdoulaye Faunal Reserve	4	300	0.013	68th			S	P
Mali	Gourma Range	498	37991	0.013	69th			S	U
Nigeria	Kambari	5	414	0.012	70th			S	U
Cote d`Ivoire	Songan-Tamin-Mabi-Yaya FC	20	1698	0.012	71st	41st	D	F	P
Cote d`Ivoire	Duekoue forest	6	536	0.011	72nd	42nd	E	F	U
Benin	W du Benin National Park	56	5872	0.010	73rd			S	P

Nigeria	Omo Forest Reserve	30	4068	0.007	74th	43rd	D	F	U
Guinea Bissau	Corubal_Dulombi Area	7	1342	0.005	75th	44th	E	F	U
Nigeria	Gashaka-Gunfi National park	30	5860	0.005	76th			S	P
Cote d`Ivoire	Comoe National Park	10	11500	0.001	77th			S	P
Senegal	Niokolo-koba National Park	2	9130	0.000	78th			S	P
Togo	Oti-Mandouri Faunal Reserve	0	1484	0.000	79th			S	U
Togo	Keran National Park	0	1636	0.000	80th			S	P
Togo	Fosse aux Lions National Park	0	17	0.000	81st			S	U
Burkina Faso	Koakranka Hunting Zone	0	229	0.000	82nd			S	U
Burkina Faso	Pagou-Tandougou HZ	0	350	0.000	83rd			S	U

** Survey reliability rankings as interpreted by Blanc et. al. (2002)*
A = (Individual registration, aerial and ground total counts)
B = (Aerial or ground sample counts with 95% CL or dung counts with 95% CL and dung decay rate measured on site)
C = (DC with 95% CL but no on-site dung-decay measurement or Genetic dung counts)
D = (Aerial and ground sample counts and dung counts without 95% CL or Informed guess)
E = (Other guesses or above survey types in which estimate is more 10 years old)

The elephant population that uses the entire Goaso group of FRs (area of 2,035 sq km) ranks 50th in the sub region with an average elephant density of 0.04 elephants per sq km. In terms of density, it ranks 31st among forest populations. It is also the 11th largest forest elephant population in the entire sub region. While many of the estimates of populations in the sub-region are mere guesses, it is worth noting that the Goaso population is currently one of the four forest populations with the most reliable estimate. Being gazetted forest reserves, the habitat or range of this population is likely to be secured than many other elephant populations in the sub-region.

7.6.2 Indices of governance and other variables that determine elephant abundance

Exploratory analysis showed that Tene Forest, with 4 elephants in a small forest, was an extreme outlier and so it was removed. Further regression diagnostics (ref) showed that there were other outliers: Niokola-Koba, Keran, Oti-Mandouri and Comoe NP. These were removed, leaving a sample size of 72 sites in 12 countries. The model was re-fitted and the residuals examined to confirm a good fit.

The governance indicators were found to be highly correlated across countries. Hence, only one or two indicators that are not too strongly correlated were added. The correlation coefficients (both Pearson (corP), and non-parametric Spearman (corS)) between governance indicators and elephant density or abundance across countries were all positive, except for with "hd" (Human Development). However, correlations were generally low (all <0.5), and none was statistically significant ($p > 0.05$). The highest correlations were with "va" (Voice and Accountability). The other relationships were more mixed but seem relatively higher for "ps" (Political Stability) and "srl" (Safety and Rule of Law) for abundance. Also, the correlations generally appeared to be stronger with abundance than with density.

Figure 7.2 shows examples of plots of correlations at country level (with linear fit added) for "va", "ps", "srl" and "hd" indicators in relation with elephant abundance.

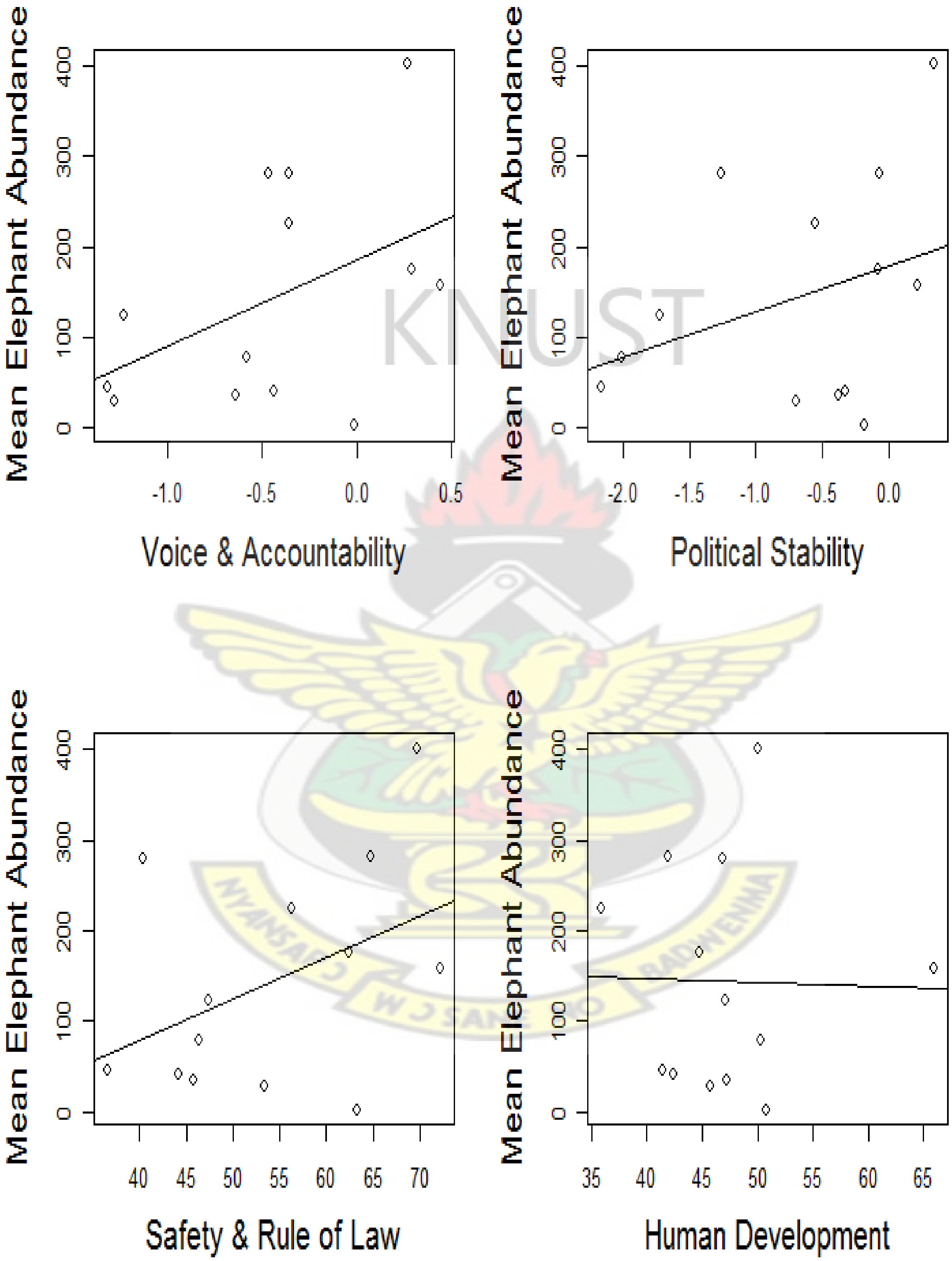


Figure 7.2 Correlations between mean elephant abundance at country level and four governance indicators (va, ps,srl and hd)

The model output (from R software):
Call:
lm(formula = c.abun ~ c.range + c.rain + c.human + va + hd)

Residuals:

```
    Min        1Q        Median       3Q      Max
-157.156   -38.137   -7.199       62.747  140.723
```

Coefficients:

```
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  5.712e+02  3.049e+02   1.873   0.1032
c.range     -1.420e-02  1.150e-02  -1.235   0.2568
c.rain      -1.174e-02  6.555e-02  -0.179   0.8629
c.human     -1.642e-07  9.041e-07  -0.182   0.8610
va           1.701e+02  8.537e+01   1.992   0.0866 .
hd          -6.164e+00  6.222e+00  -0.991   0.3548
---
```

Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1; Residual standard error: 122.4 on 7 degrees of freedom; Multiple R-squared: 0.422; Adjusted R-squared: 0.009122; F-statistic: 1.022 on 5 and 7 DF, p-value: 0.4712.**

The general suggestion is that these variables do a poor job of explaining country-level variation in elephant abundance (r^2=0.422, p=0.471). There is a suggestion that "va" (voice and accountability) could have a marginally statistically significant effect ($p < 0.1$), which is potentially interesting. Model simplification (based on Akaike Information Criterion (Buckland *et al*, 2001) - AIC) suggested that a better model excludes rainfall and human density (output shown below), but it is still not a very strong model (r^2=0.416, P=0.165).

lm(formula = c.abun ~ c.range + va + hd)

Coefficients:

```
              Estimate Std. Error t value Pr(>|t|)
(Intercept) 580.426439 266.569491   2.177   0.0574 .
c.range      -0.013487   0.009335  -1.445   0.1824
va          177.622872  70.262302   2.528   0.0323 *
hd           -6.777000   5.094886  -1.330   0.2162
---
```

Signif. codes: 0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1; Residual standard error: 108.5 on 9 degrees of freedom, Multiple R-squared: 0.4162; Adjusted R-squared: 0.2216; F-statistic: 2.139 on 3 and 9 DF, p-value: 0.1653.**

When the correlations between park abundance (and density) and the governance indicators were explored, the two highest correlations for abundance were with “va” and ps” (and again, governance indicators were generally highly correlated). Below (Figure 7.3) are three example plots of the relationships (with linear fits):

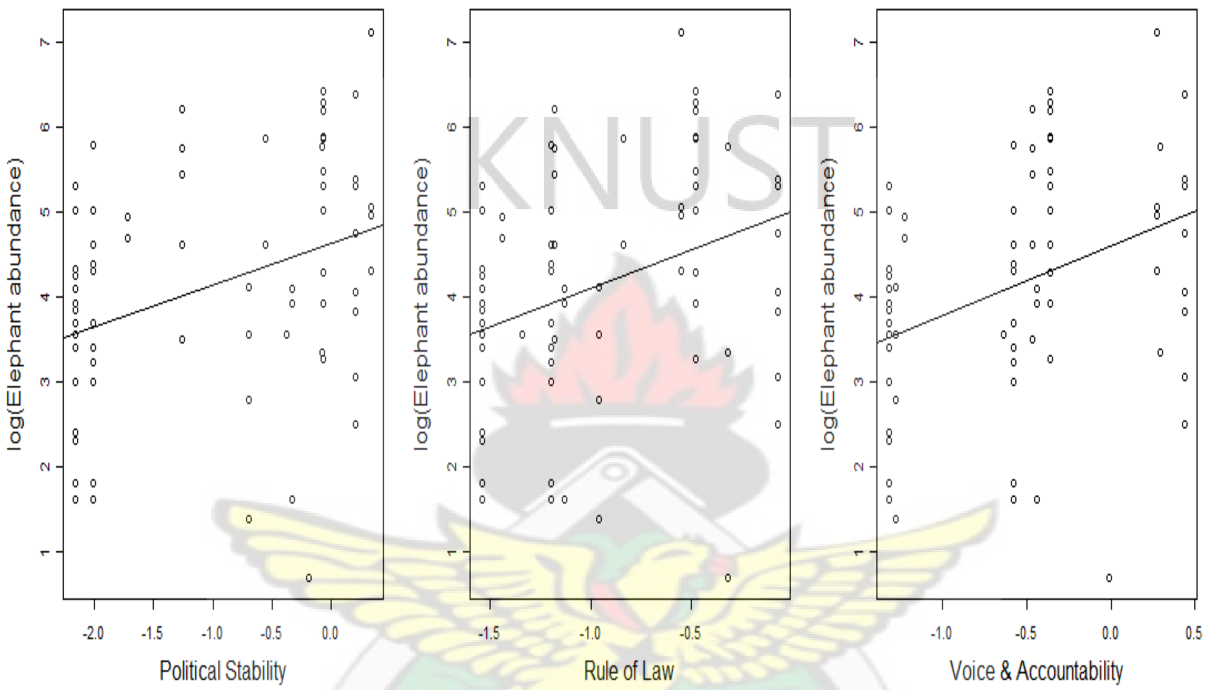


Figure 7.3 Correlations between mean elephant abundance at site level and three governance indicators (ps, rl & va)

An exploratory linear multiple regression model on ln(abundance) with the following predictor variables: ln(range area), rainfall, ln(human population size), protected, geology (categorical variable), and political stability (“ps.mean”) was done.

Call:

lm(formula = log(abun) ~ log(range) + rain + log(human) + protected + geology + ps.mean, data = data)

Residuals:

Min	1Q	Median	3Q	Max
-4.3381	-0.5782	0.1110	0.6680	2.6058

```
Coefficients:
                          Estimate Std. Error t value Pr(>|t|)
(Intercept)             -0.5882491  2.9648942  -0.198  0.84330
log(range)               0.4754323  0.1081317   4.397 3.78e-05 ***
rain                     0.0001289  0.0002059   0.626  0.53328
protected                0.8357116  0.2796228   3.153  0.00361 **
log(human)               0.0765602  0.1679953   0.456  0.64998
geologyFlood Plain       1.1048268  1.2576843   0.878  0.38266
geologyGranite           0.7977155  0.3430771   2.325  0.02293 *
geologyMarine Sediments -0.5094869  0.9302182  -0.548  0.58561
ps.mean                  0.5407195  0.1763754   3.066  0.00307 **
---
```

Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.181 on 71 degrees of freedom; Multiple R-squared: 0.3398; Adjusted R-squared: 0.2747; F-statistic: 5.22 on 7 and 71 DF; p-value: 7.789e-05. (Geology – Basement and Basin was treated as the intercept here).

As shown above, the model suggests that range area is an important predictor, that protected and geology may be important, and that political stability has an important influence (as an example governance indicator). Again, the significance values need to be treated with caution (due to non-independence).

