LONG TERM SYSTEM FOR MONITORING THE ILLEGAL KILLING OF ELEPHANTS (MIKE)

ELEPHANT SURVEY 2004

KAKUM NATIONAL PARK, GHANA

PROJECT TITLE: CITES – MIKE KAKUM NATIONAL PARK ELEPHANT SURVEY 2004

(FINAL REPORT)

PROJECT PERIOD: 1ST JUNE TO 30TH DECEMBER 2004

PREPARED FOR: CITES MIKE PROGRAMME
P. O. BOX 68200, 2ND FLOOR ACS PLAZA,
LENANA ROAD, NAIROBI - KENYA

PREPARED BY: A ROCHA GHANA
P. O. Box KN 3480
KANESHIE - ACCRA
GHANA

PROJECT OFFICIALS

PROJECT EXECUTANT:	Emmanuel Danquah, Scientific Officer, A Rocha Ghana, Accra
PROJECT SUPERVISOR:	Moses Kofi Sam, Elephant Expert/ Research Coordinator, Wildlife Division - Ghana
CITES-MIKE CONTACT PERSON:	Nigel Hunter, Director, CITES-MIKE Programme, Nairobi
A ROCHA GHANA CONTACT PERSON:	Theresa Maa Ohui Ayiku, Projects Coordinator, A Rocha Ghana, Accra

EXECUTIVE SUMMARY

Based on a ten-day reconnaissance exercise undertaken in May 2004, the Kakum Conservation Area (KCA) was divided into two strata; high and low-density. A retrospective dung decay experiment was then conducted from June to August 2004 during the long wet season in the KCA. A total of 147 fresh dung piles were marked and monitored and this yielded an estimated mean survival time of 67.0424 (SE=3.4620, CV=0.00516).

In September 2004, a line transect survey was carried out. Sixty (60) transects were systematically distributed within both strata based on dung pile density recorded during the reconnaissance. The average dung density calculated for KCA was 583.65 dung piles per sq. km. Estimates of elephant numbers were calculated based on a retrospective dung decay model, as well as two other estimation models (rainfall and steady state assumption models) and compared with previous estimates, including one based on DNA collected from dung.

The various estimates fall into two separate fields; estimates between 164 and 170 (the current retrospective estimate and Eggert's DNA accumulation curve), and those between 225 and 239 (Eggert's DNA capture-recapture and the various EBM dung counts as well as current rainfall model). We recommend survey work to be repeated at two year intervals in order to show which methods are biased.

Analysis of dung pile distribution in relation to human\ecological variables showed that distance to the nearest boundary line explained a high proportion of the variance in elephant density. Elephants were more or less clustered within 3km from the park boundary line. Illegal activity was weakly correlated to elephant abundance but was significantly influenced by proximity to the boundary line, i.e. more signs of illegal activity were seen as one moved away from the boundary line into the park. This suggests that poachers may be keeping away from the periphery of KCA, to possibly, avoid being detected by patrol teams whose activities effectively cover these areas.

ACKNOWLEDGEMENT

A Rocha Ghana wishes to gratefully acknowledge the contributions of the following organizations; CITES – MIKE, for largely financing this project and the Wildlife Division of the Forestry Commission of Ghana for provision of staff and facilities.

A Rocha Ghana is also thankful to the following people; Mr. Ofori- Frimpong (Executive Director of WD) and Mr. Lamptey (International Conventions Manager of WD) for granting permission to work within the KCA and the management and staff of the KCA, especially Mr. Cletus Nateg (Park Manager) and his two deputies, Mr. Joseph Bilinla and Mr. Sylvester Azika without whom this study would not have been possible.

We are also very grateful for the comments and suggestions received from Mr. M. K. Sam and Dr. R. F. W. Barnes.

This survey and the production of this report were facilitated with the financial assistance of the **United States Fish and Wildlife Service**.

The views expressed herein are those of the author and can therefore in no way be taken to reflect the official opinion of the United States Fish and Wildlife Service.

TABLE OF CONTENTS

LIST OF FIGURES **PAGE**

LIST OF TABLES **PAGE**

1.0 INTRODUCTION

Elephants were once found throughout West Africa, from the coast, north to the Sahel, and from Senegal, east to Nigeria. But heavy hunting and loss of habitat have taken a severe toll on their populations. Today the plight of elephants is far graver in West African than in eastern, southern, or central Africa. Currently, West Africa accounts for 4% of the continent's elephant range (Blanc *et al*., 2003). Sixty-three percent of the West African populations listed in Blanc *et al*. (2003) are thought to consist of less than 100 elephants.

Information on elephant abundance and factors that affect abundance over time is essential to manage wild elephant populations effectively (Laing *et al*., 2003). There is a wide variety of techniques available to obtain estimates of elephant numbers (Blanc *et al*. 2003) including methods that exist for direct surveys of animals in general (Laing *et al*., 2003, Norton-Griffiths, 1978). In the savanna-dominated habitats of eastern and southern African forests where good visibility facilitates uninterrupted observation from the air, direct aerial sample counts are commonly used. Unfortunately, aerial surveys require great technical expertise and coordination, as well as the use of expensive equipments (Blanc *et al*., 2003). Furthermore, this technique cannot be used in equatorial forests where the closed tree canopy precludes aerial observation (Barnes, 2001; Barnes *et al*. 1997b). The dense undergrowth also renders direct ground counts of elephants particularly problematic (Eggert *et al*., 2003; Barnes *et al*., 1995; Barnes & Jensen, 1987) rare, fleeting and potentially dangerous (Morgan and Lee, 2003). Thus, to obtain objective estimates of elephant populations in forests, one is obliged to use indirect methods (Barnes & Dunn, 2002; Barnes, 2001).

A new indirect sample counting technique has recently been introduced for estimating the size of elephant populations in forests (Eggert *et al*., 2003). Kakum Conservation Area (KCA) is one of the few sites in West Africa where this technique has been tested. This census method relies on the identification of individuals based on DNA extracted from dung piles and it is likely to find wide application in sites where more traditional methods are unlikely to give reliable results (Blanc *et al*. 2003).

Nevertheless, dung counts remain the most common type of indirect census method for counting elephants (Eggert *et al*., 2003; Barnes & Dunn, 2002) and it produces population estimates as accurate and precise as those obtained using other methods for a wide range of species (Barnes, 2001; 2002). Dung counts relate elephant number to a count of dung-piles detected along line transects, corrected for variables such as the rainfall in the 2 months before the count, rate of deposition of dung piles and rate of dung decay (Barnes & Dunn, 2002; Barnes *et al*., 1997a). The last of these is usually the most problematic (Laing *et al*., 2003) and many elephant surveyors have relied on data from other sites, usually many kilometers from where they are working. Unfortunately, decay rates can be highly variable between sites and in many cases, monitoring has not been initiated at the same time as the dung surveys. This approach, termed the 'prospective' method, can lead to significant biases because it does not estimate the mean time to decay of dung piles that are present at the time of the survey (Laing *et al*., 2003).

While the DNA technique involves a rather complex laboratory analysis and could take a much longer period to estimate numbers, a new alternative and seemingly more advantageous approach which estimates the mean time to decay of dung piles already present at the time of the survey (Laing *et al*., 2003), known as the 'retrospective' dung count, has been developed. While the mathematical theory underpinning this method is very solid, it involves less fieldwork and does not require repeated visits to marked signs.

The KCA provides the opportunity to refine and test survey techniques like the 'retrospective' method of dung counts especially since it has already undertaken many of the steps prerequisite to such testing (Barnes *et al*., 1997a; Barnes *et al*., 1994; Barnes, 1993; Barnes and Jensen, 1987). In June 2004 the CITES-MIKE programme supported the Wildlife Division of the Forestry Commission of Ghana and A Rocha Ghana to initiate a survey of the elephants of Kakum using the 'retrospective' dung survey method to obtain estimates to be compared with estimates of two other estimation models; a steady state assumption model (McClannahan 1986), which employs a 'prospective' dung decay rate, and a rainfall model (Barnes & Dunn, 2002; Barnes *et al*., 1997a) that makes no assumptions concerning either steady states or normality.

The DNA survey technique is assumed to have provided the most accurate estimate of elephant numbers for KCA since 1997 when Eggert *et al*. (2003) collected their data. Hence, for the basis of evaluation, the estimate provided by the DNA technique was to be compared with estimates derived from the retrospective, steady state assumption, and rainfall models.

The project was also to investigate and determine factors (human, ecological etc.) that affected elephant conservation and abundance in the KCA.

