DETERMINING THE RATE OF DECAY OF ELEPHANT DUNG AND THE FACTORS AFFECTING IT IN TWO DIFFERENT HABITATS OF ABERDARE NATIONAL PARK, KENYA

BY

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A Thesis Submitted in Partial Fulfilment of the Requirements for the award of a Master of Science degree (in Biology of Conservation) of the University of Nairobi.

1997

DECLARATION

This thesis is my original work and has not been presented for

a degree in any other University.

20/11/1997

Martin J. S. Mulama

This thesis has been submitted for examination with my approval as University Supervisor.

Warui Karanja 25/4/98

Dr. Warui Karanja

DEDICATION

This thesis is dedicated to my

Mother and the memories of my Father.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

I am grateful to my supervisors - Drs. Warui Karanja and Ian Gordon for their unfailing guidance, assistance and encouragement throughout the study and in writing this thesis.

The study would not have been a success without funding for both the course and field work by Kenya Wildlife Service (KWS) Elephant Programme. I am particularly grateful to Dr. Joyce Poole for providing this alternative source of funding at the eleventh hour.

Dr. Edward Vanden Burghe can not be forgotten for his active involvement in developing the proposal. And to Dr. Poole once again and several other people who spared their time to read through and comment on the draft thesis, I say **THANK YOU**.

I must salute the entire Zoology Department for constructive criticisms during the seminars in which I presented this study. I am particularly indebted to Mr. M. Githaiga of Zoology Department and Mr. E. Mwangi of JKUCAT for their tireless assistance in execution of different data analysis programmes.

Special thanks to the senior warden Aberdare National Park, Mr. John Muhanga, for providing permission to work in Aberdare and all the necessary support. I can not forget James Isiche, Theodeus Obari, Pius Mulwa and the late Paul Mbui for their hospitality during my fieldwork and especially Isiche for allowing me to store elephant dung in his house.

The KWS Elephant Programme forest survey team deserves special thanks for assisting in data collection. The same applies to the National Museum of Kenya's (NMK) Entomology Department for insect identification and in particular the late Mr. J. Muhagani and the Meteorology Department (at Dagoretti) for providing the climatology instruments, in particular Mr. Muchemi.

Special thanks are due to my brothers - Sammy and Ben - and sisters - Rose and Sophie for their encouragement and support throughout this project.

Finally I thank my wife Sarah Mulama and son Bunny Mulama for their patience especially during the field work, and to my class and work mates at KWS who nicknamed me ***"SHITOLOGIST"*** or Mr. ***"DUNG"***, I hold nothing against you though the nickname is there to stay!.

ABSTRACT

Since the uplisting of the African elephant (*Loxodonta africana*) from appendix II to appendix I of the Convention In Trade of Endangered Species (CITES), it has become important to monitor their numbers and trends. Different survey techniques are used for this purpose. In forests, conventional aerial counts of elephants, as done in the African savannah can not be applied, and Barnes & Jensen (1987) have since developed an indirect method of censusing forest elephants. In this method, the density of elephant dung piles is used as an index of elephant abundance, which is later used to estimate elephant numbers by multiplying it with a correction factor. The correction factor in this case is the ratio of the quantity of dung that disappears from the environment through decay to the quantity of dung produced per elephant per day. In this study, the more robust model for estimating forest elephants indirectly as proposed by Dawson (1990) was adopted. This study aimed at; i) determining the rate of dung decay in the bamboo and the shrub habitats of Aberdare National Park, (ii) identify the climatic, environmental and biological factors that influence the rate of dung decay and determine how they differ between the two habitats, and (iii) estimate elephant densities and numbers in these two habitats of the Park.

Dung decay was measured by marking fresh dung piles and monitoring them (at an interval of approximately seven to ten days) until they disappeared. A total of two hundred and thirty one fresh dung piles were marked in the two habitats and monitored until they disappeared. There was a significant seasonal difference of dung decay rate in the Bamboo habitat. In the Shrub habitat, the seasonal difference of dung decay rate was not significant. In the dry season, dung decayed faster in the shrub habitat compared to the bamboo habitat. Dung beetles and termites were observed to be the major decomposers dominating the wet and dry season respectively. It was also observed that in the wet season, minimum temperature and total rainfall had a positive effect on the dung decay rate while in the dry season, the decay rate was affected positively by maximum temperature, minimum humidity, and total rainfall but negatively by minimum temperature.

The perpendicular distance model of the line transect sampling Method (Burnham, *et al*, 1980) and the Fourier Series estimator was used to estimate the dung density. In wet season, the shrub habitat registered the highest mean dung density. Since the rate of elephant defecation was not estimated for these habitats, the defecation rate estimated by Wing and Buss (1970) was used in the equation for the model of estimating forest elephants. Both habitats showed a high elephant density. However, the density in the shrub habitat did not change much with season as compared to the bamboo habitat which showed a wet season elephant density that was one and a half times greater than its' dry season density. The number of elephants in the two habitats was estimated to be 1,085 in wet season and 900 in dry season.