AIC-based model simplification suggested dropping rainfall and human population from the model but retaining range size, protected, geology and stability:

Call:

lm(formula = log(abun) ~ log(range) + protected + geology + ps.mean, data = data)

This gave r^2=0.335, and p=0.124e-04). A comparison of the above model with a model excluding political stability (“ps.mean”, i.e., only including range, protected and geology) suggests that including the governance indicator improves model fit (lower AIC is better):

- AIC value for model with range area + protected + geology =265.6; R^2 = 0.235

- AIC value for model with range area + protected + geology + ps.mean = 256.6; R^2 = 0.335

7.7 Discussion

7.7.1 *Importance of area for elephant conservation in West Africa*

Comparatively, elephants in West Africa came under earlier greater pressure from human population competing for space than those in Central, Eastern and Southern Africa. As a result, forest elephants, which were once widespread in West Africa, are now found in small fragments in the Upper Guinea forest block, presently extending from eastern Sierra Leone through Ivory Coast to Western Ghana (Roth and Douglas-Hamilton, 1991). Blanc *et al*. (2003) reported that West African Elephants account for only about 2% of the continental total, consisting of small isolated populations scattered throughout the sub region.

Many (74%) of the population estimates listed in the African Elephant Status Report 2007 for West Africa are not covered by systematic surveys and are of low-quality data with 53% of them being guesses (Blanc *et al*., 2003). Also, over 21% of the range information for the region (in terms of km^2) is more than 10 years old. Furthermore, because of serious habitat fragmentation, many elephant populations in the region are probably not viable and may be genetically isolated. For this reason, West African elephants may have diverted from the rest of Africa's elephants more than two million years ago (Eggert *et al*., 2002) and may constitute a separate taxon. If this is confirmed by more extensive genetic sampling, the implications would make securing the long term survival of the small and fragmented remaining populations of West African elephants very important and challenging (Blanc *et al*., 2003).

The above arguments provide a basis for seriously considering the importance of the Bia – Goaso elephant population and range for elephant conservation in the sub region. Firstly, the Bia elephant population is extremely very important for being one of the populations with more than 100 individuals in the sub region; the West African Elephant Conservation Strategy (2003) encourages that, conservation priority is foremost given to all populations above 100. The population is also important because its range is a Protected Area (PA) and not likely to be destroyed or encroached in the nearest future. It is salso the nearest range to link elephant populations in the Ghanaian forests to those in Ivory Coast. There is ample evidence that these populations used to interact (Martin, 1982) and probably do till now.

The Goaso population on the other hand falls far below the 100 individuals expected to be considered a priority population in the West African context. However, considering the fact that the Goaso elephant population far exceeds the mean size of 40 individuals recorded for forest elephants in West Africa and ranks 31st in density and 11th in number of individuals, among all forest elephant populations, it could be considered quite important. This is further strengthened by the fact that more than 60% of the forest populations are guesses and that among forest populations with survey reliability up to C, it is ranked 8th Also, the high possibilities of linking this population to the Bia population and ultimately the Ivory Coast populations makes it even more important.

The Mpameso-Bia Shelterbelt population has a crucial role to play in ensuring the long-term survival of the recently rediscovered Bare-headed rock fowl (*Picarthartes gymnocephalus*), a globally endangered bird species found in Mpameso FR. Such a high concentration of elephants (0.76 per km^2) in relatively a small area in combination with the rock fowl has management implications for tourism development in Mpameso which could go a long way to ensure the species' own survival while boosting the local economy and thereby community interest in conservation.

7.8 Conclusion

Even though West Africa has only about 2% of the total of all African elephant populations, theses are scattered in as many as 75 populations. This has been as a result of the rapid exploitation of the forests of the sub-region for several reasons as well as the brisk trade in ivory in the last few centuries. As resources available for management of natural resources continue to dwindle, it has become important to prioritize elephant populations and ranges. This study has identified various criteria that can be used for prioritization of the populations. These included population size, density, and the degree of accuracy of information on the latter two criteria. Other criteria are degree of security of the elephant range and the potential of a population to intermingle with other populations. By utilising these criteria it has been established without doubt that both the Bia and Goaso elephant populations are very important populations in the sub-region. Their survival is therefore critical in ensuring that the sub-species continue to thrive in the sub-region. It has also been demonstrated that within the sub-region elephant abundance is best explained by a fairly large protected range with fertile soil in a country politically stable with least violence.

CHAPTER EIGHT

GENERAL DISCUSSION

8.1 Status of elephants in the Bia-Goaso forest enclave

With the exception of the Bia NP, elephants were expected to be found to inhabit all the reserves in the study area in considerable densities (de Leede, 1994). An informed guess (Oppong, Goaso Biodiversity Monitoring Unit, personal communication, 2000) suggested that the area (both Bia and Goaso) harboured up to about 600 elephants. Consequently, one would have expected this study to show a much higher population than what was found.

Estimated elephant densities show that the Bia RR shelters a far larger elephant population than the Mpameso FR. Results also indicate that elephant density have reduced significantly in the other reserves in the Goaso area. This contra indication to de Leede's work in 1994 and Parren *et al* (2002) is important as it is barely a little over a decade ago when that study was conducted. With such alarming decline (over 60%) in elephant numbers in such a short period, all efforts should be put into investigating the causes, and steps taken quickly to address them.

Illegal hunting for almost all species of animals occurs in Bia Conservation Area as well as all the forest reserves in the Goaso area. Also a significant proportion of elephant killings in Ghana have been recorded from these two populations (Sam, 2000). In addition to that, the Bia elephant range has shrunk to about one-fourth of the original size, partly as a result of Sukusuku and the Bia Tawya FRs being illegally and completely reduced to farmlands (Martin, 1982). However, the Bia elephant population faces less immediate threat to the illegal killing of elephants than the Goaso population because they are better protected by wildlife guards. This is confirmed in this study by the fact that, index of illegal activity in the

Mpameso FR and the rest of the reserves in the Goaso region were twice higher than that for Bia Conservation Area.

It has been amply demonstrated through this study that the current population levels and distribution of elephants have been as a result of the actions of humans; the closeness of settlements, farms, roads and markets are all factors (Barnes, 1991; Barnes, 1999; Sam, 2000; Parren and Sam, 2003). Logging companies have not adhered to the prescriptions in the Logging Manual leading to excessive creation of forest access and disruption of the natural functions of the ecosystem such as reducing flow of water.

As alluded to earlier in section 3.7, though these study can only suggest and do not provide conclusive data as to a decline in elephant density in the Goaso area (because previous data were not this comprehensive), it is widely known in the local communities that there has been an upsurge in the spate of illegal elephant killings by local and foreign hunters (from neighbouring Ivory Coast) during recent years. According to the local people interviewed during the survey these elephants are mostly killed for their ivory, though the meat is not spared by local people when the news is heard. This has serious implications for the Wildlife Division of the Forestry Commission (FC) since elephants are completely protected in Ghana.

8.2 Pachyderms, Plantains and Poverty

The premise that wildlife should not negatively affect local livelihoods and human well-being is becoming increasingly central to both field conservation programmes and international policy (Wadpole, 2006). Undoubted, of all the pachyderms (including hippopotamus and rhinoceros) none generates such high levels of local acrimony like elephants, despite their extreme conservation concern and interest. As a species, its need for space often bring them into direct conflict with expanding human populations (Kangwana, 1993; Ngure, 1993; Kiiru, 1994).

Over 75% of elephants range in Africa lies totally outside the protected area network (Douglas-Hamilton *et. al*.1992). Comparatively as far back as the 1970s, 79% of the Bia elephant range fell outside the protected area, and extended into cultivated areas (Martin, 1982). Elephants have therefore, often shared land with the local communities. However, with the growing human population resulting from the steady influx of migrant farmers into the study area, the conflict that such proximity broods is high and it's predicted to escalate.

According to Osborn and Parker (2006) and Naughton-Treves (1997), such conflict is a critical issue in conservation as it creates intense animosity amongst the rural poor towards the wild animals that destroy their crops and threaten their livelihoods (Adams and McShane, 1992; Naughton-Treves, 1997).

Whereas in other areas in Africa, competition over the use of limited water resources between humans and elephants, human injury and mortality caused by elephants, damage to watering structures by elephants and the killing of livestock by elephants are prevalent (Sitati *et al*, 2005), the conflict between humans and elephants in the Bia-Goaso area usually revolves around the destruction of crops by elephants, and this is paramount given the impacts it has on food and livelihood security and poverty levels for the affected farmers and local communities (Sam, 1998).

8.2.1 Pachyderms - profile and behaviour of elephants involved in crop- raiding

As a species, elephants are particularly intelligent, and weigh up the expected benefits and costs of different courses of action (Sam, 1998). This assertion differs for males and females (Barnes, 1983). Male elephants are known to take greater risks than female elephants. It is believed that a strategy of risk taking maximizes nutrient intake allowing males to better compete for rank and therefore access to female elephants in oestrus. This is called the male behaviour hypothesis. The observation in this study about both family and bull groups participating in crop-raiding has a serious implication for management as well as the issue of food security. Sam (1998) made a similar observation in the Red Volta Area of Ghana. This, however, contrasts with elephants in the Kibale National Park and elsewhere in Africa, where family groups rarely raid crops (Naughton-Treves, 1997; Osborn and Parker, 2006), they would usually consider the risk that a particular line of action will have on their calves. Thus, if they have to travel for a very long distance to get food, exposing their calves to a greater chance of danger, they may consider forgoing the easily-digestible food needed for the weaning calves.

The key to preventing crop-raiding is about creating risk to a level where it will deter most elephants raiding crops. The presence of cows and calves in raiding groups also suggests that farmers do not do much to protect their crops. Having demonstrated the predictability in the movement of the elephants in the study area, the strategy for mitigation should focus on using the pepper-grease method in their paths, and especially along the boundary to ward them off even before they get out of the CA. However, it must be noted that nothing is more tempting to an elephant than food crops which are planted right behind the 'windows' (boundary of the reserve) of the elephant.

8.2.2 Plantains - the case of cultivated plants palatable to elephants

Elephants love plantains! The stems of these plants are eagerly devoured, and they find every portion except the outside rind nourishing. Around Kakum National Park, Barnes (2009) suspected that plantains were a major risk factor that attracted elephants on to farms. However, in as much as elephants love plantains, evidence from this study and elsewhere suggest that elephants enjoy eating a whole range of cultivated food crops. Elephants are generalist feeders, and it is assumed that anything which is palatable for humans, is commonly also fit for elephant consumption. The same can be said about the cultivation and production of other palatable food crops such as maize, yams and cocoa., This, as well as encroachment into species habitats and the resultant shrinking of the its ranges have been identified as some immediate causes for human-wildlife conflicts (FAO, 2008).

The return of elephants to habitual feeding grounds on farms show the appeal of such farms and also indicate how much its feeding behavior and preference has evolved from wild foods to cover the range of food crops cultivated by man. Plants which were selectively bred by humans for hundreds of years, contain less deterring chemicals and high levels of nutrients, and are therefore interesting food source for elephants (Barnes, 2010). Several studies have documented selection by elephants of foods low in secondary compounds and high in energy, protein and minerals (Jachmann, 1989; Sukumar, 1989; Omondi, 1995,) and wild foods of elephants have been found to be lower in protein and minerals than food crops (Sukumar, 1989; Osborn,, 1998). Thus food crop consumption could be used to supplement deficient diets. Introducing unpalatable crops on raided farms in crop-raiding prone zone will not only reduce the costs of conflict borne by the farmer, but may also improve livelihood security.

According to FAO (2008) the occurrence and frequency of crop raiding is dependent upon a multitude of conditions such as the availability, variability and type of food sources in the natural ecosystem, the level of human activity on a farm and the type and maturation time of crops as compared to natural food sources. Climatic and weather conditions can also play a role; there is some anecdotal evidence suggesting that elephant crop raiding around forests is is correlated with rainfall. For the study area evidence gathered suggests that elephant crop raiding activities occurs throughout the year, making it even more serious.

8.2.3 Degree of poverty in communities resulting from elephant crop-raiding activities

Though there are a considerable number of studies on damage caused by particular elephant populations, most stop short of determining what proportion of farms in a given area is affected by their damage and the general cost to the local society. For a rigorous analysis this information is needed since presenting an overall level of elephant damage which is applicable only to the affected farms is somewhat misleading. The overall level of damage in the whole farming area is what really needs to be quantified (Hoare, 1995; Sam, 2000).

A closer examination of the population around the forest reserves and the conservation areas shows that the BCA has about 22 communities with several villages within 5 km of the boundaries with an estimated population of about 22,040. These represent about 10% and 11% of the total population of the Bia and Juabeso districts respectively (Agyare, 2010). Farmers in the district concentrate on cocoa production while undertaking food crop farming as a complementary activity. The general trend in farm practice is that all other crops grown on farmlands are meant to provide food for subsistence and shade for cocoa which is intended to take over the land (develop canopy) in due course. Accordingly, about 74% of the population are cocoa farmers and non-cocoa farmers being 26%. It is also estimated that 81%

of earnings in the district come from agriculture with cocoa alone accounting for 68% of gross earnings (Agyare, 2010).

Average farm holding among cocoa farmers in the Bia - Juaboso district is generally estimated at 3 hectares (Agyare, 2010). By the calculations of COCOBOD, cocoa farmers in Ghana produce on average 400kg of cocoa per hectare, which translates into 1,200kg per farm holding (≈ 20bags, taking into account the 60kg weight of a full bag of dried cocoa beans) in Bia – Juaboso district. Taking into account the current purchasing price of GH¢150 per bag, it can be inferred that a farm holding obtains about GH¢3,000 which implies that the productivity per acre of cocoa farm is about GH¢400. For the other crops, net profit per acre of cassava can range between GH¢ 190 to GH¢ 690; acre of maize GH¢ 335 to GH¢ 585 ; plantain GH¢ 155 to GH¢205; vegetables GH¢ 1,615 to GH¢ 2,575 per annum for the study area (Agyare, 2010).

The Production Level of cocoa in the Juaboso and Bia Districts for the 2008/2009 cocoa season was 105,827 metric tons (worth ≈ GH¢264,567,495), which suggests that the area of land under cocoa production alone in the districts would be about 264,568 ha. It can therefore be estimated that the total area of farmland damaged or destroyed in the 32 affected villages is only 0.006% of the total area under cultivation in the two districts. It can also be surmised that in the course of the period of the study, the communities living around the BCA lost about GH¢ 16,910 (an average of about GH¢ 528.44 per affected village) as a result of crop raiding by elephants.

Crop damage in terms of its repercussions for poverty at the village level or within the larger area (5 km around BCA) could be said to be insignificant when the value is spread across.

However, for the individual affected farmers, an average of about 46% of his/her farm is destroyed (≈ 0.000004% of the total land area under cocoa production). This translates into a financial cost estimate of about GH¢130, rising up to about GH¢ 420 to one farmer. For a poor farmer, this could be very significant, especially given the small area per farm holding in the district. It should be noted that, the above estimate is for only cocoa and would be higher for a mixed crop farm with vegetables or other crops which may be more expensive than cocoa.