1.1 Objectives

The objectives of this project are to:

1. undertake an elephant survey of KCA using the 'retrospective' dung decay rate model
2. compare results of a DNA technique used in KCA (Eggert, *et al*., 2003), with results of the above and results using the steady state assumption (McClannahan 1986) and rainfall models (Barnes & Dunn, 2002; Barnes *et al*., 1997a)
3. provide some measure of possible encounter rates for illegal activities (especially, relating to elephant poaching and carcasses sightings) on alternative travel recces
4. determine factors influencing elephant conservation and abundance in KCA

1.2 Study Site

The Kakum Conservation Area (KCA) is located in southern Ghana and comprises the Kakum National Park and its adjacent Assin Attandanso Resource Reserve (Figure 1). Both forests form a block of 366km^2 in the moist evergreen zone (Hall and Swain, 1976).

The vegetation comprises mainly of *Celtis zenkeri-Triplochiton scleroxylon* moist semi-deciduous forest, which is transitional towards the more typical rainforest *Lophira alata-Triplochiton scleroxylon* association in the southern part of the Kakum Reserve (Dudley *et al.*, 1992).

Rainfall is bimodal, occurring in March-July and September-November and a long dry season between December and March. The prevailing winds are southwesterly and generally light. The average relative humidity is about 85% with temperatures fluctuating between 10.2°C and 31.6°C (Ghana Wildlife Division, 1996).

Eggert, *et al.* (2003) gave two estimates for its elephant population based on two different methods of analysis; accumulation curve: 170 elephants (CLs from 96 to 270) and capture-recapture method: 225 (CLs from 173 to 308).

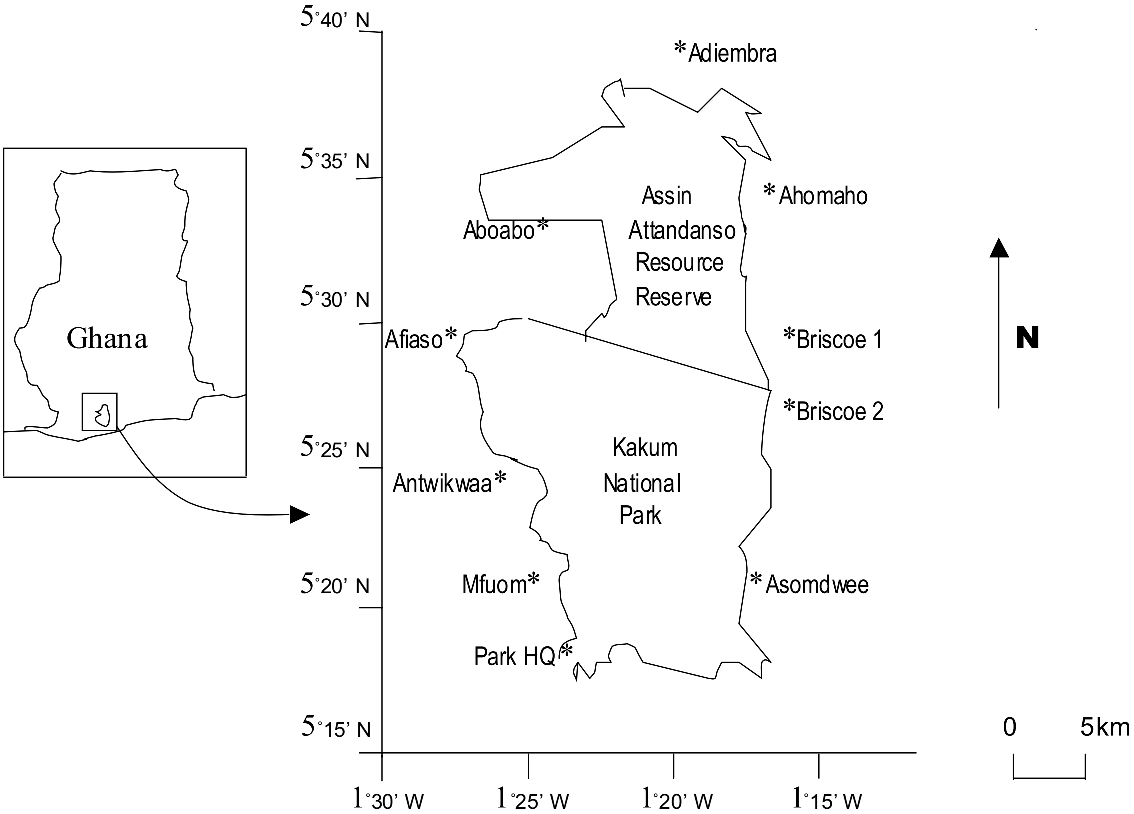


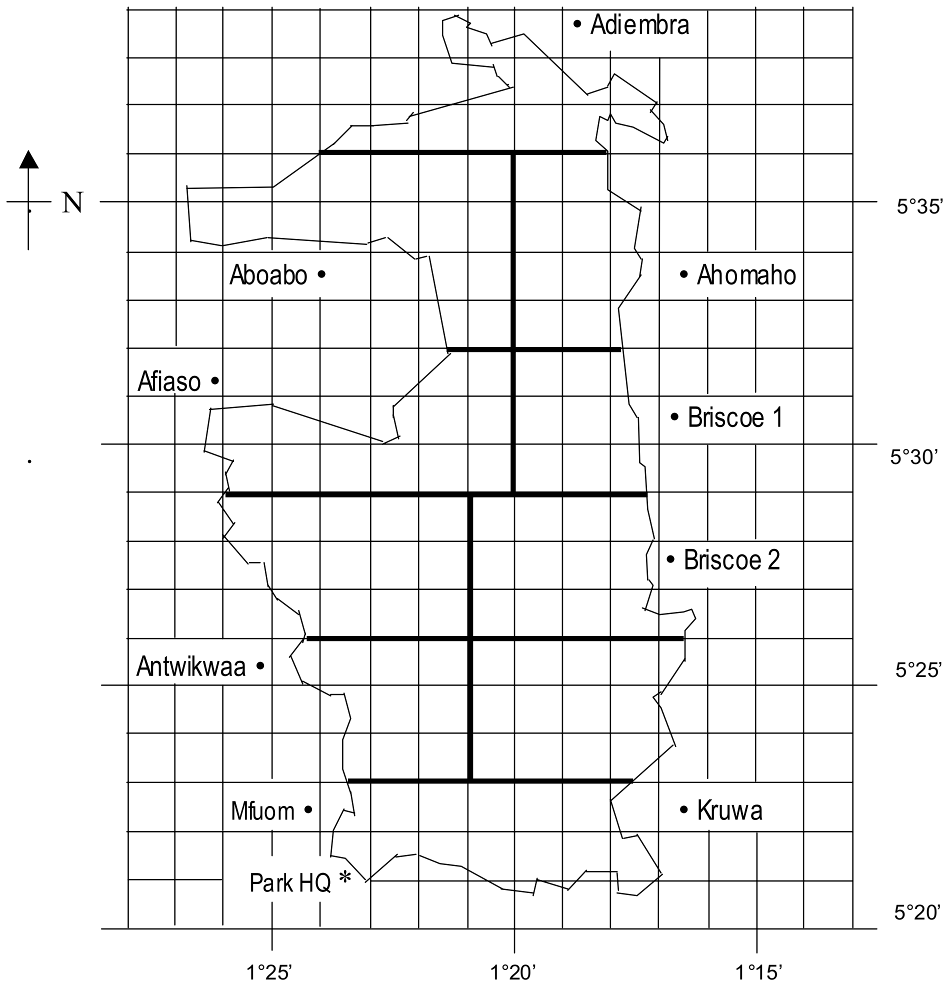
Figure 1: The Kakum Conservation Area. The inset map shows the location of KCA in Ghana.

2.0 MATERIALS AND METHODS

2.1 Reconnaissance

A ten-day reconnaissance exercise to provide data on the relative dung pile density in the Kakum Conservation Area (KCA) was undertaken from the 22nd to 31st of May 2004 as wildlife guards performed their routine patrol duties. The intention was to serve as a basis for stratification of KCA.

To equalize sampling effort, KCA was divided into 10 blocks of approximately 36 km2 (Figure 2). Each block was thoroughly searched for elephant dung piles by a patrol team of four persons each, led by a compass man (team leader).



Legend

•: Wildlife camps

▬ : Boundary of classified blocks

Scale 1: 1.84km

Figure 2: Kakum Conservation Area classified into ten blocks

2.2 Stratification

The reconnaissance exercise showed that elephant dung density decreased suddenly around the periphery of KCA as one moved beyond 3km from the boundary line towards the middle portions.