CHAPTER 1
INTRODUCTION AND LITERATURE REVIEW

1.1.0 INTRODUCTION

Poaching and habitat loss has, over the last two decades, resulted in the decline of the African elephant (*Loxodonta africana*) population. Most of this decline especially in 1970's and 1980's is attributed to illegal ivory trade (Poole *et al.*, 1992). In an attempt to curb the poaching crisis, the African elephant was uplisted in 1989 from Appendix II to Appendix I of the Convention on International Trade in Endangered Species (CITES), thus banning the international trade in ivory and other elephant products (Western, 1990; Poole *et al*, 1992). The ban resulted in a drastic reduction in the price of elephant ivory around the world, leading to a decline in the frequency of poaching-related elephant deaths. Loss of elephant habitat due to increase in human population still remains a threat to the elephant population. CITES requires a close monitoring of species in Appendix I. It has, therefore, become important to monitor elephant numbers and trends.

Several different survey techniques are used for counting elephants, such as; aerial surveys (Norton-Griffiths, 1975) and carcass ratios (Douglas-Hamilton & Hillman, 1980; Douglas-Hamilton & Burril, 1991). Using these techniques, a lot of information on savannah elephants has been obtained (Barnes, 1979; Laws, 1966; Douglas-Hamilton, 1972; Malpas, 1978; Weyerhaeuser, 1982). In forests, these methods of obtaining information on numbers and occupance of elephants are impractical, since visibility is limited. An indirect method of censusing forest elephants has since been developed. In this method, the density of elephant dung piles is used as an index of abundance that is later converted into elephant numbers (Barnes & Jensen, 1987). The method involves the estimation of three variables, namely: number of dung piles per km^2; rate of dung decay and number of dung piles produced per elephant per day. The method has been used widely in the huge Central African forests, where it was developed. However, there is uncertainty in its use in the relatively smaller East African forests, which are recognized as important elephant habitats (Reuling, 1991). This uncertainty is basically attributed to the methods of estimating rates of dung decay and defecation.

1.2.0 LITERATURE REVIEW

Faecal pellets have been used as an index of abundance in sampling populations of various deer species since the 1940's (Bennett *et al.*, 1940; McCain, 1948; Rodgers *et al.*, 1958). Other animal species that have been studied by this method include the rabbits *(Lepus califonicus)* (Taylor *et al.*, 1935), several species of small mammals (Emien *et al.*, 1957) and big game species (Neff, 1968). This technique has recently been used to estimate elephant populations where the general survey techniques have failed.

Although studies on forest elephants date back to the last two decades or even earlier, it is not until the early 1980's that work on a wide scale started. Most of the studies carried out on forest elephants have concentrated on elephant densities (Short, 1983; Merz, 1986; Barnes & Jensen, 1987; Fay, 1989). The transect method (Barnes & Jensen, 1987) which is used to obtain dung density - that is, the number of dung piles per km^2, has been improved with time (Burnham *et al.*, 1980). However, the accuracy with which the decay and defecation rates are obtained is still poor. In many cases, the defecation rate used is that obtained by Wing & Buss (1970).

Wing & Buss (1970), using dung counts estimated elephant population of Kibale forest in Uganda. They, however, doubted the accuracy of their results. Jachman & Bell (1979) used the same method to estimate the population of woodland elephants and then confirmed the accuracy of their results by aerial censusing. This indirect method of counting elephants has also been used in West Africa (Short, 1983; Merz, 1986); Central Africa (Barnes & Jensen, 1987; Fay, 1989); East Africa (Wing & Buss, 1970; Reuling, 1991) and India (Dawson, 1990).

Most of the Kenya's forest elephant populations still remained uncensored in 1990, after which a series of surveys were initiated by Kenya Wildlife Service (Poole *et. al.*, 1992). Some of the forests already surveyed include: Aberdare (Blom *et al.*, 1990); Arabuko Sokoke (Gesicho, 1991); Mt. Kenya and Mt.Elgon (Reuling *et al.*, 1992a); Mathews Range (Reuling, *et al.* 1992b), the Mau (Reuling, 1992c); Shimba Hills (Reuling, *et al.*, 1992d); Marmanet Complex (Litoroh, *et al.*, 1992) and Marsabit (Litoroh, *et al.*, 1994).

In all the studies mentioned above, variables influencing dung decay, which is one of the key parameters in estimating the elephant populations were not evaluated. The decay studies also assumed homogeneity of vegetation (which, in turn, is dependent on altitude, soil type). Thus, only one decay rate was calculated and used to estimate the elephant density for the entire study area. Third, these decay studies had been based on the assumption that dung decays exponentially (McClanahan, 1986). However, results from some studies do not obey this assumption (Reuling *pers. comm.*). Working on the Indian elephant (*Elephas maximus*), Dawson(1990) showed that the rate of dung disappearance was not constant and, therefore, indicated that the exponential assumption gave a biased estimate of the dung decay rate. Another study by Reuling (1991) showed that decay rate follows a reverse sigmoid curve rather than an exponential curve.