The above figure is however, smaller than that reported for the Queen Elizabeth National Park area of Western Uganda (Bariregа *et. al*., 2010) where crop raiding dominated by elephants resulted in 14% annual reduction in household food security of park-adjacent communities. FAO (2008), estimated the cost of crop damage by elephants across Africa to range from 0.2% (Niger) to 61% (Gabon) of planted fields. In financial terms estimates of annual costs of elephant raids ranged from $60 (Uganda) to $510 (Cameroon) per affected farmer. Despite the highly irregular and localized pattern of elephant damage (some are either too close to a reserve, a water source or in a migration route), the cost to the farmer is quite phenomenal.

8.3 Conservation, Corridors, and CREMAs

8.3.1 Conservation and long term survival of elephants in the Bia-Goaso area

Parren and Sam (2003) mentioned that between 685 and 855 elephants occurred within the Ivory Coast and Ghana border area in the late 1980s. This study has suggested that far less than half of this number occur today, split into some five isolated populations with two at the Ghana side of the border. Hunting and habitat fragmentation activities such as agriculture, logging and settlements have been two of the main causative factors (Holbech, 1998; Caspary, 1999; Sam, 2000).

In order to ensure the conservation of forest elephants in West Africa it is important to ensure that the above elephant populations form a meta-population (Vucetich and Waite, 1998), in which sub-populations can still interact with one another. This is so as there are several survival challenges with small populations. Firstly, they are more prone to environmental catastrophes such as drought or flooding; then, they are likely to lose genetic diversity because heterozygosity declines faster in small populations through genetic drift (Caughley, 1994). Furthermore, mating between relatives is not only more likely in small groups, reducing heterozygosity, but small numbers of animals in general often have distorted sex ratios and age structures as a consequence of hunting, and are more vulnerable to random demographic events (REF).

As this study has amply demonstrated that there is (if at all) very limited interaction between the elephants in the Bia area and that of Goaso, as well as either of these and those in the neighbouring Ivory Coast (Bosomattie and Songan). It is important to ensure two things, the first being to provide protection to the species through improved law enforcement and enhancing the level of social acceptance of the people living within the elephant zone.

Elephants occupying small areas have a low probability of survival compared to those in larger ranges (Barnes, 1999). Also, small patches of habitats may not have the resources necessary to support an elephant population year round, especially, in periods of scarcity, hence the need to ensure unobstructed movement of elephants for their conservation (AfESG, 1999). Hence to ensure the conservation of the species a network of forest corridors needs to be established between these populations to enhance connectivity, and the ability of elephants to travel among the separated patches of suitable habitat (Taylor et al., 1993), without much difficulty.

8.3.2 Corridors within the Bia-Goaso forest Area

Corridors promote the movement of animals between the reserves and therefore reduce the effects of genetic isolation and allow access to a wider range of resources The Action Plan for the Management of Transfrontier Elephant Conservation Corridors in West Africa (2003), classifies two categories of corridors. The more basic type is the “migration corridor” which consists of a strip of habitat that links two patches of lands or reserves. Examples are the existing shelterbelts in the study area, some of which have served effectively as elephant corridors (Parren and Sam, 2003). Such a corridor will be required along the Bia river to provide a migratory route for elephants from the Bia-Goaso forest enclave into Ivory Coast and vice versa.

The creation of the Bia river corridor would not only have the advantage of providing drinking water for the elephants but also enhance the use of the corridor by other species. Ghanaian legislation calls for the creation of buffers measuring at least 50m for the efficient conservation of riparian zones. Relying on this legal provision, a wider corridor (ca. 1.5 km wide) can be advocated along this strategic river to ensure movement of elephants from the Mpameso FR to the Songan Foret Classee in Ivory Coast. Parren and Sam (2003) mentioned how 1.5 km wide linear corridors had the potential to be used as passage by large mammals such as elephants in the Goaso area.

The second type may be termed as a conservation corridor and comprises a portion of landscape embracing several different but compatible land uses that is managed to achieve specific conservation objectives (AfESG/IUCN, 2003). This is the kind of corridors which would be required between the Bia Resource Reserve to Krokosua Hills Forest Reserve as well as the Bia Resource Reserve to Djambarakrou Foret Classee in Ivory Coast. Hence migration and landscape corridors which share the same general conservation objectives should be combined in the study area to achieve the conservation of the species. A collaborative resource management tool which is currently being piloted by the Wildlife Division of the Forestry Commission (WD, 2008) is a key avenue through which the concept of landscape corridors can be modelled, or adapted for use, especially in the study area.

8.3.2.1 Community Resource Management Areas (CREMAs): An Integrated Landscape Approach to Corridors

In making a case for corridors, Bennett (1998, 2003) intimated that in the situation where conservation reserves are few, sparsely distributed or inadequate for effective long-term conservation as is the case in the Bia-Goaso Area, then an integrated landscape approach is the most relevant. It is generally recognized that many formally protected areas are too small to maintain healthy populations of many plant and animal species (Osborn and Parker, 2003). Substantially increasing the number and extent of reserves is an important step, however, this is not possible especially for the patches of forest situated in a matrix of cultivated land like those found in the study area. Besides, there is persistent and growing pressure for land by ever increasing subsistence farmers. The above situation combined with the ever increasing demand on existing reserves and protected areas for bushmeat by rural communities has subjected virtually all species of wildlife to over-hunting and makes conservation unsustainable. Despite the major importance of hunting and bushmeat activities for the households and economy of the rural communities, neither hunting nor the bushmeat trade is organised or effectively regulated by any local by-laws or current national wildlife regulations (Parren and Sam, 2003).

With this backdrop, the Wildlife Division of the Forestry Commission has since 1991 been developing and piloting a community based natural resource management programme that has the potential to dramatically change the status of wildlife and other resources outside reserves. According to Wells and Brandon (1992) along with monitoring and protecting natural resources inside the parks, reducing the exploitation pressure in peripheral zones should be another crucial target.

The CREMA concept involves a number of communities that come together with the aim of conserving their natural resources on their own lands. It is based on the establishment of areas where wildlife management is incorporated into existing land use through the use of District by-laws.

According to Bennett (1998, 2003) one of the most effective ways to obtain broad support for biological linkages or corridors is to integrate their planning and management with other programmes that deliver benefits in sustainable land management (such as protection of water resources or sustainable use of natural products). CREMAs aim at involving local communities and devolving wildlife management and utilization outside protected areas. The structures are designed so as to enable the promotion of wildlife as a viable complement to agricultural practices that are carried out in Ghana (Wildlife Division's CREMA briefing document, 2003). It is meant to create a financial incentive for farmers to use and sustainably manage natural resources by devolving management rights and responsibilities to them. It uses an organisational structure that is based on existing decision-making structures and is consistent with local land tenure relationships.

Experiences within some portions of the Bia area have shown that the deforestation process has been slowed down in the agricultural landscape of farms, fallow areas and remnant forests as a result of introduction of CREMA over the past few years (PADP II, 2010). These forest fragments are no longer converted to other land uses but preserved as a breeding area of wildlife forming a source for game in the agricultural landscape. Fig 8. 1 shows how two CREMAs have been established to link BRR and KHFR (Agyare, 2010).

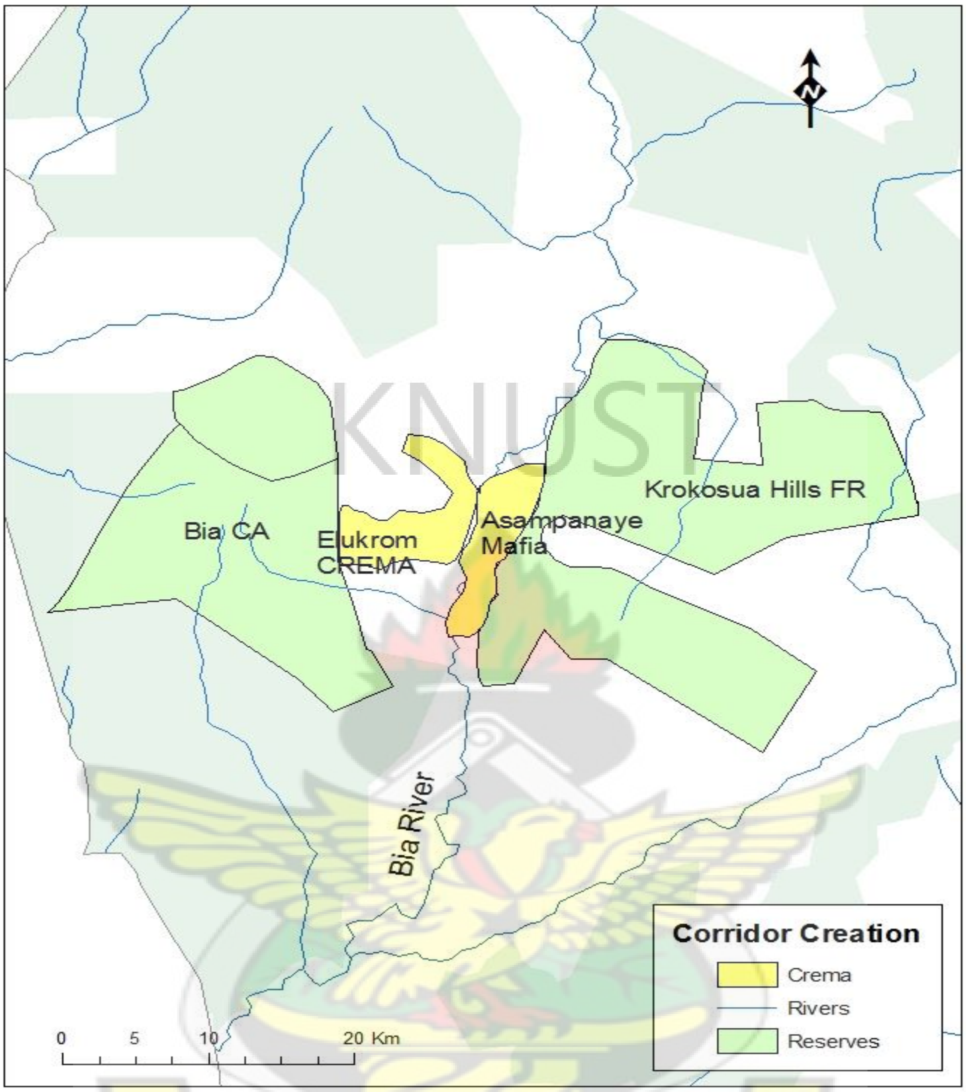


Figure 8.1 The use of CREMAs as corridors to link key biological areas. Adapted from Agyare (2010).

At the end, preserving and managing these forest fragments provide higher annual income than conversion into other land uses. Though some challenges still exist on its monitoring mechanisms in relation to population trends of wildlife species, trade and pricing, human structures and organisation, and regulation compliance demonstrated social acceptance and implementation by people living within the area could serve to encourage and assure efficient conservation of elephants and other species living within their range. It is hoped that the proposed feasible migratory corridors will serves as the loci for the creation of the CREMAs in the study area.

8.3.2.2 Enhancing the quality of the Corridor habitats

Elephants will not necessarily utilise a corridor because it has been established. As noted elsewhere in this document, there will be the need to "bait" them into the corridor. This calls for ensuring that the special requirement of the species is provided. In such consideration, the quality of habitat within the corridor created is a factor that will determine its use or otherwise. Factors such as presence of food and availability of water determine to a large extent the degree to which elephants would use the corridor. Hilty *et al* (2006) inferred that habitat found in corridors must be of higher quality than that in larger core habitat patches to attract and maintain the species. The enrichment of the proposed corridor along the Bia River with tree species whose fruits and leaves are known to be well favoured by elephants in the area (Alexandre, 1978; Merz, 1981; Short, 1981; Parren *et al.*, 2002) will go a long way to ensure its use. Hence, the corridors, whether the one along the Bia river or the CREMAs should be planted with preferred forest tree species such as *Tieghemella heckelii, Parinari excelsa, Balanites wilsoniana, Panda oleosa, Sacoglottis gabonensis and Duboscia viridiflora* (Martin, 1991; Hawthorne and Parren, 2000; Sam, 2000). Dudley *et al*. (1992) linked a sharp reduction in crop raiding around Assin Attandaso Resource Reserve to the fruiting of *T. heckelii* within the reserve. Enrichment planting to ensure the return of wildlife is one of the key activities during CREMA implementation stage (WD, 2008) so this would not be an additional activity outside the schedule of communities. Besides, communities in this area are used to planting on large scale so are not strangers to the issue of plantations (Asare, 2005).

A key element that is critically linked to habitat quality is the availability of water which this study has amply demonstrated that is extremely critical to the survival of the elephants in the area. This rather striking observations of the affinity of elephants to the Bia River and other watering points strongly suggest the need to ensure that many watering points are created, especially in the corridors where CREMAs would be employed. Waitkuwait (1992) mentioned how artificial waterholes have been created and successfully used inside FC Bossematié to ensure the elephants stay within the reserve boundaries. *F*orests elephant favour fruiting trees in the dry season (Taylor, 1960; Alexandre, 1980). As the water from these fruits is not enough, providing water will reduce the incidence of elephants moving out of corridor to crop-raid.

8.3.2.3 Mitigating Potential Negative effects of Corridor establishment

Whereas not discounting the promise of corridors and CREMAs in enhancing connectivity, dispersal and the range of hospitable habitats for elephants and other wildlife, a number of potential problems associated with habitat corridors have been identified for which one needs to appreciate. These include their potential to spread pest species, the increased exposure of animals to predators, and the risk that assigning resources to maintenance of linkages will be less cost-effective than undertaking other conservation measures (Bennet 1998, 2003). However, of particular concern in the case of the proposed corridors is the issue of the increased possibility for crop raiding and confrontation between farmers and elephants.

Through careful planning and management efforts, adverse impacts can be avoided or minimised so that the corridor's benefits (to both farmers and wildlife) outweigh any negative impacts of downsides. Fortunately, while some particular groups of animal species may be greatly disadvantaged by the human modified habitat, other species are tolerant and even thrive in such environments. Parren and Sam (2003) reported that five species (cane rat, giant rat, Maxwell's duiker, brush-tailed porcupine and bushbuck) made up 60-70% of the volume of the bushmeat trade, and were all associated with farmland and secondary forest. The creation of the corridors will not benefit solely elephants but other wild animal species like the bushbucks, porcupines primates and duikers. As many of these are exploitable by law and their subsequent exploitation through the CREMA arrangement can be achieved, it is hoped that this will increase the tolerance of farmers for the elephants.