Hence, a grid consisting of cells, each one-minute of latitude or longitude was superimposed on the map of the KCA and used to divide it into 2 strata: high and low-density strata. Dung density in the high and low-density strata was in the proportion of 4:1. The high-density stratum (232.3km2) consisted of a one and half cell band (approx. 3km) from the boundary line. The low-density stratum (133.7km2) covered the rest of the KCA (Figure 3).

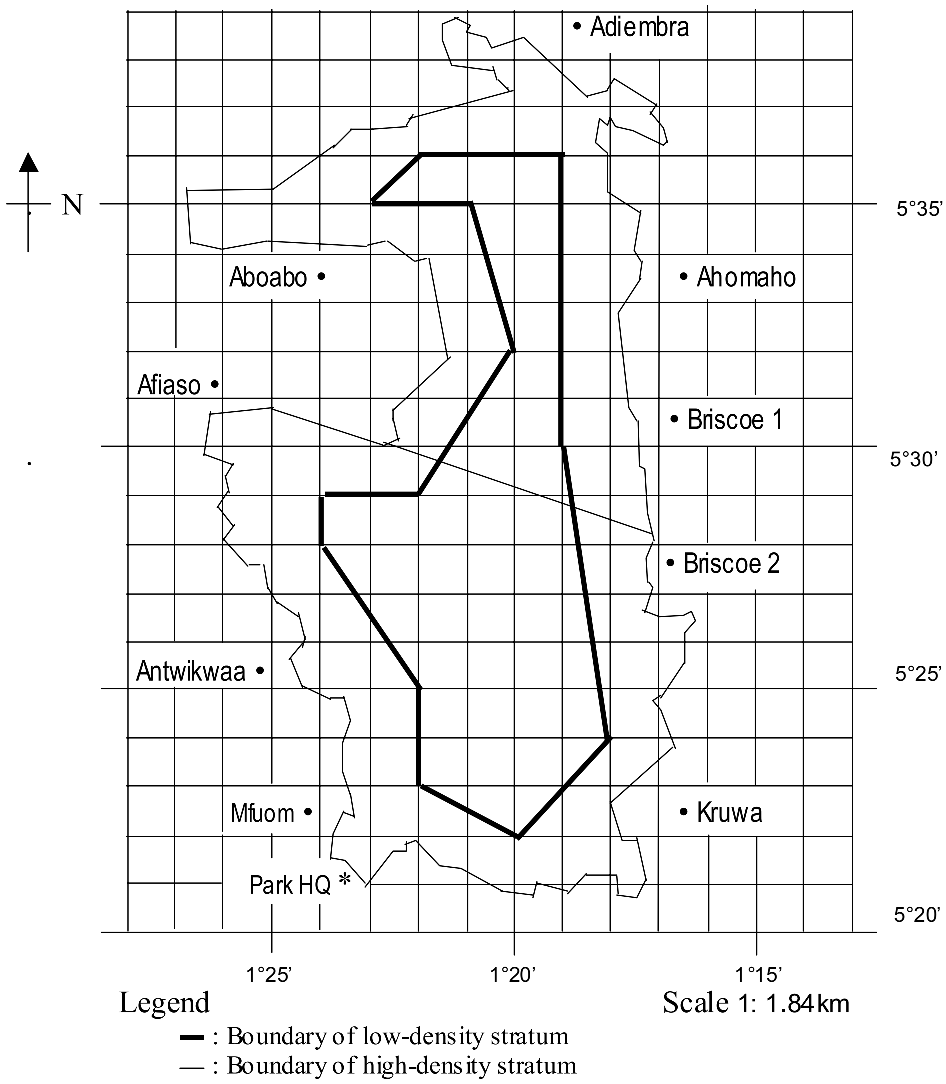


Figure 3: Kakum Conservation Area showing high and low density strata

2.3 Experimental Procedure

2.3.1 Retrospective Dung Decay Rate Experiment

At KCA the time from defecation to disintegration of elephant dung piles is affected by rainfall (Barnes *et al*., 1997a), and a previous dung decay study had shown that about 90% of dung piles completely disintegrated by three months in Kakum (Barnes *et al*., 1997a). Hence we planned to search the park (each block) for fresh dung-piles on five occasions between June and August 2004, at three weeks intervals.

Strata within each block were sampled in proportion to the occurrence of dung piles (Laing *et al*., 2003; Buckland *et al.,* 2001; Norton-Griffiths, 1978) recorded during the reconnaissance exercise. Hence, the high-density stratum within each block (peripheral areas) was sampled on four occasions whilst the low-density areas (inner sections) were sampled once.

2.3.2 Line Transect Dung Count

A two-day recce (involving about 60km of recce transects) was again undertaken to complement the above to assist in stratifying the park before commencing the main line transect dung count.

Sampling effort was then allocated to a high or low stratum based on dung densities recorded during the reconnaissance (Norton-Griffiths, 1978). Thus, of 60 transects of length 1km each used in the main line transect dung count, the first was randomly placed and the remaining 59 systematically distributed in the proportion of 48 transects to the high density stratum and 12 transects to the low density stratum (Figure 2). Transects were placed in the middle of the selected grids and oriented perpendicular to the major streams (Norton-Griffiths, 1978).

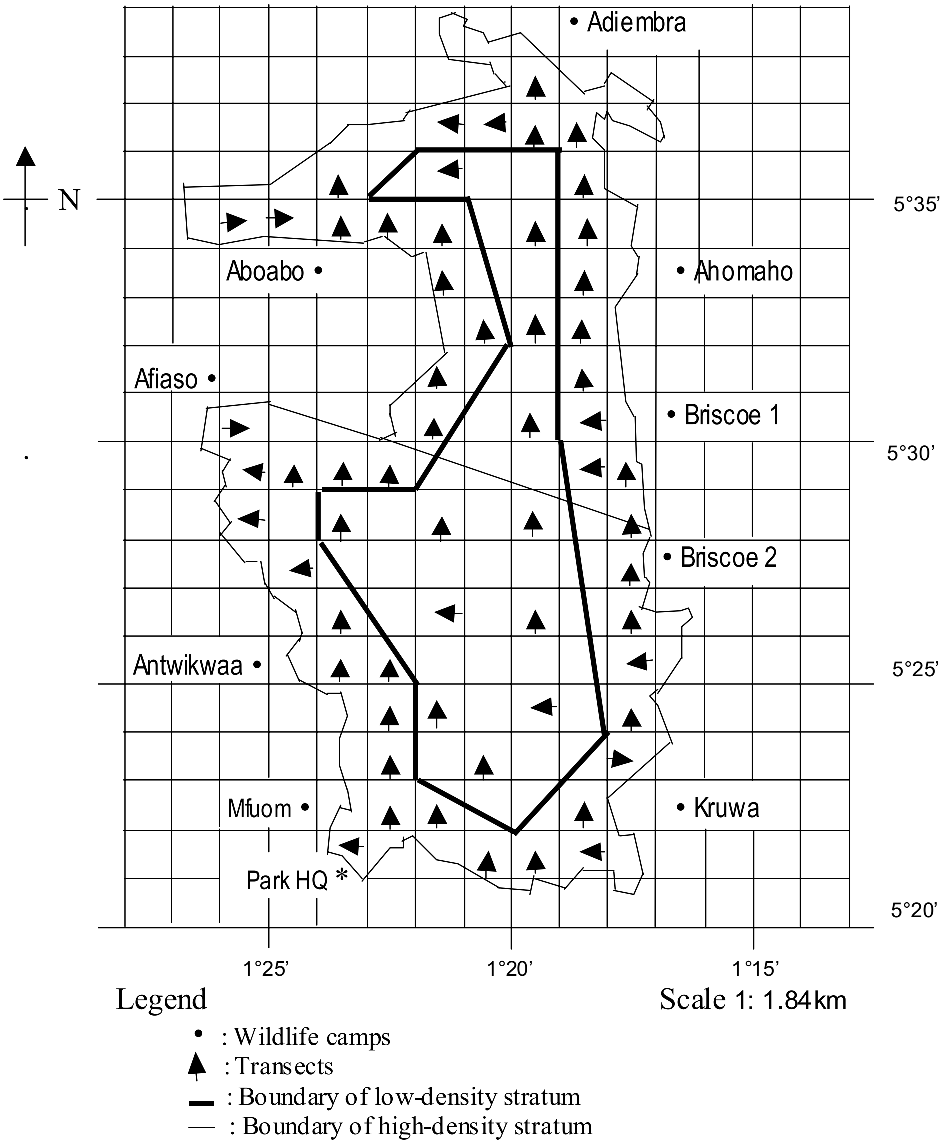


Fig 4: Kakum Conservation Area showing transects distribution in the two strata

2.3.3 Factors affecting elephant distribution

Human and ecological factors that affect elephant distribution were simultaneously collected with the dung data from the above-described line transects.

2.4 Data Collection

2.4.1 Retrospective Dung Decay Rate Experiment

Each block was assigned to a survey team of two wildlife guards (project executor randomly joined a different team on each occasion). Thus, 10 teams simultaneously spent a day following elephant trails and marking and recording as many fresh dung piles as possible in the 10 blocks into which the KCA has been divided.

A combination of wooden marker stakes with rubber tags to identify piles, flagging tapes to aid in their location and GPS to record the exact position of each pile was used. Number of boli and type of vegetation in which dung was found was noted. The age of the dung was determined using the criteria by Barnes & Jensen (1987) and only those of stage A were collected. This translates to dung piles that were very fresh, i.e. dung samples that were no older than 48 hours old.

2.4.2 Line Transect Dung Count

The standard line transect method (Buckland *et al*., 2001; Barnes 1996) was adapted for counting elephant dung piles (Barnes and Jensen 1987) in September 2004. Two survey teams of five persons each and led by a compass man (team leader) were maintained throughout the counts to ensure consistency in data collection procedures. The perpendicular distance of the dung piles seen on transects was measured from the transect centreline using tape measures. The distance along a transect was measured with a hip-chain. Dead straight transects were maintained throughout the survey.

2.4.3 Factors affecting elephant distribution

Human variables including an index of illegal activity such as wire snares, empty cartridge cases, poaching camps, carbide spots (spent carbide emptied from hunting lamps), cane or wood cuttings, etc. encountered on the transects and on alternative travel recces were recorded whilst survey teams conducted the dung survey. An index of past logging activities in the form of trails or points associated with the haulage or loading of timber products was also determined.

Geographical/natural variables like changes in the type of vegetation; secondary forest (disturbed forest), *Raphia* stand, riverbank vegetation and other vegetation types (which would then be specified) were also noted. Again, the condition of the upper canopy (presence of gaps, length of gaps traversed by transect), fruiting trees and water sources such as streams, rivers, ponds and swamps without r*aphia* were also noted.

2.4.4 Reconnaissance (Recce) Transects

An index of illegal activity as described above was also noted on alternative recce transects which were used by teams to access the line transects, when teams moved from one transect to another. The total distance walked to access transects for a particular field day and to return to camp was used to represent one recce transect. Such an index is also vital to describe the general density and distribution of illegal activity in the park.

2.5 Data Processing and Analysis

2.5.1 Retrospective Dung Decay Rate Experiment

The estimated mean survival time of animal signs (reciprocal of decay rate), t with its standard error and CV was calculated using a Genstat program (Genstat version 7). The survey date chosen as the fixed reference date to assess the status of marked dung piles was 16 September 2004. Thus on that day, only a single observation was needed for each marked pile, i.e. whether it was still "present" or whether it had "disappeared" (Laing *et al.*, 2003).

2.5.2 Line Transect Dung Count

2.5.2.1 Retrospective Dung Decay Rate Model

The density of elephants D_a is estimated as (Laing *et al.*, 2003):

$D_a = D_s / (p \times t)$ ----------------------------------- (1)

where D_s is the estimated density of elephant signs (dung piles) in the study area, p is the estimated rate of production of signs per elephant (defecation rate) 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:

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

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

No estimate of defecation rate has been done in KCA. Instead, Tchamba's (1992) estimate of p = 19.77 dung piles a day (SE = 0.23) from Cameroon was substituted in equation 1. The value of dung pile density, D_s, was calculated using the DISTANCE programme (Laake *et al.*, 1993).

Dung pile outliers were discarded in order to improve the fit of the model in the DISTANCE program (Buckland *et al*., 2001).

2.5.2.2 Steady State Assumption Model

Assuming steady state in the forest, the density of elephants can also be calculated using equation 1 (Barnes & Jensen, 1987; McClanahan, 1986) and the precision of the estimate of elephant density calculated with equation 2 (Barnes, 1993).

However, mean survival time of elephant signs was substituted with the existing Kakum value obtained from dung decay studies done in the rainy season of 1993.

2.5.2.3 Rainfall Model

The rainfall model takes into account the rainfall preceding the dung count and makes no assumptions concerning either steady states or normality. Data on rainfall two months prior to the main line transect dung survey (July and August 2004) was collected from rain gauges mounted around the KCA and the mean total rainfall value calculated for each area.

A model that relates dung density (Y_t) to rainfall two month preceding the survey was used to estimate density (Barnes *et al*. 1997a). Thus

$Y_t = 1020.24 - 0.79RAIN_{t-1} - 0.46RAIN_{t-2}$ (Barnes and Dunn, 2002) ------------------- (6)

Where Y_t is dung density if there is one elephant per sq km and $RAIN_{t-1}$ and $RAIN_{t-2}$ are respectively the total rainfall (mm) in the first and second months preceding the month of the survey.

Elephant density (E) is represented by

$$E = \frac{Y}{Y_t} \quad \text{-- (7)}$$

Where Y is dung density from the survey.

Precision of the estimate of elephant density was calculated following Barnes and Dunn (2002).

2.5.3 Factors affecting elephant distribution

Regression analyses were used to investigate relationships between dung density and variables recorded on transects to determine which factors influence elephant distribution in the KCA. The number of dung piles and variables 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 transformed before analyses.

2.5.4 Reconnaissance (Recce) Transects

The relationship between dung density on recce transects and illegal activity was examined. The total dung piles found on line transects was compared with total illegal activity recorded on recce transect walked on each field day in specific areas of the KCA.

3.0 RESULTS

3.1 Retrospective Dung Decay Rate Experiment

A total of 147 fresh (stage A) dung piles were recorded and marked for monitoring their rate of decomposition (Figure 5). Mean survival time of dung piles was 67.0424 (SE=3.4620, CV=0.00516).

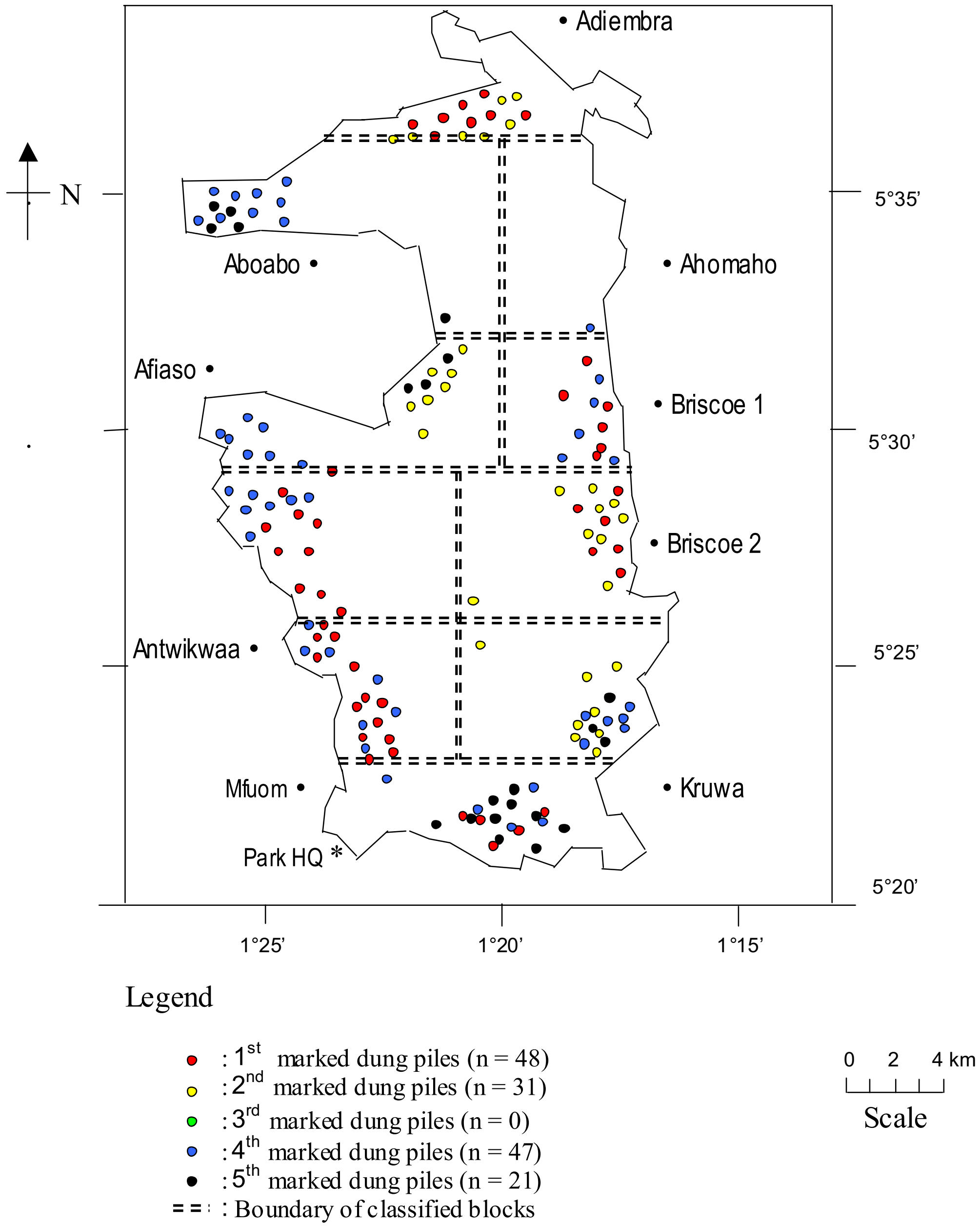


Fig 5: Kakum Conservation Area showing distribution of marked dung piles in the ten classified blocks