Furthermore, the Wildlife Division has successfully piloted the "pepper-grease method" as an effective deterrent measure against crop-raiding elephants at crop-raiding areas around Kakum National Park (Sam *et. al.*, 2009). This method has been recently introduced around Bia NP (PADP II, 2010) and will be applied where necessary to ward off elephants from farms to lessen the threat posed by crop-raiding elephants and the level of damage they might cause.

The increased presence of elephants and other wildlife could provide the basis for the promotion of an alternative form of livelihood and revenue generation by way of tourism receipts that the farmers and rural communities can derive which can reduce any losses they might incur from crop raiding wildlife.

Another, source of concern to some farmers in CREMA areas may be where some parcel of land might be set aside as core areas for one reason or the other, with restrictions on their utilization. Where such areas exist and are significant, there will be the need to look for the introduction of alternative and/or additional livelihoods (PADP, 1999). The role of NGOs is critical in such situations. It is also very important to explore the potential to use the corridors/CREMAs to access funding from current funding mechanisms such as REDD+, CDM, Payment for Ecosystem Services (PES), etc. It is hoped that the combination of these strategies will serve to offset the losses of rural communities through crop-raiding and other sacrifices, lessen the antagonism that the creation of corridors and CREMAs might initially bring and let them appreciate the need to undertake such endeavours.

CHAPTER NINE

CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

The Bia CA still contains a viable elephant population and efforts should be made to link it to the Goaso population where elephant density is lower and elephants are less protected. This would then make the study area to contain the most important forest elephant population in the sub-region.

Human activity/disturbance have a negative impact on elephant conservation in the Bia – Goaso range. WD checkpoints should be mounted on the major roads to check the illegal trade in bush meat. Surveillance, including the use of intelligence information should be stepped up around towns that host major markets in and around the study area.

Crop damage by elephants continues to be a serious problem in the study area. While this was a major source of friction between farmers and park authorities this is gradually reducing as the park improves on its ability to handle the problem in particular and improve upon its community relations in general. Any future natural resource conservation project should find ways of mitigating this.

The existing use of shelterbelts by elephants in the study area shows that linear corridors may be successfully used to connect existing reserves and elephant populations into a transnational forest network supporting one of the most important forest elephant populations in West Africa. However, the CREMA concept provides an even brighter opportunity for applying the landscape approach in the establishment of corridors to ensure the conservation of the species. The opportunities (physical, ecological, socio-economic, etc.) of establishing these corridors were brighter a decade ago than currently and the situation, especially for the physical and ecological, keeps worsening with time. The need for immediate intervention is therefore paramount.

9.2 RECOMMENDATIONS

Many useful lessons have emanated from this study. Hence many aspects of the movement patterns of elephants in the study area as well as the phenomenon of crop damage need further investigations. Also, much work entails convincing the local populace to agree to release part of their lands to create elephant corridors. The following short and long term management strategies have been discussed in this light.

Elephant numbers and distribution

It is of utmost importance to know more by possibly repeating this study, as more information might be required on the movements and their use of the proposed corridors by elephants. Furthermore, some more in-depth habitat studies might be useful for the conservation and management of the species in this range. It is also recommended to put in a few more transects into the low density stratum, in future surveys. This measure is likely to improve the accuracy of the survey.

A decade ago, a small population was reported to be occupying the northern portion of the Bia North FR (de Leede, 1994). It is interesting that the 2004 study also reports of a similar situation in the spate of the level of elephant poaching in the area. A more comprehensive survey on this population is required.

Rehabilitation of Sukusuku and Bia Tawya FRs

The Sukusuku and Bia Tawya FRs, were part of the range for the Bia elephant population, which provided a link to some populations in eastern Ivory Coast. They have been encroached and turned into cocoa farms. The Community Resource Management Area (CREMA) initiatives and other agro-forestry practices could be introduced into the area through collaboration between Forest Services Division, Wildlife Division and Ministry of Food and Agriculture to rehabilitate the FRs and re-establish the corridor for the Bia population and the Djambamakrou (Ivory Coast) population.

Strengthening on-going corridors establishment efforts

The long-term viability of the elephant population in western Ghana will depend on the exchange of genetic material between the Bia and Goaso populations and then with the neighbouring populations of Ivory Coast. IUCN/WWF (2003) encourages range states to "promote national land use planning that secures the future of elephant ranges by giving them importance at national level. Encourage planning that covers entire systems; even those crossing national boundaries". Hence it is essential that the on-going discussions between the two countries be pursued more vigorously since the ecological and socio-economic possibilities for establishing the corridors keep dwindling with time.

Enrichment planting of reserves and riverbanks

Whilst focusing on the rehabilitation of reserves and the establishment of corridors, further research should consider the species composition, structure and functions of the trees to be considered for enrichment planting. The trees should serve as a source of food to attract elephants and other wild animals into the corridors. It is important to have detailed information on the diet of elephants in all the reserves. This is important because the species composition and forest structure may vary in the different reserves especially for the Bia and Goaso forests.

Changes in the land use and improved agricultural techniques

Changes in land use are recommended to conserve the remaining patches outside the conservation area. Agricultural planning and techniques also need improvement in the area to feed an increasing human population faced with deteriorating natural conditions and to reduce the vulnerability of their crops to damage by elephants. Farmers should be encouraged not to plant too close to the FRs or far from the villages. Also, they should farm close to each other so that traditional deterrent methods used against elephants could be effective (Mubalama, 1996).

Alternative sources of income and protein

Hunting activities in forest reserves should be properly controlled. Alternative protein and income sources (e.g. fish farming and bee keeping) should be developed in the local communities to help reduce the over reliance on bush meat and land for farming.

Human – elephant conflict data gathering system

The first step in understanding the extent and severity of the crop raiding is to establish a method of quantifying information about incidents. The human – elephant conflict data gathering protocol developed by the AfESG is simple and very useful and can easily be mainstreamed by the park authorities for making quick assessment of the nature and extent of the annual crop damage situations. Currently, Bia CA is where this form has been used the longest and it is important to continue this as solutions are developed.

More concentration on corridor areas

As stated in sections 5.6 and 5.7, the analyses of information on the corridors are not anywhere near conclusion. The use of various participatory forest management tools such as timelines, mappings, H-diagrams etc. in many more communities, this time concentrating only on those within proposed corridors are recommended. These give better community views than the questionnaires that were largely used. The issue of resource replacement should also be fully investigated.

REFERENCES

Adjewodah, P.; Beier, P.; Sam, M. K. and Mason, J. J. (2005) *Elephant Crop-Damage in the Red Volta Valley, North eastern Ghana*. *Pachyderm 38: 38-48*

AFESG (1999). *Strategy for the Conservation of West African elephants*. IUCN/SSC African Elephant Specialist Group Ouagadougou.

AfESG/IUCN (2003). *Action Plan for Management of Transfrontier conservation corridors in West Africa*. IUCN, Nairobi

Agyare, A. K. (1996). *Preliminary study of the socio-economic perspective of Bia Biosphere Reserve – a follow-up report*. Report submitted to the Man and Biosphere Committee of Ghana. EPA, Ghana.

Agyare, A. K. (2010). *Socio-Economic Setting of Bia Section of the Proposed Bia – Diambarakro Corridor*. Consultancy report for Conservation Alliance/FAO, Accra

Alexandre, D. Y. (1978). Le rôle disseminateur des éléphants en forêt de Taï, Côte d'Ivoire. *La Terre et la Vie*, 32, 47-72.

Alexandre, D. Y. (1980). Caractére saisonnier de la fructification dans une forêt hygrophile de Côte d'Ivoire. *La Terre et la Vie*, 34, 335-350.

Alpers, E. A. (1992) The ivory trade in Africa: an historical overview: In elephants: The animal and its ivory in *African Culture* (Ed by D. H. Ross). Pp.349-363. Fowler Museum of Cultural History, University of California, Los Angeles.

Ambruster, P. and Lande, R. (1993). A population viability analysis for African elephant *(Loxodonta africana):* how big should reserves be? *Conservation Biology 7:602-610.*

ARG (2010). Field trip to Ivory Coast on Project No. GA-0582: Status survey and conservation of chimpanzees and other endangered primates in South-Western Ghana. Mimeo. A Rocha Ghana/USF&WS project. Accra.

Asare, A. (2005) *Community involvement in forest restoration and management: evaluation of the modified taungya system*. Paper presented at Akosombo III (Restoration and Sustainable Management of Forests in Ghana) Workshop for stakeholders of NRM in Ghana.

Bacles, C.F.E., Lowe A.J. and Ennos R.A. (2004). Genetic effects of chronic habitat fragmentation on tree species: the case of Sorbus aucuparia in a deforested Scottish landscape. *Molecular Ecology* 13: 573–584.

Barnes, R.F.W. (1996a). *A training course in elephant biology for Ghanaian wildlife officers*. Unpublished final reports to U.S Fish and Wildlife service.

Barnes, R.F.W. (1996b). Estimating forest elephant abundance by dung counts. In: Kangwana, K., ed. *Studying elephants.* AWF Handbook No.7. African Wildlife Foundation, Nairobi.

Barnes, R.F.W. (1999). Is there a future for elephants in West Africa? *Mammal Review* 29: 175-199.

Barnes, R.F.W. (2010). Evolution and strategic management of the elephant crop-raiding syndrome in West Africa. *Africa Journal of Ecology*

Barnes, R. F. W., Asamoah-Boateng, B., Naada Majam, J. and Agyei-Ohemeng, J. (1997). Rainfall and the population dynamics of elephant dung piles in the forests of southern Ghana. *African Journal of Ecology* **35**: 39-52.

BARNES (2009) IN TEXT BUT NOT HERE? IS IT A PERSONAL COMMUNICATION??

Barnes, R.F.W., Azika, S. and Asamoah-Boateng, B. (1995). Timber, Cocoa and Crop-raiding elephants: a preliminary study from Southern Ghana. *Pachyderm* 19: 33-38

Barnes, R. F. W., Barnes, K. L., Alers, M. P. T., and Blom, A. (1991). Man determines the distribution of elephants in the rainforest of northern Gabon. *African Journal of Ecology*, 29, 54 – 63.

Barnes, R.E.W., Boafo Y., Nandjui, A., Dubuire, U.F., Hema, E.M., Danquah, E. and Manford, M. (2003). *An overview of crop raiding by elephants around the Kakum Conservation Area.* Elephant Biology and Management Project, African Programme Conservation International. Washington, DC 20037, USA.

Barnes, R. F. W. and Dunn, A. (2002). Estimating forest elephant density in Sapo National Park (Liberia) with a rainfall model. *African Journal of Ecology*. **40**: 159-163.

Barnes, R. F. W. and Jensen, K. L. (1987). How to count elephants in forest. IUCN/AERSG *Technical Bulletin* 1:1-6.

Barnett, J.L., How, R.A. and Humphreys, W.F. (1978). The use of habitat components by small mammals in eastern Australia. *Australian Journal of Ecology*. 3: 277-285.

Beier, Paul, Maryann Van Drielen and Kankam, B. O. (2002). Avifaunal collapse in West African forest fragments, *Conservation Biology,* Vol 16, No. 4. Pages 1097-1111

Bickel, R. (2007). Multilevel analysis for applied research: It's just regression! New York, The Guilford Press.

Blake, Stephen, Inkamba-Nkulu, Clement (2004) Fruit, Minerals, and Forest Elephant Trails: Do All Roads Lead to Rome**?** *BIOTROPICA* Volume: 36

Blanc, J. J., Thouless, C. R., Hart, J. A., Dublin, H. T., Douglas-Hamilton, I., Craig. C. G. and Barnes, R. F. W. (2003). *African Elephant Status Report 2002: An update from the African Elephant Database*. IUCN/SSC African Elephant Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. vi + 302pp.

Bos, E.,Vu, M.T., Massiah, E. and Bulatao, R.A. (1994). *World Population Projects*,1994-1996 Edition. John Hopkins University Press, Baltimore.

Breckwoldt, R. (1983) *Wildlife in the Home Paddock*. Angus and Robertson, Australia.

Buckland, S.T., Anderson, D.R., Burnham, K.P., and Laake J.L. (1993). *Distance Sampling: estimating abundance of biological populations*. Champ man and Hall London.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L and Thomas, L. (2001). *Introduction to Distance Sampling. Estimating Abundance of Biological Populations*. Oxford University Press.

Burnham, K. P., Anderson, D.R and Laake, J. L. (1980) Estimating of density from line transect sampling of biological populations. *Wildlife. Monger* 72 : 1 - 202.

Campbell, B.H. (1981). An aqueduct as a potential barrier to the movements of small mammals. Southwest. *Nature* 26: 84-85.

Caspary, H-U. (1999). Wildlife utilization in Côte d'Ivoire and West Africa – potentials and constraints for development cooperation. *Tropical Ecology Program and GTZ*, Eschborn, Germany.

Chen, X.Y. (2000). Effects of habitat fragmentation on genetic structure of plant populations and implications for the biodiversity conservation. *Acta Ecologica Sinica* 20: 884–892.

Cumming, D.H.M., Du Toit, R.F. and Stuart, S.N. (1990). *African Elephants and Rhinos: Status Survey and Conservation Action Plan.* IUCN, Gland, Switzerland.

Danquah, E., Boafo, Y., Dubiure, U. F., Awo, N., Hema, E. M. and Amofah Appiah, M. (2001). Elephant census in the Ankasa Conservation Area in South – Western Ghana. *Pachyderm* **31** (63-69).

De la Mensbruge, G. (1996). *La germination et les plantules des essences arborées de la fôret dense humide de la Côte d'Ivoire*. Publication no. 26. Centre Technique Forestier Tropical, Nogent-sur-Marne (Seine), France.

De Leede, B. M. (1994). *Feasibility study on the establishment of corridors for forest elephants (Loxodonta africana cyclotis, Matshie) between forest reserves in western Ghana and eastern Ivory Coast*. Ghana Wildlife Department, Accra. 39 p.

De Iongh Hans, H., Tchamba Martin T., Aarhaug Per and Verhage Bas. (2004). Impact of dam construction on two elephant populations in northern Cameroon. *Pachyderm* 36.

Dekker, A.J.F.M. and Dawson, S. (1992). ELEPHANT. Program - a programme for estimating the density of elephants.

DGW (1991). *Elephant conservation plan for Ghana*. Department of Game and Wildlife. Unpublished Report.