3.2 Line Transect Dung Count

A total of 329 dung piles (stage A to D) were spotted: 308 in the high density and 21 in the low-density stratum (Figure 6).

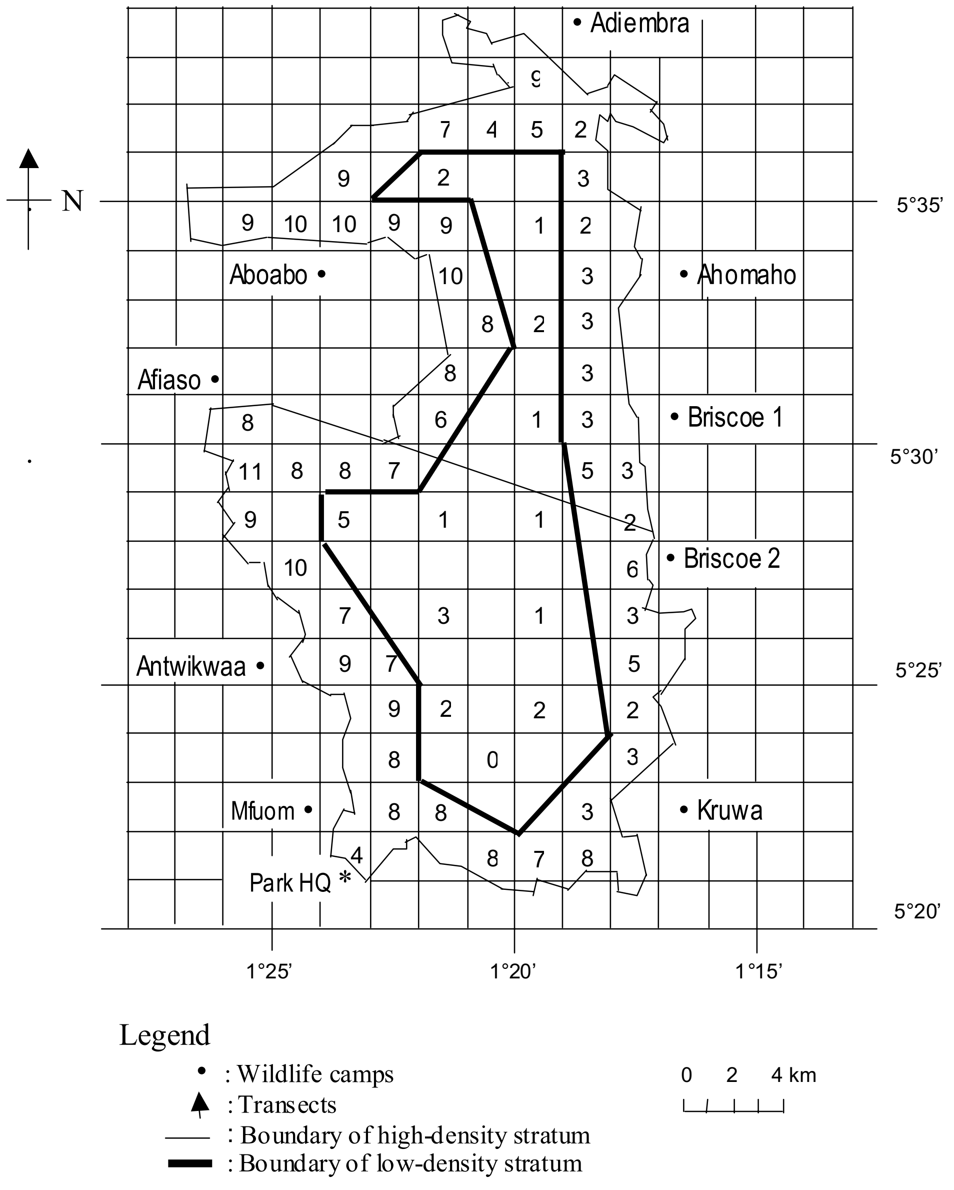


Fig 6: Kakum Conservation Area showing number of dung piles per transect in the various strata.

The number of dung piles per transect ranged from 2 to 11 for the high-density stratum with an average of 6.42 dung piles per transect. In the low-density stratum the number ranged from 0 to 5 with an average 1.75 dung piles per transect. The dung-pile density per transect was significantly higher in the high-density stratum than low-density stratum (Mann-Whitney U test: U=28.5, P<0.05).

Table 1: Estimates of dung pile density per stratum in the Kakum Conservation Area

Stratum	Area (km^2)	Dung-pile Density (Y)	Variance	Number of transects
High-density stratum	232.3	Hazard rate 759.51	Hazard rate 5641.51	48
Low-density stratum	133.7	Hazard rate 309.39	Hazard rate 7818.27	12

The high-density stratum had a higher density of dung piles and a lower variance than the low-density stratum. The DISTANCE programme was used to estimate the overall dung-pile density for the whole park, which was 583.65 dung piles.

Table 2: The combined estimates (high and low stratum) of elephant numbers in the KCA (method from Norton-Griffiths, 1978)

	Population estimate	Confidence limits
Retrospective dung decay Model	164	+\- 37
Rainfall Model	231	185-271
Steady state assumption Model	236	+\- 64

NB: Rainfall model gives asymmetrical CLs

More dung piles were seen nearer the transect centreline (within 1m) in the high-density stratum (Figure 7). The shape of the histogram follows the usual curve one hopes for when doing a line-transect survey.

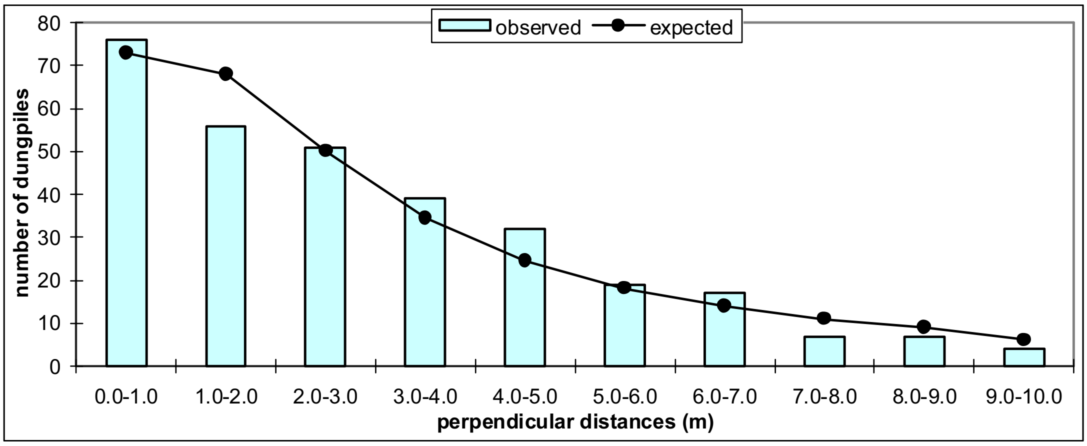


Figure 7: Frequency distribution of the perpendicular distances of dung piles in the high-density stratum of the KCA (n=308, f(0)=0.24). The curve shows the fitted hazard rate model.

On the other hand, fewer dung piles were seen nearer the transects centreline in the low-density stratum (Figure 8). The poor shape of the curve is due to the smaller number of droppings seen in the stratum.

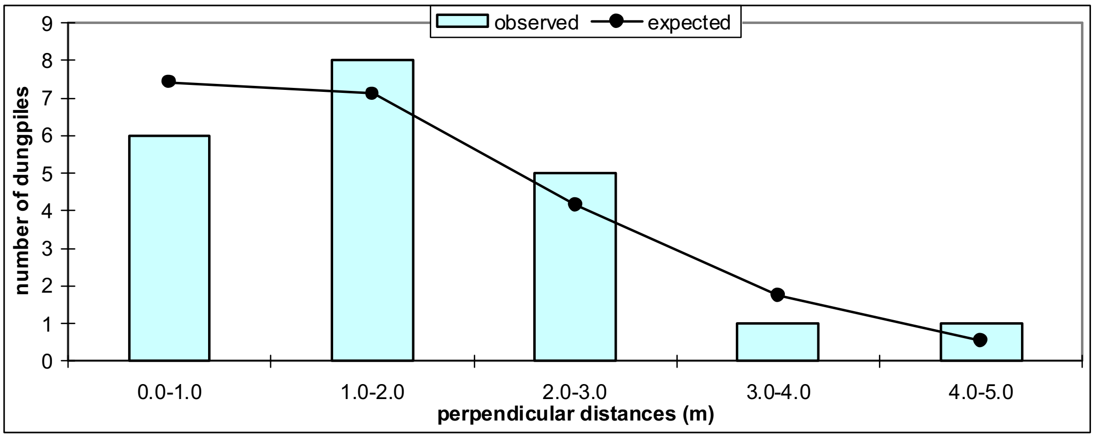


Figure 8: Frequency distribution of the perpendicular distances of dung piles in the low-density stratum of the KCA (n=21, f(0)=0.35).

3.3 Factors affecting elephant distribution

Table 3 Correlation coefficients (r) between the number of dung piles per km and a suite of human and ecological variables recorded on transects. In each case the sample size is 60 transects.

Variable	r	P
Number of fruiting trees	0.129	> 0.05
Index of logging activity	0.108	> 0.05
Number of water sources	0.263	> 0.05
Length of gaps in canopy	0.145	> 0.05
Length of *Raphia* stand	0.123	> 0.05
Length of secondary vegetation	0.116	> 0.05

All the above variables recorded on the line transects, did not significantly influence dung distribution in the study area (Table 3).

3.3.1 Index of illegal activity

The relationship between dung density and index of illegal activity is shown in Figure 9.

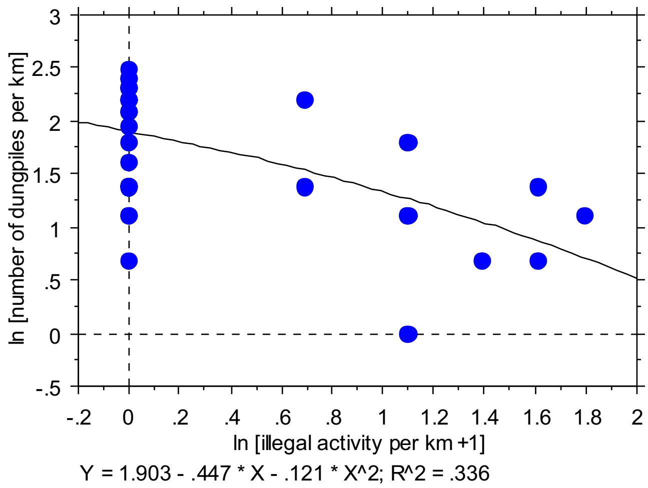


Figure 9: Correlation (r^2 = -0.336, P<0.05) between dung density and an index of illegal activity per km

The mean index of illegal activity was 0.63 activities per km and 74% (n = 38) consisted of wire snares. Other activities were empty cartridges cases (13%), carbide spots (8%) and poacher camps (5%). No gunshots were heard throughout the survey.

3.3.2 Distance to nearest boundary line

The relationship between dung density and distance to the nearest boundary is shown in Figure 10.

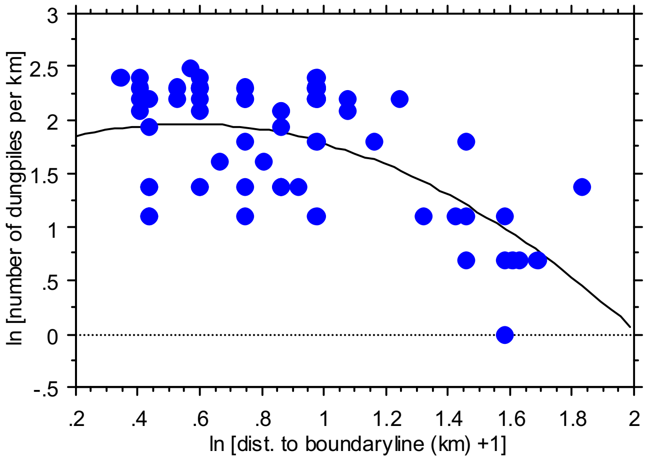


Figure 10: Correlation (r^2=0.650, P<0.05) between dung density and distance to the nearest boundary line

The relationship between index of illegal activity and distance to the nearest boundary line is shown in Figure 11.

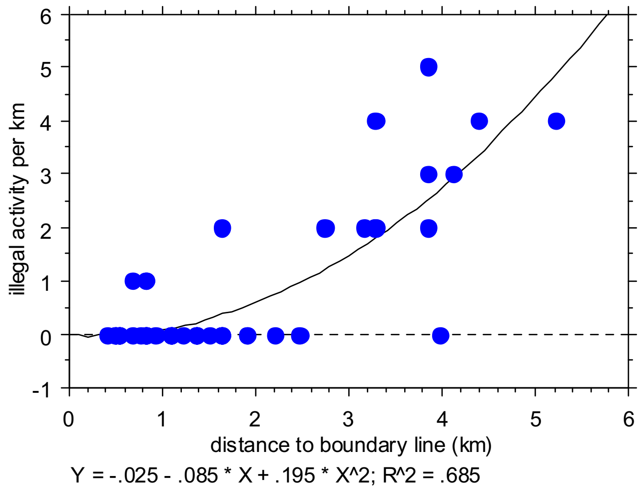


Figure 11: Correlation (r^2=0.685, P<0.05) between index of illegal activity and distance to the nearest boundary line

Here, the distance of the centre point of the transects to the boundary line was measured and the relationship assessed with dung pile density and illegal activity respectively.

3.4 Reconnaissance (Recce) Transects

Illegal activity index per km on the recce transects was not significantly different from that on line transects (U=185.5, P>0.05). The relationship between dung density and index of illegal activity on the recce transects is shown in Figure 12.

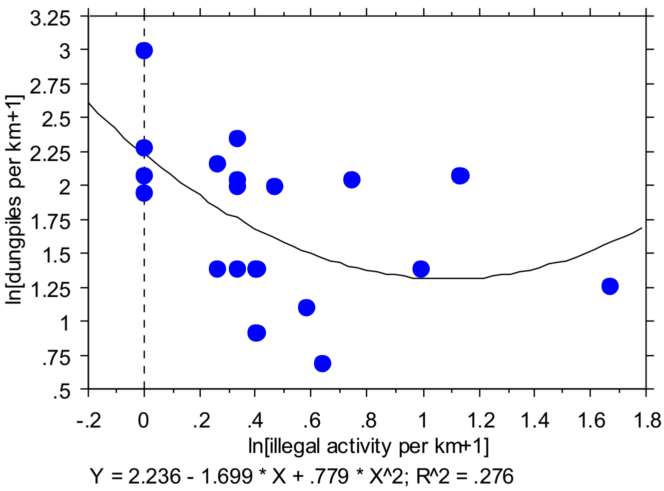


Figure 12: Correlation (r^2 = -0.276, P>0.05) between dung density and index of illegal activity on recce transects

The density of illegal activity (n = 85) was lower at 0.59 activities per km, it also consisted mostly of wire snares (82%). Other activities were carbide spots (12%) and empty cartridges cases (6%).

The average illegal activity on both the line and recce transects was 0.60 activities per km (n = 123)

4.0 DISCUSSION

4.1 Retrospective Dung Decay Experiment

The spread of dung piles (Figure 5), gives us reason to believe that dung piles have been marked and monitored over a wide range of differing habitats and vegetation types to reflect the vast array of forest conditions and locations. A random and wider dispersion of marked dung piles limits the bias caused by forest conditions, which are seldom randomly distributed in natural populations.