Dickinson, B. (1990). *An estimation of population density of forest elephant (Loxodonta africana cyclotis. Matschie) in Bia Tano and Subin forest reserves, Brong Ahafo Region, Ghana*. Unpublished report. Game and Wildlife Department, Accra, Ghana.

Douglas-Hamilton, I. 1979. The African elephant action plan. Typescript Report to IUCN.

Douglas-Hamilton, I. (1987). African elephants: population trends and their causes. *Oryx 21:11-24*

Douglas-Hamilton, I., and Douglas-Hamilton, O. (1978): *Among the Elephants*. Collins, Glasgow, U.K.

Dublin, H. T. (2002). African Elephant Specialist Group Chair / Président's.report. *Pachyderm* 31.

Dudley. P. J. (1996). African elephants in coastal refuges. *Pachyderm* No. 21

Dudley, J. P., Mensah-Ntiamoah, A. Y. and Kpelle, D. G. (1992). Forest elephants in a rainforest fragment: preliminary findings from a wildlife conservation project in southern Ghana. *African Journal of Ecology*, 30, 116-126.

Dytham, C. (2003). Choosing and using statistics, a biologists guide. Blackwell Science, 108 Cowley Road, Oxford UK.

Eggert, L. S., Rasner, C. A. and Woodruff, D. S. (2002). The evolution and phylogeography of the African elephant inferred from mitochondrial DNA sequence and nuclear microsatellite loci. *Proceedings of the Royal Society of London, Series B 269: 1993-2006.*

Eisenberg, J.F. (1981). *The Mammalian Radiations.* University of Chicago Press, Chicago.

Eltringham, S.K. (1990). Wildlife carrying capacities in relation to human settlement. *Koedoe* 33:87-97.

EU (1996). *Technical Assistance Tender Dossier for Protected Areas Development Programme in South–West Ghana* Project No 6 ACP GH 045. Prepared by MGM Environmental solutions for European Union, Accra.

FAO (2002). Community-based forest resource conflict management: a training package. Rome.

Friend, G.R. (1980). Wildlife conservation and softwood forestry in Australia: some considerations. *Aust. For*. 43: 217-224.

Grainger, J. (1994). *A Protected Area System Plan to Conserve Biodiversity in Ghana*. Unpublished report, GWD/IUCN, Accra

GWD (1991) *Elephant conservation plan of Ghana*. Department of Game and Wildlife, Accra.

Hall, J.B. and Swaine, M.D. (1981). *Distribution and Ecology of Vascular Plants in a Tropical Rain Forest: Forest Vegetation in Ghana*. Dr W. Junk Publishers, The Hague.

Harris, L. D (1984). *The Fragmented Forest: Island Biogeography Theory and Preservation of Biotic Diversity*. University of Chicago Press, Chicago.

Harris, L. D. and Scheck, J. (1991). From implications to applications: the dispersal corridor theory applied to the conservation of biological diversity. In: *Nature Conservation 2: the Role of Corridors*. Surrey Beattyand Sons, NSW, Australia.

Hawthorne, W. D. and Parren, M. P. E. (2000). How important are forest elephants to the survival of woody plant species in Upper Guinean forests? *Journal of Tropical Ecology*, 16, 133-150.

Hawthorne, W. D. (1993). Forest regeneration after logging in Bia South GPR, Ghana. O. D. A. *Forestry Series 3*. Natural Resources Institute, Chatham, UK.

Heffernan, P.J. and Graham, N.A.J. (2000). *Bia Elephant Census Ghana. Report I. Elephant Census*. Unpublished report. University of Newcastle, UK.

Hillman Smith, K., de Merode, E., Nicholas, A., Buls, B., and Ndey, A. (1995). Factors affecting elephant distribution ad the Garamba national park and surrounding reserves, Zare, with a focus on human-elephant conflict. *Pachyderm* 19: 39-48

Hoare, R.E. and Du Toit, J.T. (1999). Coexistence between people and elephants in African Savannas. *Conservation Biology* 13 (3) : 633 -639.

Hoare, R.E. (1995) Options for the control of elephants in conflict with people. *Pachyderm*. 19:54-63.

IUCN/WWF (2003). *Strategy for the conservation of West African elephants (Update)*. Unpublished report. AfESG (IUCN)\WWF.

Jachman, H. and Bell, R.H.V. (1984). The use of elephant droppings in assessing numbers, ocupance and age Structure: a refinement of the method. *African Journal of Ecology* 22:127 – 141.

Jachmann, H. and Croes, T. (1991). Effects of browsing on Elephants on the Combretum/ Termanalia at the Nazinga Game Ranch, Burkina Faso, West Africa. *Biological Conservation*.

Keller L.F. and Waller D.M. (2002). Inbreeding effects in wild populations. *Trends in Ecology and Evolution* 17: 230–241.

Laing, S.E., Buckland, S.T., Burn, R.W., Lambie, D. and Amphlett, A. (2003). Dung and nest surveys:estimating decay rates. Journal of Applied Ecology 40: 1102-1111.

Laryea, B. (2006). What happened to the elephants : Land cover change and its implications for forest elephants in the Goaso forest reserves, Ghana. M. Sc Thesis, IYC, Eschede – The Netherlands.

Laws, R.M. (1970). Elephants as agents of habitats and landscape change in East Africa *Oikos* 21:1-15.

Laws, R. M., Parker. I. S. C., Johnstone, R.C.B. (1975). *Elephants in North Bunyoro, Uganda*. London: Oxford University Press.

Lee, P.C. (1986). Early Social development among African elephant calves. *National Geographic Research* 2 : 388 – 401.

Lieberman, D., Lieberman, M. and Martin, C. (1987). Notes on seeds in elephant dung from Bia National Park, Ghana. *Biotropica*, 19, 365-369.

Lindenmayer, D.B. (1999). Future directions for biodiversity conservation in managed forests: indicator species, impact studies and monitoring programs. *Forest Ecology and Management*, 121, 177-189.

Littell, R., Milliken, G. et al. (2006). SAS for mixed models, 2nd edition. Cary, North Carolina, SAS Institute Inc.

Mader, H.J. (1984). Animal habitat isolation by roads and agricultural fields. *Biological Conservation* 29: 81-96.

Malima. C, Richard H. and Blanc, J.J (2005). Systematic recording of Human elephant conflict: a case study in south-eastern Tanzania. *Pachyderm* No. 38. January-June 2005.

Mann, C. C. and Plummer, M. L. (1995). Are wildlife corridors the right path? *Science*, 270, 1428-1430.

Martin, C. (1982). *Management plan for the Bia Wildlife Conservation Areas, part I. Final report IUCN/WWF project 1251*. Wildlife and National Parks Division, Ghana Forestry Commission, Accra, Ghana.

Martin, C. (1991). The rainforests of West Africa. Ecology, threats, conservation. Birkhäuser Verlag, Basel, Switzerland.

McClanahan, T.R. (1986). Quick population survey method using faecal droppings and a steady state assumption. *Africa Journal of Ecology* 24**:**37–39.

Mc Evedy, C. and Jones (1978). *Atlas of World Population History*. Penguin Books, London.

Merriam, G. (1991). Corridors and connectivity: animal populations in heterogenous environments. In: *Nature Conservation 2: the Role of Corridors* (Ed.W. E. Hudson). Surrey Beatty andSons, NSW, Australia.

Merz, G. and Hoppe-Dominik, B. (1991). Distribution and status of forest elephants in the Ivory Coast, West Africa. *Pachyderm* 14:22-24

Merz, G. (1981). Recherches sur la biologie de nutrition et les habitats préférés de I’éléphant de forét, Loxodonta africana cyclotis, Matschie 1900. *Mammalia*, 45, 299-312.

Merz, G. (1982). Untersuchungen uber lebernstraum und verhalten des Afrikanischen waldelefenten im Tai National Park der Republik elefenbeinkuste unter dem einfluss der regionalen entwicklung. PhD thesis, Ruprecht-Karls-Universitat, Heidelberg.

Merz, G. (1986). Movement patterns and group size of the African forest elephant Loxodonta africana cyclotis in the Tai National Park, Ivory Coast. *African Journal of Ecology*, 24. 133-136.

Milner-Gullard, E .J. and Beddington, J. R. (1993). The relative effects of hunting and habitat destruction on elephant population over time. *Pachyderm* 17:75-90.

Mpanduji, D. G., Hofer, H., Hilderbrandt, T. B., Goeritz, F., and East, M. L. (2002). Movement of elephants in the Selous-Niassa wildlife corridor, southern Tanzania. *Pachyderm 33: 18 – 31.*

Mubalama, K., L. (1996). *An assessment of crop damage by large mammals in the Reserve de Faunae Okapi – Ituri Forest – Zaire, with special emphasis on African forest elephant*. M.Sc. thesis. University of Kent.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B. and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403, 853-858.

Naugton – Treves, L . (1998) predicting patterns of crop damage by wildlife around Kibale National Park, Uganda.*Conservation Biology* 12:156 – 168.

Newmark, W.D., Manyanza, D.N., Gamassa, D.G.M. and Sariko, H.I. (1994). The conflict between wildlife and the local people living adjacent to protected areas in Tanzania: human density as a predictor. *Conservation Biology 8:249-255.*

Norton-Griffiths, M. (1978). *Counting animals.* African Wildlife Foundation, Nairobi. Oates, J.F., Abedi-Lartey, M., McGraw, W.S., Struhsaker, T.T. and Whitesides, G.H. (2000) Extinction of a West African red colobus monkey. *Conservation Biology* 14: 1526-1532.

Olivier, R.C.D. (1978) Conservation of the Asian elephant. *Environmental Conservation 5:156.*

Opoku, G.K. (1988). *The elephant (Loxodonta africana cyclotis) farm raiding around the Bia National Park: incidences, causes and solutions*. Diploma Thesis, University of Science and Technology Kumasi.

Oppong, J. (2000). Goaso Biodiversity Monitoring Unit, personal communication.

Osborn F. V and Parker, G. E. (2003). Linking two elephant refuges with a corridor in the communal lands of Zimbabwe. *African Journal of Ecology,* 41: 68-74

PADP (1998). *Large mammals survey of Bia and Ankasa.* Accra: Protected Area Development Project, Ghana Wildlife Division.

PADP (1999). *Socio–economic survey of the Ankasa and Bia Conservation Areas*. Protected Areas Development Programme, Wildlife Dept. EU Project No 6 ACP/GH 045.

PADP (2010). *Protected Area Development Project- Final Project report.* WD/LTS Int. /EDG to Min of finance and Economic Planning and the European Commission, Ghana.

Parker, I.S.C. and Graham, A.D. (1989). Men, elephants, and competition. *Symposium of Zoological Society of London.* 61:241-252.

Parren, M. P. E. and de Graaf, N. R. (1995). The quest for natural forest management in Ghana, Côte d'Ivoire and Liberia. *Tropenbos Series 13*. Tropenbos Foundation, Wageningen, The Nethelands.

Parren, M.P.E., de Leede, B.M. and Bongers, F. (2002). A proposal for a transnational forest network area for elephants in Ivory Coast and Ghana. *Oryx 36: 249-256*.

Parren, M.P.E. and Sam, M.K. (2003). *Elephant corridor creation and local livelihood improvement in West Africa*. Paper presented at a CIFOR conference titled 'Rural Livelihoods, Forests and Biodiversity' in Bonn, Germany, May19-23, 2003. CD ROM, CIFOR, Bogor, Indonesia.

Phillip Mensah, Camp 9 Leader, personal communication, 2004

Pitman, C.R.S. (1934). *Faunal Survey of Northern Rhodesia with Special Reference to Game, Elephant Control and National Parks*. Government Printer, Livingstone.

African Elephant Status Report (2002). African Elephant Specialist Group of the World Conservation Union. Kenya.

Poache, R. M. (1974). Ecology of the African Elephant (*Loxodonta, a. africana*) in Niger, West Africa. *Mammalia* 38: 567-580

Poole, J.H. (1994). Sex differences in the behaviour of African elephants In : *The Differences Between the Sexes* (Eds, R. Short and P. Lynch) Cambridge University Press, Cambridge.

Roth, H. H. and Douglas-Hamilton, I. (1991) Distribution and status of elephants in West Africa. *Mammalia* 55: 489-527.

Sachtler, M. (1968). *General report on national forest inventory in Liberia*. Technical Report No. 1. German Forestry Mission to Liberia, Bureau of Forest and Wildlife Conservation, Monrovia, Liberia.

Said, M. Y., Chunge, R., Craig, G.C., Thouless, C.R., Barnes, R. F. W. and Dublin, H. T. (1995). *African Elephant Database*. IUCN SSC Occasional Paper No.11.

Sam, M. K. (2000). *People and Elephants: The distribution of elephants in relation to crop damages around Bia Conservation Area during the 1999 raining season*. Unpublished Report. Nairobi. Human-Elephant Conflict Task Force. IUCN/SCC African Elephant Specialist Group.

Sam, M. K., Danquah, E., Oppong, S. K. and Ashie, E. A. (2005). Nature and Extent of Human-Elephant Conflict in Bia Conservation Area, Ghana. *Pachyderm* 38 (49-58).

Sam, M.K., Haizel, C. and Barnes, R.F.W. (1997). *Crop-raiding of elephants during the 1996 harvest season in Red Volta Valley (Upper East Region, Ghana)*. Unpublished report, Wildlife Department, Accra.

Sam, M. K., Haizel, C. A. K. and Barnes, R. F. W. (2002). Do cattle determine elephant distribution in the Red Volta Valley of northern Ghana? *Pachyderm 33:39-42*.

Sam, M.K., Okoumassou, K. and Barnes, R.F.W. (1996). *A preliminary survey of the elephants of North Eastern Ghana and Northern Togo*. Unpublished report, Wildlife Department, Accra.

Sam, M.K., Barnes, R.F. W. and Okoumassou, K. (1998). Elephants human ecology and environmental degradation in northeastern Ghana and northern Togo. *Pachyderm* 26: 61- 68.

Sam, M. K; Ayesu, S; and Kumordzi, B. B. (2003). A reconnaissance survey of the human-elephant conflict situation around Dadieso area in western Ghana. *Pachyderm* 35 (132-136).

Sam, M. K., Ewur, D. K., Binlinla, J., Wiafe, E., and Danquah, E. (2009). *Evaluation of low-tech method to combat elephant crop-raiding activities – a case in Kakum Conservation Area, Ghana*. A paper presented at the 2009 African Elephant Specialist Group Meeting. Nairobi.

Santiapillai, C. and Jackson, P. (1990). *The Asian Elephant: An Action Plan for its Conservation.* IUCN, Gland, Switzerland.