4.2 Line Transect Dung Counts

Table 4: Elephant population estimates for the Kakum Conservation Area

Study	Survey type	Year	Population estimates	Confidence limits	Precision (CV%)
Dudley et al, 1992	Spoor measurements	1992	100 - 150	–	–
Eggert et al, 2003	DNA:accumulation curve	1997	170	96 – 270	26.11
Eggert et al, 2003	DNA: Capture-recapture	1997	225	173 – 308	15.11
EBM, 2000	Line transect dung count	2000	228	158 – 337	19.12
EBM, 2000	Line transect dung count	2000	239	165 – 362	20.07
EBM, 2000	Merged estimate	2000	233	160 – 347	20.58
Retrospective, 2004	Line transect dung count	2004	164	+\- 37	10.51
Rainfall model, 2004	Line transect dung count	2004	231	185 – 271	11.50
Steady state, 2004	Line transect dung count	2004	236	+\- 64	13.83

Since the Wildlife Division took over its management from the Forestry Services in 1989, there have been a number of studies on the population size of the elephants in the KCA. Dudley *et al*. (1992) were the first to come up with an estimate of between 100 to 150 elephants using spoor measurements to distinguish between individuals (Table 4). However, their 1992 estimate is not reliable and simply cannot be compared with the other survey types because they sampled only a small area of the park and extrapolated over the entire area, whereas all the others sampled the whole park. As they themselves stated, the data they used were limited and their estimate was just a very rough figure.

Eggert *et al*. (2003) undertook a DNA study in 1997 but published their results in 2003. They gave two estimates for the KCA elephants, because they used two different methods of analysis. Their accumulation curve yielded a less precise estimate of 170 elephants (CLs from 96 to 270) (Table 4) whilst their capture-recapture method gave a more precise figure of 225 (CLs from 173 to 308). The DNA method is a new indirect census technique and according to Blanc *et al*. (2003), it is likely to find wide application in sites where more traditional methods are unlikely to give reliable results.

Shortly afterwards, the Elephant Biology and Management Project provided estimates from two extensive dung count surveys in the dry and wet seasons of the year 2000. They analysed their data based on the rainfall model but both estimates were not very precise. Their wet season was 228, with a confidence interval of 158 to 337 and dry season estimate was 239, with a confidence interval of 165 to 352. Merging the two estimates using the rainfall model still gave an estimate of 233 with a rather larger CL of between 160 to 347 elephants for KCA.

In the current CITES-MIKE supported Retrospective Dung Survey study for 2004, of the three estimation models used, the retrospective model has the best-studied underlying theory. We are encouraged by the highest level of precision (percent coefficient of variation) achieved in comparison to the other estimation methods used at KCA. It was also closest to the estimate provided by the accumulation curve (Eggert *et al*., 2003). Laing *et al*. (2003) term it as a retrospective estimate of the mean time to decay, because a time point is identified and the mean time of signs already present to decay is estimated. There is little doubt that it is the method most likely to give the most accurate result.

Our estimates from the rainfall model (231 CLs from 185-271) and steady state assumption model (236 +/- 64) were however closer and more comparable to the capture-recapture method estimate (Eggert *et al*., 2003). The rainfall model was closest to the retrospective estimate in terms of precision. Incidentally, the rainfall model is another type of retrospective survey; i.e. it uses the rainfall data from previous months to estimate the numbers of dung-piles that are likely to be on the ground when you conduct your survey and makes no such assumptions as the steady states or normality. Hence, between the rainfall and steady state assumption models, the rainfall model is a better method for analysing data on dung-count (Barnes and Dunn, 2002).

The steady state assumption model on the other hand employs a prospective estimate of the mean time to decay. According to Laing *et al*. (2003) prospective estimates are biased estimates of the required mean time to decay because they do not estimate the mean time of the signs that are present at the time of the survey to decay to estimate sign density. 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. In the same way, Barnes *et al*. (1997) showed that the Kakum system was probably in a steady state only during the second half of the dry season. Therefore the assumption was violated for the time of year when we undertook this survey, and for that reason, we could not expect it to give an accurate estimate.

The real question remaining is whether one accepts those methods that give an estimated population of between 160 and 170 (retrospective estimate and Eggert's accumulation curve) or those methods that give an estimate between 225 and 239 (Eggert's capture-recapture and the various EBM dung counts as well as the rainfall model). Since the various estimates fall into two separate categories, we think survey work should be repeated at two-year intervals and subsequent work will reveal which methods are biased.

Being one of the populations with more than 100 individuals (the West African Elephant Conservation Strategy recommends that conservation priority be given to all populations above 100) one can argue along the lines of Sam (2005) that the Kakum elephant population is very important in West Africa. Based on an average elephants density of 0.45/km^2 (from the retrospective model), the Kakum population ranks 2nd and 4th among all forest populations and forest –cum– savannah populations respectively in West Africa. The Kakum population is also important because unlike other West African populations, the range fall within a protected area (PA) and not likely to be destroyed or encroached in the nearest future.

Although a population fewer than 200 elephants may be fairly large for today's fragmented forests, it is still very small indeed, and less than the viable population size estimated by Sukumar (1993).

4.3 Factors affecting elephant distribution

4.3.1 Factors outside

The study period (long wet season) occurred in the 2004 main crop-growing season. This season also coincides with KCA's peak crop raiding season (Barnes *et al*., 2003; Barnes *et al*., 1991 and Dudley *et al*., 1992) when most crops especially maize are ready for harvest (Danquah, 2003; Dickinson, 1998; Nchanji, 1994 and Dudley *et al*., 1992). Thus, elephants were observed lurking close to the boundary line from where they could easily venture out to raid nearby fields with more palatable and succulent food crops. The most important predictor of elephant distribution was proximity to the park boundary line. This type of distribution is encouraged by the fact that, more than 75% of farmers share their land boundary with that of KCA (Nchanji, 1994). The estimated average damage to farms around KCA is about 48% (Dickinson, 1998; Barnes *et al*., 1995).

4.3.2 Factors within

Analysis of dung pile distribution confirmed that the distance to the park boundary line accounted for a large proportion of the variation in elephant distribution. Sam (2000) also reported an inverse correlation between elephant abundance and distance to the boundary line during the peak crop-raiding season in the Bia Conservation Area. Danquah (2003) has shown that elephant movement and distribution during the long wet season (study period) may largely be restricted by low fruit availability within the park and/or increased food abundances outside the park's confinement. Dudley *et al*. (1992) also indicated the effect of fruiting trees on the seasonal movements of elephants in KCA.

The different indices of illegal human activity within the park did not influence elephant density significantly. The use of wire snares dominated the signs of illegal activity in comparison to hunting with guns. Hunting with guns poses a greater threat to the elephant population than wire snares. No poacher or gunshot was encountered during the day whilst walking transects. Poachers may have been more active in the night than daytime. Poachers also avoided areas close to the periphery of the park possibly because of the danger of being easily apprehended. It seems that most of the illegal activity seen on the transects were those targeted at small game and not elephants.

Nevertheless, some elephants have been reported shot but the study could not ascertain the intensity. In 1999 alone, there were at least 4 officially recorded elephant-poaching cases in KCA. At Briscoe 2 (a native community at eastern KCA) for instance, an elephant was reportedly killed less than three months to the study. In addition, park management have on several occasions been alerted to alleged elephant poachers in the vicinity of the reserve in different locations and there had been some evidence suggesting that they succeeded in operating in the park.

Average illegal activity reported for conservation areas elsewhere in Ghana are: 1.14/km for the Ankasa Conservation Area (Danquah *et al*., 2001), 0.74/km for the Bia Conservation Area, 1.52/km for the Goaso group of forest reserves (Sam, 2005) and 10/km for Dadieso Forest Reserve (Sam *et* al., 2003). In KCA, the density of illegal activity in the 2001 wet season and 2002 dry season was 0.97/km and 0.89/km respectively (Boafo pers. com.). These figures are relatively higher than reported in the current study, suggesting a probable better protection strategy adopted by the management of KCA. Thus, the KCA elephant population may face less immediate threat to the illegal killing of elephants than other populations. However if unchecked, illegal activity could conceivably become a threat to the Kakum area in the future, as illegal hunting for almost all species of animals still occurs in the KCA.

5.0 REFERENCES

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

Barnes, R. F. W. (2001). How reliable are dung counts for estimating elephant numbers? East African Wildlife Society, *African Journal of Ecology*. **39**: 1-9.

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

Barnes, R. F. W., Beardsley, K., Michelmore, F., Barnes, K. L., Alers, M. P. T. & Blom, A. (1997b). Estimating forest elephant numbers with dung counts and a geographic information system. *Journal of Wildlife Management*. **61**(4): 1384-1393.

Barnes, R.F.W. (1996). 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., Blom, A., Alers, M. P. T. & Barnes, K. L. (1995). An estimate of the numbers of forest elephants in Gabon. *Journal of Tropical Ecology*. **11**: 27-37.

Barnes, R. F. W., Asamoah-Boateng, B., Naada Majam, J., Agyei-Ohemeng, J., Tchamba, M. N., Ekobo, A. & Nchanji, A. (1994). Improving the accuracy of forest elephant census methods: studies of dung decay rates in Ghana and Cameroun. African Elephant Conservation Programme Final Report, Volume 5. Environment and Development Group, Oxford, UK.

Barnes, R. F. W. (1993). *Indirect methods for counting elephants in forest*. Pachyderm **16**: 24-30.

Barnes, R. F. W. & Jensen, K. L. (1987). How to count elephants in forests. IUCN African Elephant and Rhino Specialist Group Technical Bulletin **1**: 1-6.

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.

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

Danquah, E. (2003). *Food and feeding behaviour of the forest elephant in the Kakum Conservation Area and an assessment of the impact of logging on fruiting trees*. M. Phil Thesis, Kwame Nkrumah University of Science and Technology.

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) pp 63-69.

Dickinson, B. (1998) A summary of the elephant crop raiding situation around Kakum NP in 1997. Unpublished report. Conservation International.

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. *Africa Journal of Ecology* **30,** 116 - 126.

Eggert, L. S., Eggert, J. A. & Woodruff, D. S. (2003). Estimating population sizes for elusive animals: the forest elephants of Kakum National Park, Ghana. *Molecular Ecology*. **12**: 1389-1402.

Ghana Wildlife Division (1996). Kakum National Park and Assin Attandanso Resource Reserve-the management plan. Wildlife Department, Accra.

Hall, J. B. & Swain, M. D. (1976). Distribution and ecology of vascular plants in a tropical rainforest. Forest vegetation in Ghana. *The Hague,* Netherlands. Junk Publishers

Laake, J. L., Buckland, S. T., Anderson, D. R. & Burnham, K. P. (1993). DISTANCE user's guide. Version 2.0.

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

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

Morgan, B. J. & Lee, P. C. (2003). Forest elephant (Loxodonta Africana cyclotis) stature in the Reserve de Faune du Petit Loango, Gabon. *Journal of Zoology, London*. **259**: 337-344.

Nchanji, A. (1994). Preliminary survey of the forest elephant (*Loxodonta africana cyclotis*) crop damage situation around the Kakum National Park. Unpublished report. Conservation International.

Norton-Griffiths, M. 1978. *Counting animals.* African Wildlife Foundation, Nairobi.

Sam, M. K. (2005) A preliminary investigation into the possibilities of creating elephant corridors in the Guinean forest of western Ghana. Final report to SSC/IUCN African Elephant Specialist Group. Kenya.

Seber, G., A., F. (1982). *The estimation of animal abundance and related parameters*. Macmillan, New York.

Sukumar, R. 1993. Minimum viable populations for elephant conservation. *Gajah* 11:48–51.

Tchamba, M. (1992). Defecation by the African forest elephant (*Loxodonta africana cyclotis*) in the Santchou Reserve, Cameroun. *Mammalia* **56**: 155-158.

White, L., Edwards, A. eds.. (2000). *Conservation research in the African rain forests: a technical handbook*. Wildlife Conservation Society, New York. 444 pp. many illustrations.

Appendix 1: Summary of variables collected on the transects

Transects (km)	Number of dung Per km	Dist. to boundary line	Water sources per km	Fruiting tree spp per km	Illegal activity per km	Logging roads per km	Gaps in canopy (km)	Length of raphia (km)	Length of 2° forests (km)
LD1	2	2.75	0	4	2	0	0	0	0
LD2	1	3.30	0	1	4	0	0	0	0.321
LD3	2	3.16	0	0	2	0	0	0.025	0.250
LD4	1	3.99	0	2	0	0	0	0	0.456
LD5	5	3.3	0	6	2	2	0.005	0.009	0.026
LD6	1	4.13	0	0	3	2	0.010	0	0.560
LD7	1	4.40	0	3	4	0	0	0	0.890
LD8	3	5.23	0	3	4	0	0	0	1
LD9	1	3.85	0	4	3	0	0	0	0.147
LD10	2	3.30	0	0	2	0	0	0	0.089
LD11	2	3.85	0	0	5	0	0	0	1
LD12	0	3.85	0	5	2	0	0	0	0.369
HD1	9	1.10	2	3	0	0	0	0	0.258
HD2	7	0.83	0	3	0	6	0.056	0	0.253
HD3	4	1.24	0	4	0	0	0.004	0.022	0.127
HD4	5	2.20	0	0	0	0	0	0	0.554
HD5	2	0.55	0	2	0	0	0	0	1
HD6	9	1.65	2	4	0	0	0	0	0.010
HD7	3	0.55	0	6	0	1	0.008	0	0.023
HD8	9	0.83	0	1	0	2	0.002	0	0.520
HD9	10	0.83	0	4	0	0	0	0	0.853
HD10	10	0.50	0	2	0	0	0	0.030	0.230
HD11	9	0.50	0	0	0	0	0	0	0.144
HD12	9	0.83	0	1	0	1	0	0	1
HD13	2	1.65	0	3	0	0	0	0	0.056
HD14	10	0.41	1	3	0	3	0.040	0	0.220
HD15	3	1.38	0	0	0	0	0	0	1
HD16	8	1.65	0	5	0	0	0	0	0.756
HD17	3	1.38	0	0	0	2	0	0	0.745
HD18	8	0.55	3	0	0	0	0	0	0.055
HD19	3	1.51	0	4	0	0	0	0.003	0.200
HD20	8	0.83	0	4	1	0	0	0	1
HD21	6	1.38	0	3	0	0	0	0	1
HD22	3	1.38	0	3	0	0	0	0	0.112
HD23	11	0.77	1	0	0	1	0	0	0.502
HD24	8	2.48	1	5	0	0	0	0	0.229
HD25	8	1.93	0	0	0	1	0.012	0	0.887
HD26	7	1.38	0	5	0	0	0.020	0	0.026
HD27	5	1.65	2	1	2	1	0.004	0	0.502
HD28	3	0.55	2	1	0	1	0.006	0	0.213
HD29	9	0.83	5	3	0	1	0	0	0.111
HD30	2	0.55	0	3	0	0	0	0	0.204
HD31	10	1.65	0	2	0	0	0.023	0.006	0.460
HD32	6	0.55	0	0	0	0	0	0.021	0.501
HD33	7	1.38	0	2	0	0	0	0	0.586
HD34	3	0.83	0	1	1	0	0	0	0.795
HD35	9	0.69	0	2	0	0	0	0	1
HD36	7	1.93	2	3	0	0	0	0	0.548

HD37	5	1.10	6	0	0	1	0.012	0	0.551
HD38	9	1.65	2	5	0	0	0.006	0	0.486
HD39	2	1.10	1	5	0	0	0.034	0	0.776
HD40	8	1.65	0	4	0	0	0	0	0.765
HD41	3	0.83	0	2	0	0	0	0.036	0.545
HD42	8	1.10	0	2	0	2	0	0.011	0.525
HD43	8	1.10	0	0	0	0	0	0	0.599
HD44	3	1.10	0	6	0	2	0	0	0.582
HD45	4	0.94	3	3	0	2	0	0	1
HD46	8	0.50	0	3	0	0	0.001	0	0.335
HD47	7	0.50	0	1	0	0	0.320	0	0.636
HD48	8	0.69	0	1	1	0	0	0	0.263

Appendix 2: Index of illegal activity collected on the Recce transects compared to Line transects

	Line Transects			**Recce transects**	
Field days	Total length (km)	Total dungpiles	Illegal activities	Total length (km)	Illegal activities
1	4.0	38	0	5.6	2
2	3.0	20	2	3.8	4
3	3.0	20	2	5.0	2
4	4.0	35	1	5.8	0
5	3.0	21	0	3.8	8
6	4.0	25	0	6.5	4
7	4.0	8	4	7.1	6
8	3.0	9	0	4.2	7
9	4.0	12	2	8.9	3
10	3.0	9	4	11.0	6
11	3.0	9	4	10.3	4
12	2.0	5	0	2.1	9
13	2.0	2	7	12.4	11
14	3.0	18	1	4.3	0
15	4.0	28	0	6.8	0
16	3.0	19	2	9.4	4
17	3.0	23	0	7.6	2
18	1.0	19	0	3.6	0
19	2.0	3	4	12.0	6
20	2.0	6	5	14.7	7
Total	60.0	329	38	144.9	85