Saunders, D. A. and Hobbs, R. J. (1991). The role of corridors in conservation: what do we know and where do we go? In *Nature Conservation 2. The role of corridors* (eds. D. A., Saunders and R. J. Hobbs), pp. 421-427. Surrey Beatty and Sons, Chipping Norton, Australia.

Saunders, D.A., Hobbs R.J. and Margules C. R. (1991). Biological consequences of ecosystem fragmentation: A review. *Conservation Biology* 5: 18–32.

Seidensticker, J. (1984). *Managing elephant depredation in agricultural and forestry projects.* World Bank Technical Paper, World Bank, Washington D.C.

Shaffer, M.L. (1981). Minimum population sizes for species conservation. *Bioscience* 3 1: 13 1 - 134.

Short, J. (1981). Diet and feeding behaviour of the forest elephant. *Mammalia*, 45, 178-185.

Short, J. C. (1983). Density and seasonal movements of the forest elephant (Loxodonta africana cyclotis, Matscie) in the Bia National Park, Ghana. *African Journal of Ecology* 21: 175-184.

Sikes, S. K. (1975). *Report on preliminary elephant population survey in Bia National Park*. Type written.

Simberloff, D. and Cox, J. (1987). Consequences and costs of conservation corridors. *Conservation Biology* 1: 63-71.

Sitati, N.W, Walpole M.J, and Leader-Williams. (2005). *Journal of Applied Ecology*. 42, 1175-118.

Taylor, C. J. (1960). *Synecology and sylviculture in Ghana*. Thomas Nelson and Sons, Edinburgh.

Tchamba, M.N. and Mahamat, H. (1992). The effects of elephant browsing on the vegetation in Kalamaloué National Park, Cameroon. *Nature et Faune* 8,8-14.

Tewkesbury, J.J., Levey, D.J., Haddad, N.M., Sarget, S., Orrock, J.L., Weldon, A., Danielson, B.J., Brinkerhoo, J. Danschen, E.I. and Townsend, P. (2002). Corridors affect plants, animals, and their interactions in fragmented landscapes. *Proceedings of the National Academy of Sciences 99*: 12923-12926.

Thomas, L., Laalce, J.L., Strindberg, S., Marques, F.F.C., Buckland, S.T., Boarchers, D.L., Anderson, D.R., Burnham, K.P. Hedley, S.L. and Pollard, J.H. (2002). *Distance 4.0 Release 1*. Research Unit for Wildlife population Assessment, University of St. Andrews, U.K.

Van Rossum, F., De Sousa S.C. and Triest L. (2004). Genetic consequences of habitat fragmentation in an agricultural landscape on the common Primula veris, and comparison with its rare congener, P. vulgaris. *Conservation Genetics* 5: 231–245.

Versteegden, C. J. G. M. (1995). *Can corridors save the last forest elephants in the eastern Ivory Coast? The preservation of Loxodonta africana cyclotis Matschie in the remaining forest reserves in the east of Ivory Coast and the west of Ghana*.

Vucetich, J. A. and Waite T. A. (1998). On the interpretation and application of mean times of extinction. *Biodiversity and Conservation* 7(12): 1539–1547

Waitkuwait, W. E. (1992). Restauration d'un écosystème forestier: contribution de I'aménagement de la faune. Dans *Compte rendu séminaire sur I'aménagement intégré des forêts dense humides et des zones agricoles périphériques* (éds. A. P. Vooren, W. A. Blokhuis et A. J. C. Spijkerman, pp. 203-214. Tropenbos Series 1. La Fondation Tropenbos Wageningen, Pays-Bas.

Wambwa, E., Manyibe T., Litoroh M., Gakuya F., Kanyingi J. (2001). Resolving human–elephant conflict in Luwero District, Uganda, through elephant translocation. *Pachyderm*.

Warren, P. (1998). *Developing participatory and integrated watershed management. A case study.* FAO Series

WD (2000). *Strategy for the Conservation of Elephants in Ghana*. Wildlife Division (Forestry Commission), Accra, Ghana. Page 18

WD (2004). A Brief Guide to Establishing a CREMA. CRMU of the Wildlife Division of the Forestry Commission. Accra, Ghana.

WD (2009). *Training Manual – Community Resource Management Areas (CREMAs) – Ghana*. Wildlife Division (Ghana) and Living Earth (Ghana).

Willis, E.O. (1974). Populations and local extinctions of birds on Barro Colorado Island, Panama. *Ecological Monogram* 44: 153-169.

Wilson, D. and Ayerst, P. (1976). *White Gold: The story of African Ivory*. Heinemann, London

Wilson, E.O. and Willis, E.O. (1975). Applied biogeography. In: *Ecology and Evolution of Communities*. pp. 522-534. Edited by M.L. Cody and J.M. Diamond. Belknag Press, Cambridge, Mass.

Young, A., Boyle T. and Brown T. (1996). The population genetic consequences of habitat fragmentation for plants. *Trends in Ecology and Evolution* 11: 413–418.

Appendix 1: Survey of attitudes of members of fringe communities in selected forest reserves in the Goaso–Bia forest enclave on issues of corridor creation and elephant management.

Personal Information

1. Community……………………… Age…… Occupation…………….. Sex……..
2. Are you a native of this village? Yes or No
3. If farmer, how many farms do you have and what are the sizes?………………………..
4. How far is your farm from the reserves? * <1 km * 1-2 km * 3-5 km * 6-8 km *
5. In what way has the forest reserves affected your farming?……………………………..
6. If hunter, what animals do you hunt?…………………………………………………….
7. Do you know of any forest reserve in this area?…………………………………………
8. What benefit do you derive from the forest?……………………………………………
9. What benefit does your community derive from the forest?……………………………

Land Use Practices

10. What are the land use practices in the area? * farming * charcoal burning * fishing * others * (state)
11. What have you observed about the forests? * increased * reduced * no idea * (state)
12. If reduced, what is the cause? * bush burning * farming activities * others * (state)
13. Can something be done to improve the situation? * no * regulate logging * others * (state)
14. Have you been engaged in tree planting exercise before? Yes or No
15. Would you like to do it again? Yes or No
16. If Yes, why……………………………………………………………………………...
17. If No, why?……………………………………………………………………………..

Movement (pre and post independence)

18. Have you seen an elephant before? Yes or No
19. Have you observed any seasonal movement of elephants? Yes or No
20. If Yes, give date (s)………………… season (s)……….. ………………………….
place (s)………………… direction of movement……………………...
21. If No, did your fathers talk about elephants passing here some time ago? Yes or No
22. If Yes, give date (s)………………… season (s)……….. ………………………….
place (s)………………… direction of movement……………………...

Numbers

23. How many groups normally passed?……… average group size?…………………
24. Were calves normally in the group? Yes or No
25. Do you have any other animal coming to your farm? Yes or No
26. Observation about the elephants in last 10 years? * increased * reduced * no idea *
27. If increased, give reasons………………………………………………………………
28. If decreased, give reasons………………………………………………………………
29. Do you think elephants and wild animals should be protected/important? Yes or No
30. If Yes, why? * bush meat * heritage * tourism * ecosystem function * others * (state)

31. Is any part of the elephant used for medicinal purposes? Yes or No
32. If Yes, list specific parts used for treating various ailments……………………………

…………………………………………………………………………………………………
33. If No, give reasons……………………………………………………………………...

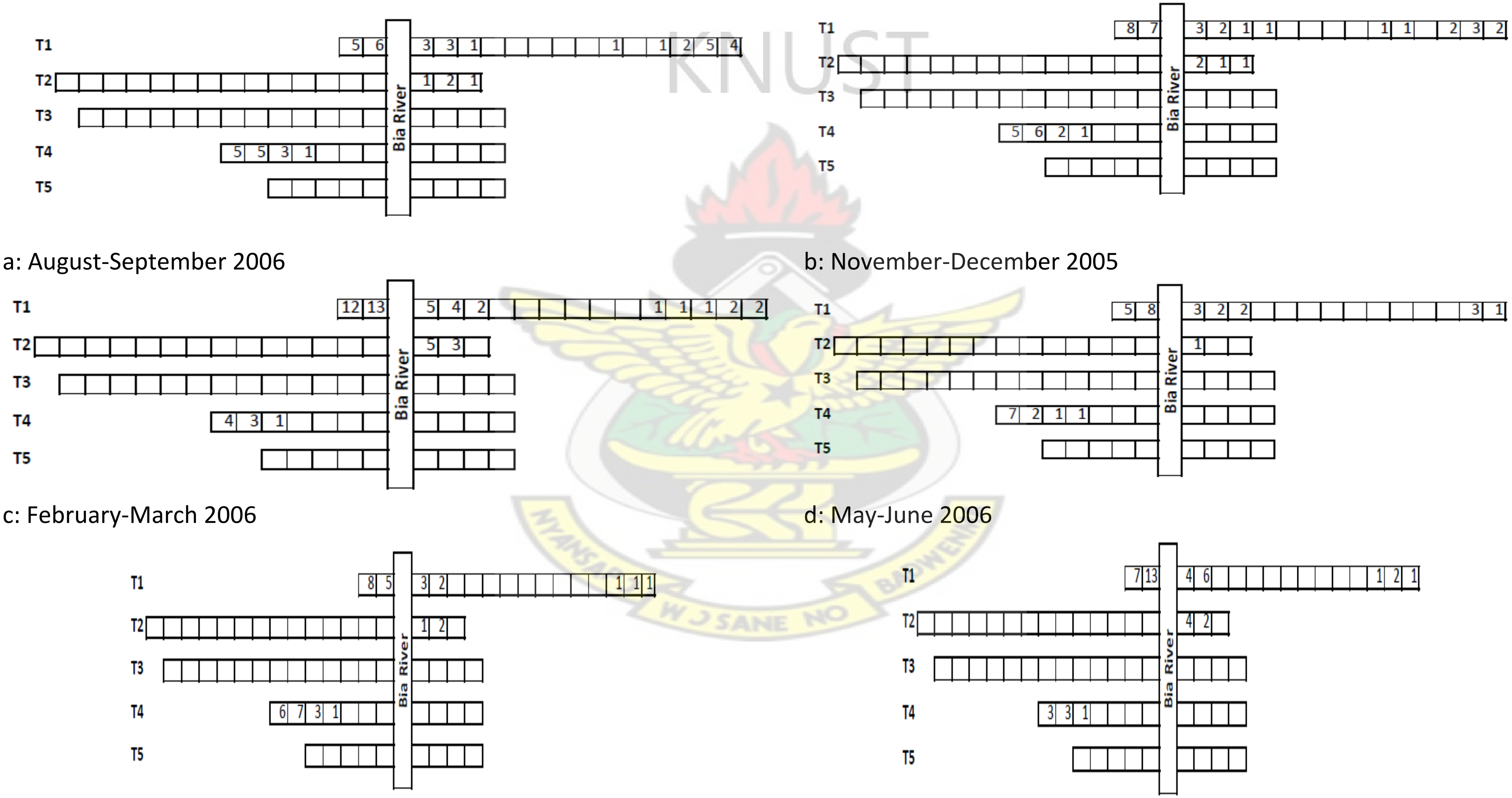
Human – Elephant Conflict and Management

34. Is Human – Elephant Conflict serious in your area? Yes or No
35. If Yes, what form does it take? * crop raids * human injury * well raids * others * (state)
36. In case of crop raids, give time of year your farm was raided?………………
37. Which crop (s) were raided?……………………………………………………………
38. Give date and time when elephants last visited your farm……………………………
39. Do you employ any elephant deterrent method on your farm? Yes or No
40. If Yes, give name (s)……………………………………….… Is it effective? Yes or No
41. Do you need help to drive the elephants away? Yes or No
42. Is the Goaso Biodiversity Monitoring Unit effective in dealing with HECs Yes or No
43. If No, give reasons…………………………………………………………………
44. Are there any problems associated with living in your area? Yes or No
45. If Yes, would you like to relocate and be compensated? Yes or No
46. Could you give practical reasons for dealing with elephants?.......................................
....
....

NGO Involvement in Elephant Management

47. Have you been taught how to drive elephants away from your farm? Yes or No
48. If Yes, who taught you?……………………………………………………………
49. If No, would you like to be taught?…………………………………………………….
50. Are you aware of any NGO in this area? Yes or No
51. If Yes, give name and their focus……………………………………………………
52. Are you willing to sacrifice part of your land to create elephant corridors? Yes or No
53. If No, give reasons……………………………………………………………………...

Appendix 2. Activities of elephants on transects along the Bia River to detect movements along the river. Each box represent one km



a: August-September 2006

b: November-December 2005

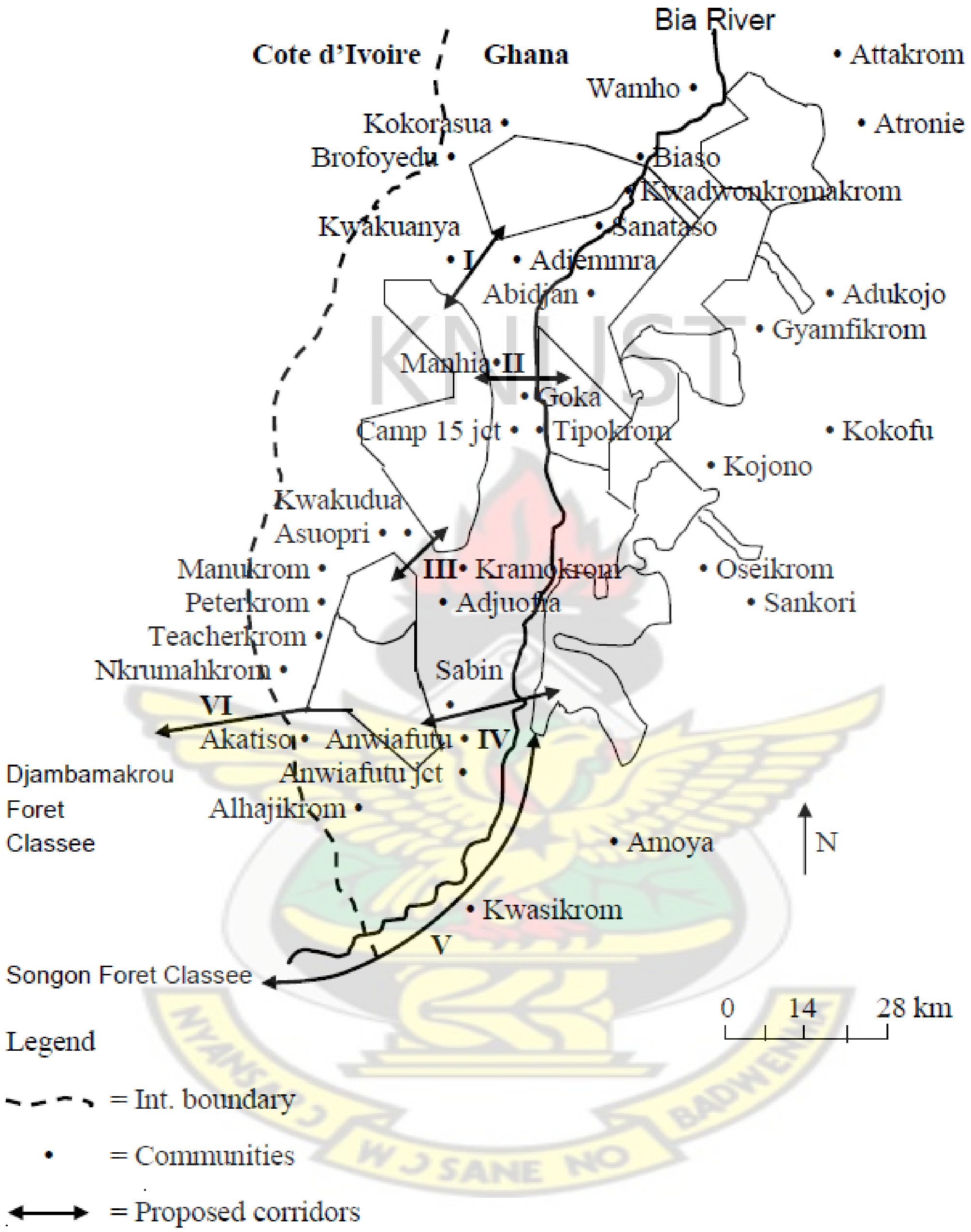
c: February-March 2006

d: May-June 2006

e: August-September 2006

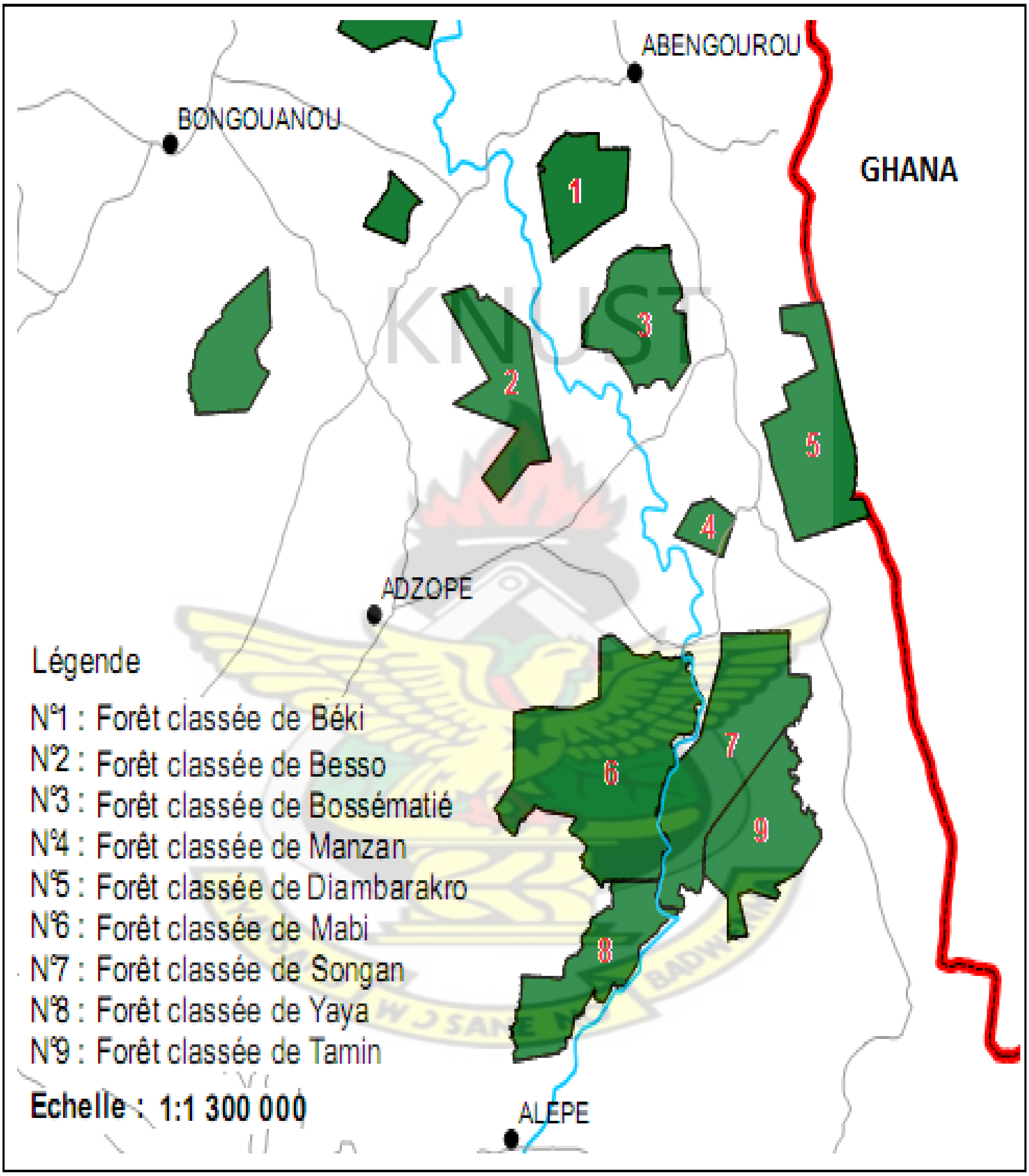
f: November-December 2006

Appendix 3: Study area with proposed corridors to link the Bia and Goaso elephant populations with those in eastern Cote d'Ivoire and fringe communities surveyed.



I. Mpameso FR to Bia North FR
II. Bia North to Subin FR
III. Bia North to Bia NP
IV. Bia RR to Krokosua Hills FR
V. Krokosua Hills, along the Bia River to Songon Foret Classee in Cote d'Ivoire
VI. Bia RR to Djambamakrou Foret Classee in Cote d'Ivoire

Appendix 4: Location of forest reserves (foret classee) on the Ivory Coast side of the border. ***Apart from FC Besso and Manzan, elephant are believed to use all the reserves***



Appendix 5: AfESG Elephant Damage Report Form

REGION:…………………………………………….. FORM No…………..
DISTRICT:………………………………………...
SUBDIVISION:………………………………………
VILLAGE:…………………………………… MAP GRID REFERENCE…………………
ENUMERATO NAME:……………………… DATE OF INCIDENCE……………………
COMPLAINANT (S) NAME (S):……………………………………………………….
DATE OF COMPLAINANT:………………...

CROP DAMAGE **QUALITY BEFORE DAMAGE** **AGE OF CROP**

CROP TYPE		GOOD	MEDIUM	POOR	SEEDLING	INTERM	MATURE
CROP 1	……….	………	………….	………….	…………...	…………	…………..
CROP 2	……….	………	………….	………….	…………...	…………	…………..
CROP 3	……….	………	………….	………….	…………...	…………	…………..
CROP 4	……….	………	………….	………….	…………...	…………	…………..
CROP 5	……….	………	………….	………….	…………...	…………	…………..

DIMENSIONS (Paces) OF TOTAL FIELD WHERE DAMAGE OCCURRED
LENGTH:………………..PACES
WIDTH:……………...…..PACES

DIMENSIONS (Paces) OF ACTUAL DAMAGED PORTION OF FIELD
LENGTH:………………..PACES
WIDTH:……………...…..PACES

OTHER DAMAGES TICK AND SPECIFY DETAIL
FOOD STORE
…………………………………………………………………………………….
WATER SUPPLY
…………………………………………………………………………………….
THREAT TO LIFE
…………………………………………………………………………………….
HUMAN INJURY
…………………………………………………………………………………….
HUMAN DEATH
…………………………………………………………………………………….
OTHER SPECIFY
…………………………………………………………………………………….

ELEPHANTS INVOLVED NUMBER VISUAL ID TRACK ID

GROUP SIZE (TOTAL)	…………..	…………….	……………..
Adult Male	…………..	…………….	……………..
Adult Female	…………..	…………….	……………..
Subadult / Calf	…………..	…………….	……………..

YOUR COMMENTS:………

Was This Report Forwarded?…………………
To Whom?…………………………………….
Where?……………………………………………….
When?……………………………………….
How?…………………………………………………

Appendix 6: Crop damage score in relation to affected farmers and raided farms

	Farmers	No. of Farms	No of Raids	Size of Farm (m2)	Area damaged (m2)	Damage category	Age score	Quality Score	Damage score	Interpretation
1	Kwaku Dabie	1	1	3,575	920	4	3	2	9	high and severe
2	Yaw Bae	1	1	2,310	1,590	5	3	3	11	high and severe
		1	1	3,210	1,560	4	3	3	10	high and severe
		1	1	2,160	1,010	4	3	3	10	high and severe
3	Kwaku Alhasan	1	1	2,440	980	4	3	2	9	high and severe
4	Kofi Sregeant	1	1	1,760	602	4	3	3	10	high and severe
		1	1	1,420	508	4	3	3	10	high and severe
5	Kofi Amankwa	1	1	2,410	702	4	3	3	10	high and severe
6	David Atibla	1	1	3,250	1,206	4	3	3	10	high and severe
		1	1	2,800	652	4	3	2	9	high and severe
7	Mr Philip Nketia	1	1	2,040	610	4	3	1	8	medium
8	Bro Samuel Nimo	1	1	3,100	1,030	4	2	2	8	medium
9	Alex Mensah	1	1	1,450	690	4	3	2	9	high and severe
10	Kwaku Bio	1	1	2,010	960	4	3	3	10	high and severe
11	Abena Sasu	1	1	4,020	1,420	4	2	3	9	high and severe
12	Badu Abraham	1	1	3,500	1,010	4	2	3	9	high and severe
13	David Nkrumah	1	1	4,200	1,170	4	3	3	10	high and severe
14	Osuman Baba	1	1	2,260	740	4	3	3	10	high and severe
		1	1	1,420	640	4	3	3	10	high and severe
15	Kofi Akuroku	1	1	1,200	510	4	3	3	10	high and severe
16	David Atebila	1	2	2,050	940	4	3	2	9	high and severe
17	Mr Augustin Ansu	1	1	1,820	820	4	3	2	9	high and severe
		1	1	2,560	1,100	4	3	2	9	high and severe
18	Kofi Adoku	1	2	2,200	1,760	5	3	3	11	high and severe
19	Samuel Ebena	1	2	2,140	1,090	5	3	3	11	high and severe
20	Opanyin Kyre	1	1	2,050	990	4	3	3	10	high and severe
21	Yaw Diawuo	1	1	1,610	720	4	3	3	10	high and severe
22	Sabi	1	1	3,360	480	3	3	1	7	Medium
23	Nana Osei Sarpong	1	1	1,620	1,460	6	2	3	11	high and severe
24	Ebenezer Amponsah	1	1	1,230	1,150	6	2	3	11	high and severe
		1	1	2,690	2,070	5	3	3	11	high and severe
25	Mr Samuel Appiah	1	1	1,920	1,220	5	3	2	10	high and severe
26	Teacher Asonmah	1	1	2,420	1,100	4	3	2	9	high and severe
		1	2	2,660	1,820	5	3	3	11	high and severe
27	Isaac Akyeampong	1	1	2,840	1,820	5	2	3	10	high and severe
28	Wofa Yesu	1	1	2,740	1,870	5	2	3	10	high and severe
29	Kwame Opoku	1	2	1,240	980	5	3	2	10	high and severe
30	Kwabena Kusase	1	1	2,750	640	3	3	2	8	Medium

Appendix 6 continuation

	Farmers	No of Farms	No of Raids	Size of Farm (m2)	Area Damaged (m2)	Damage category	Age Score	Quality score	Damage score	Interpretation
31	Kwaku Boakye	1	1	1,430	520	4	3	1	8	Medium
32	Jacob Atana	1	1	2,060	1,160	5	3	3	11	high and severe
33	Attah Gyampo	1	1	1,920	1,120	5	3	3	11	high and severe
34	Mr Agyekum	1	1	1,220	940	5	3	3	11	high and severe
35	Addo Kwadwo	1	1	1,560	960	5	2	3	10	high and severe
36	Mr P. K. Amoabeng	1	1	2,570	1,220	4	3	3	10	high and severe

Appendix 7: Comparing transects immediately inside the boundary of BCA to those immediately outside in 2004 and 2007

	No of dung-piles in 2004		Square root transformation		No of dung-piles in 2007		Square root transformation	
Transect	***Inside X***	***Outside Y***	***Inside √X***	***Outside √Y***	***Inside X***	***Outside Y***	***Inside √X***	***Outside √Y***
1	0	0	0.0000	0.0000	0	0	0.0000	0.0000
2	1	0	1.0000	0.0000	0	0	0.0000	0.0000
3	1	0	1.0000	0.0000	2	0	1.4142	0.0000
4	5	2	2.2361	1.4142	5	1	2.2361	1.0000
5	7	4	2.6458	2.0000	6	2	2.4495	1.4142
6	6	2	2.4495	1.4142	5	2	2.2361	1.4142
7	8	3	2.8284	1.7321	3	0	1.7321	0.0000
8	8	4	2.8284	2.0000	9	4	3.0000	2.0000
9	6	1	2.4495	1.0000	7	3	2.6458	1.7321
10	5	0	2.2361	0.0000	6	2	2.4495	1.4142
11	7	2	2.6458	1.4142	3	1	1.7321	1.0000
12	7	1	2.6458	1.0000	7	2	2.6458	1.4142
13	4	1	2.0000	1.0000	5	1	2.2361	1.0000
14	3	0	1.7321	0.0000	2	0	1.4142	0.0000
15	0	0	0.0000	0.0000	1	0	1.0000	0.0000
16	1	0	1.0000	0.0000	0	0	0.0000	0.0000
17	1	0	1.0000	0.0000	2	0	1.4142	0.0000
18	0	0	0.0000	0.0000	1	0	1.0000	0.0000
19	1	0	1.0000	0.0000	0	0	0.0000	0.0000
20	0	0	0.0000	0.0000	1	0	1.0000	0.0000

Appendix 8: Description of governance indicators used as variables for explaining elephant abundance

A. the Corruption Perceptions Index (CPI)

The CPI, prepared under the aegis of the TI, ranks countries annually in terms of the degree to which corruption is perceived to exist among public officials and politicians. It is a composite index in a scale of 0-10 prepared through a poll of polls - using corruption-related data from a number of expert surveys involving business leaders and analysts. All sources measure the overall extent of corruption (frequency and/or size of bribes) in the public and political sectors and all sources provide a ranking of countries. The countries with the lowest score are the ones where
corruption is perceived to be the highest among those included in the list.

B. the Worldwide Governance Indicators (WGI) project

The World Governance Indicators reports aggregate and individual governance indicators for 212 countries and territories over the period 1996–2008, for six dimensions of governance. The aggregate indicators combine the views of a large number of enterprise, citizen and expert survey respondents in industrial and developing countries. The individual data sources underlying the aggregate indicators are drawn from a diverse variety of survey institutes, think tanks, non-governmental organizations, and international organizations.

The indicators are Voice and Accountability (VA est.), Political Stability and Absence of Violence (PS est.), Government Effectiveness (Ge est.), Regulatory Quality (RQ est.), Rule of Law (RL est.), and Control of Corruption (CC est.). The WGI draw on data from 31 different sources that provide information on various aspects of governance.

C. The Mo Ibrahim Index

The Ibrahim Index provides a comprehensive ranking of African countries according to governance quality. The Ibrahim Index assesses governance against 84 criteria, making it the most comprehensive collection of qualitative and quantitative data that measures governance in Africa. The Ibrahim Index uses indicators across four main pillars: Safety and Rule of Law (SRL); Participation and Human Rights (PHR); Sustainable Economic Opportunity (SEO); and Human Development (HD) as proxies for the quality of the processes and outcomes of governance. While maintaining its progressive and consultative assessment of governance, it measures the delivery of public goods and services to citizens by government and non-state actors and remains funded and led by an African institution.

Appendix 9: Site and national levels variables that were correlated to elephant abundance and density

Elephant Site	Geo-logy	Site Rain	Human Density	Size of Range	No of Eleph	Eleph. density	F/S	P/U	CPI	VA	PS	GE	RQ	RL	Ge_est	Mi_OS	Mi_SRL	Mi_PHR	Mi_SEO	Mi_HD
Atakora HZ	B	1200	76.91	1356	343	0.253	S	P	2.9	0.27	0.34	-0.56	-0.47	-0.55	-0.59	57.89	69.78	65.76	45.91	50.08
Djona HZ	G	800	76.91	1216	36	0.030	S	U	2.9	0.27	0.34	-0.56	-0.47	-0.55	-0.59	57.89	69.78	65.76	45.91	50.08
Pendjari BR	B	1100	76.91	2827	788	0.279	S	P	2.9	0.27	0.34	-0.56	-0.47	-0.55	-0.59	57.89	69.78	65.76	45.91	50.08
W du Benin NP	B	800	76.91	5872	56	0.010	S	P	2.9	0.27	0.34	-0.56	-0.47	-0.55	-0.59	57.89	69.78	65.76	45.91	50.08
Arly NP	B	900	59.47	1224	422	0.345	S	P	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
Bontioli Partial & Total FC	G	977	59.47	422	50	0.118	S	P	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
Diefoula FC	G	1175	59.47	880	26	0.030	S	P	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
Konkom-bouri HZ	G	945	59.47	1300	490	0.377	S	U	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
Mohoun PA	G	825	59.47	3296	541	0.164	S	P	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
Nazinga GRc	G	912	59.47	940	350	0.372	S	P	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
Ouamou HZ	G	630	59.47	644	73	0.113	S	U	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
Pama Partial FnR	G	925	59.47	2230	200	0.090	S	P	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
Singou Partial FnR	G	839	59.47	1920	618	0.322	S	P	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
W du Burkina NP	B	806	59.47	2412	740	0.307	S	P	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
Zabre department	B	900	59.47	600	150	0.250	S	U	3.2	-0.36	-0.07	-0.73	-0.41	-0.48	-0.34	51.57	64.70	53.61	46.02	41.95
Abokoame-kro FnR	G	1129	65.60	135	11	0.081	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Azagny NP	G	1651	65.60	218	65	0.298	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Beki-Bossematie FC	G	1625	65.60	389	35	0.090	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Bolo forest	G		65.60	88	5	0.057	F	U	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Comoe NP	G	1200	65.60	11500	10	0.001	S	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37

Davo forest	G	1429	65.60	126	20	0.159	F	U	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Duekoue forest	G	1722	65.60	536	6	0.011	F	U	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Fresko forest	G	1465	65.60	2229	60	0.027	F	U	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Go-Bodienou forest	G		65.60	600	20	0.033	F	U	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Goin-Cayally FC	G	1443	65.60	1890	70	0.037	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Haut Bandama FC	G	1133	65.60	1230	20	0.016	S	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Haut Sassandra FC	G	950	65.60	1024	30	0.029	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Keregbo forest	G	1200	65.60	213	30	0.141	F	U	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Marahoue NP	G	1251	65.60	1010	54	0.053	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Mont Peko NP	G	1495	65.60	340	40	0.118	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Mont Sangbe NP	G	1332	65.60	950	47	0.049	S	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Niegre FC	G	1400	65.60	1056	50	0.047	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Okromodou forest	G	1800	65.60	945	50	0.053	F	U	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Scio FC	G	1750	65.60	1338	30	0.022	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Songan-Tamin-Mabi-Yaya FC	G	1500	65.60	1698	20	0.012	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Tai ecosystem	G	1850	65.60	3500	75	0.021	F	P	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Tene forest	G	1300	65.60	4	5	1.250	F	U	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Tiapleu forest	G	1500	65.60	280	10	0.036	F	U	2.05	-1.32	-2.16	-1.38	-0.97	-1.54	-1.20	36.07	36.54	27.70	38.65	41.37
Ankasa CA	G	1875	99.54	509	41	0.081	F	P	3.8	0.44	0.21	-0.15	-0.05	-0.07	-0.13	64.37	72.16	71.07	48.26	65.99
Bia CA	G	1625	99.54	306	135	0.441	F	P	3.8	0.44	0.21	-0.15	-0.05	-0.07	-0.13	64.37	72.16	71.07	48.26	65.99
Chichiban Corridor	B	1320	99.54	290	12	0.041	S	U	3.8	0.44	0.21	-0.15	-0.05	-0.07	-0.13	64.37	72.16	71.07	48.26	65.99
Digya NP	B	1375	99.54	3478	357	0.103	S	P	3.8	0.44	0.21	-0.15	-0.05	-0.07	-0.13	64.37	72.16	71.07	48.26	65.99
Goaso forest	G	1350	99.54	2035	87	0.043	F	P	3.8	0.44	0.21	-0.15	-0.05	-0.07	-0.13	64.37	72.16	71.07	48.26	65.99

Kakum CA	G	1625	99.54	366	164	0.448	F	P	3.8	0.44	0.21	-0.15	-0.05	-0.07	-0.13	64.37	72.16	71.07	48.26	65.99
Mole NP	B	1100	99.54	4504	401	0.089	S	P	3.8	0.44	0.21	-0.15	-0.05	-0.07	-0.13	64.37	72.16	71.07	48.26	65.99
Red & White Volta Ecosystem	B	950	99.54	1370	46	0.034	S	P	3.8	0.44	0.21	-0.15	-0.05	-0.07	-0.13	64.37	72.16	71.07	48.26	65.99
Oure Kaba and Sansale	G		40.83	691	57	0.082	F	U	1.75	-1.23	-1.72	-1.31	-1.02	-1.44	-1.15	41.65	47.34	36.41	35.82	47.05
Ziama SNR	G	2382	40.83	455	214	0.470	F	P	1.75	-1.23	-1.72	-1.31	-1.02	-1.44	-1.15	41.65	47.34	36.41	35.82	47.05
Corubal Dulombi Area	G		39.87	1342	7	0.005	F	U	2.05	-0.64	-0.38	-1.26	-1.07	-1.34	-1.09	43.55	45.75	50.33	30.85	47.27
Barrobo NF	G		35.51	640	100	0.156	F	P	2.25	-0.47	-1.26	-1.28	-1.42	-1.18	-0.71	41.15	40.43	47.43	29.88	46.87
Gola, Kpelle and Lorma NF	G	2700	35.51	2071	500	0.241	F	P	2.25	-0.47	-1.26	-1.28	-1.42	-1.18	-0.71	41.15	40.43	47.43	29.88	46.87
Grebo NF	G	2500	35.51	2604	230	0.088	F	P	2.25	-0.47	-1.26	-1.28	-1.42	-1.18	-0.71	41.15	40.43	47.43	29.88	46.87
Krahn Bassa NF	G	2751	35.51	5142	500	0.097	F	P	2.25	-0.47	-1.26	-1.28	-1.42	-1.18	-0.71	41.15	40.43	47.43	29.88	46.87

North East NF	G		35.51	130	33	0.254	F	U	2.25	-0.47	-1.26	-1.28	-1.42	-1.18	-0.71	41.15	40.43	47.43	29.88	46.87
Sapo NP	G	2596	35.51	1292	313	0.242	F	P	2.25	-0.47	-1.26	-1.28	-1.42	-1.18	-0.71	41.15	40.43	47.43	29.88	46.87
Gourma Range	B	275	10.46	37991	498	0.013	S	U	2.9	0.29	-0.08	-0.64	-0.37	-0.32	-0.42	53.64	62.37	59.88	47.60	44.71
Baba N`Rafi forest	G	650	12.10	430	17	0.040	S	U	2.7	-0.36	-0.55	-0.83	-0.55	-0.84	-0.87	45.73	56.31	49.87	40.85	35.89
W du Niger NP	G	850	12.10	2294	85	0.037	S	P	2.7	-0.36	-0.55	-0.83	-0.55	-0.84	-0.87	45.73	56.31	49.87	40.85	35.89
Andoni Island	B	3183	167.50	215	6	0.028	F	U	2.45	-0.58	-2.01	-0.95	-0.94	-1.20	-1.10	45.44	46.36	42.97	42.08	50.34
Chad Basin	F	400	167.50	2300	100	0.043	S	P	2.45	-0.58	-2.01	-0.95	-0.94	-1.20	-1.10	45.44	46.36	42.97	42.08	50.34
Cross River NP	M	3500	167.50	239	74	0.310	F	P	2.45	-0.58	-2.01	-0.95	-0.94	-1.20	-1.10	45.44	46.36	42.97	42.08	50.34
Gashaka-Gunfi NP	B	1800	167.50	5860	30	0.005	S	P	2.45	-0.58	-2.01	-0.95	-0.94	-1.20	-1.10	45.44	46.36	42.97	42.08	50.34
Kambari	M	1054	167.50	414	5	0.012	S	U	2.45	-0.58	-2.01	-0.95	-0.94	-1.20	-1.10	45.44	46.36	42.97	42.08	50.34
Kwiambana GR	G	1100	167.50	1715	80	0.047	S	P	2.45	-0.58	-2.01	-0.95	-0.94	-1.20	-1.10	45.44	46.36	42.97	42.08	50.34
Okomu GS	B	2032	167.50	1082	40	0.037	F	P	2.45	-0.58	-2.01	-0.95	-0.94	-1.20	-1.10	45.44	46.36	42.97	42.08	50.34
Omo FR	B	2000	167.50	4068	30	0.007	F	U	2.45	-0.58	-2.01	-0.95	-0.94	-1.20	-1.10	45.44	46.36	42.97	42.08	50.34
Taylor Creek	B	4000	167.50	145	25	0.172	F	U	2.45	-0.58	-2.01	-0.95	-0.94	-1.20	-1.10	45.44	46.36	42.97	42.08	50.34
Yankari NP	B	950	167.50	3224	348	0.108	S	P	2.45	-0.58	-2.01	-0.95	-0.94	-1.20	-1.10	45.44	46.36	42.97	42.08	50.34
Niokolo-Koba NP	B	1050	63.89	9130	2	0.000	S	P	3.5	-0.01	-0.19	-0.20	-0.29	-0.32	-0.40	56.74	63.30	65.06	48.07	50.75
Bagbe River Forest	G	2186	77.50	349	5	0.014	F	P	2	-0.44	-0.33	-1.13	-1.04	-1.13	-1.06	46.56	44.17	58.12	38.21	42.45
Gola East FR	G	2700	77.50	295	60	0.203	F	P	2	-0.44	-0.33	-1.13	-1.04	-1.13	-1.06	46.56	44.17	58.12	38.21	42.45
Gola North FR	G	2700	77.50	480	50	0.104	F	P	2	-0.44	-0.33	-1.13	-1.04	-1.13	-1.06	46.56	44.17	58.12	38.21	42.45

Outamba-Kilimi	G	2126	77.50	358	80	0.223	F	P	2	-0.44	-0.33	-1.13	-1.04	-1.13	-1.06	46.56	44.17	58.12	38.21	42.45
Abdoulaye FnR	B	1169	116.56	300	4	0.013	S	P	2.5	-1.28	-0.70	-1.50	-0.95	-0.96	-0.98	40.01	53.43	30.86	30.04	45.72
Fazao-Malfakassa NP	B	1318	116.56	1920	61	0.032	S	P	2.5	-1.28	-0.70	-1.50	-0.95	-0.96	-0.98	40.01	53.43	30.86	30.04	45.72
Keran NP	B	1050	116.56	1636	0	0.000	S	P	2.5	-1.28	-0.70	-1.50	-0.95	-0.96	-0.98	40.01	53.43	30.86	30.04	45.72
Oti-Mandouri FnR	B	1200	116.56	1484	0	0.000	S	U	2.5	-1.28	-0.70	-1.50	-0.95	-0.96	-0.98	40.01	53.43	30.86	30.04	45.72

HZ- Hunting Zone; FC- Foret Classee; FnR- Faunal Reserve; NP- National Park; NF- National Forest; FR- Forest Reserve; GR- Game Reserve; GRc- Game Ranch; PA- Protected Area; BR- Biosphere Reserve; CA- Conservation Area; GS- Game Sanctuary; SNR- Strict Nature Reserve

Variables: F/S: Forest/Savanna; P/U: Protected/Unprotected range; CPI- Corruption Perception Index; Voice and Accountability; GE- Government Effectiveness; PS- Political Stability and Absence of Violence; RQ- Regulatory Quality; RL- Rule of Law; CC- Control of Corruption; Mi_SRL- Safety and Rule of Law; Mi_PHR- Participation and Human Rights; Mi_SEO- Sustainable Economic Opportunity; Mi_HD- Human Development