For the survey of elephants and other large mammals of Aberdare National Park, the decay rate used to establish elephant estimates was obtained from only one of the habitats, dominated by shrubs (Blom *et al.*, 1990). Data collected was not sufficient to obtain an independent decay rate for Aberdare. The decay rate used in the model for estimating forest elephants was an average of that estimated in Gabon and that obtained from the insufficient data (Blom *et al.*, 1990).

The rates of production and disappearance of any substance can be used in various ways. For example, if we were interested in knowing the amount of organic matter lying on the surface of the soil at any one time, we would have to determine the difference in rates of production and disappearance of the organic matter. In the case of the model for estimating forest elephants, the ratio of dung decay (disappearance) rate to defecation (production) rate is used as a correction factor for the dung density estimates to arrive at the approximate quantity of dung in the area at any one time.

The degradation of organic matter with eventual release of carbon dioxide, minerals and water, is referred to as decomposition (Lee, 1979). However, this term has been used to mean anything from weight loss to chemical degradation of organic matter (wood, 1974). In this study, the term (which is used interchangeably with decay) is used to mean disappearance of dung from the soil surface by the combined action of invertebrate fauna and mechanical means.

There are many factors, which determine the rate of decay. These factors can be broadly divided into three main categories (Swift *et al.*, 1979); (1) the type of decomposers, (2) the quality of the decomposing material and (3) the physicochemical environment. Each of these classes of variables has its own importance, which varies spatially, and temporally (Anderson and Swift, 1983).

It has been shown that micro-organisms, macro-organisms and weather are key factors involved in dung decomposition (Leakey, 1992). Dung beetles, flies, termites, ants and earthworms are the main invertebrate groups involved in dung decay (Valiela, 1969, 1974; Schoenly, 1983). Anderson and Coe (1974) looked at the decomposition of elephant dung near Tsavo National Park, Kenya, a tropical area, using carbon dioxide evolution from dung as a measure of this rate. Their study showed that dung beetles and termites were the major decomposers while in the temperate areas beetles and earthworms have been shown to play a leading role in accelerating dung decay (Holter, 1979). Anderson and Coe (1974) concluded that dung is used as a food resource for adult beetles and larvae. Further still, there is a seasonal difference in the activities of these faunal groups in the tropics, with dung beetles dominating the wet season and termites the dry season. Only 20% of elephant dung was observed to decay in Tsavo National Park during the dry season while in wet season about 70% decayed. This high rate of decay in the wet season is linked to the activity of dung beetles (Coe, 1979;Kingston, 1977). Heinrich and Bartholomew (1979) working in Tsavo also recorded similar rates of decay and beetle activities. At the end of the rains, the beetle activity falls off rapidly thus allowing dung to accumulate in the dry season. Since the decay rate is much slower in the dry season, that is dung stays longer on the surface, termites's chances of finding the dung are greatly increased and therefore become the dry season's main agent of dung removal (Anderson & Coe, 1974; Coe, 1977). Three species of Odontotermes were found to be particularly important in removing elephant dung in Tsavo National Park (Buxton, 1979). Dung beetles are not only associated with elephant dung but also bovine dung (Waterhouse, 1974; Kairu, 1986; Leakey, 1992).

The quality of the decomposing material influences its attractiveness to the decomposing agents. The abundance and diversity of the decomposer organism is therefore greatly affected by the quality of the decomposing material. By comparing the dung of cattle *(Bos taurus)*, buffalo *(Syncerus caffer)*, horse *(Equus cabalus)*, pig *(Sus scrofa)* and donkey *(Equus asianus)*, Hafez (1939) was able to show that they had different physical conditions such as moisture and texture as well as different chemical properties. According to Kairu (1986), dung of the same animal species may show seasonal as well as individual variation. Furthermore, a single dung pile may not be homogeneous and the different components may decay at different rates.

The physicochemical factors that influence dung decay fall under climatic and soil factors (Swift *et al.*, 1979). Climatic factors such as rainfall and temperature influence rate of dung decay, while the soil factors such as pH and moisture act as immediate controllers. Smith (1986) reported that:

> "Under certain circumstances, the succession of necrophagous insects colonizing carcasses and cadavers can be used as an indication of carcass age".

1.3.0 OBJECTIVES

Aberdare is thought to have one of the largest elephant populations in Kenya and since dung count is the only practical method that can be used to establish this fact, it is important that the accuracy of this method be improved. This can be achieved by improving the estimation of each of the three variables of the model used to estimate the forest elephant numbers. The present study was therefore an attempt to improve on the estimation of the rate of dung decay and some of the factors that may influence it. To do this, the project undertook to achieve the following objectives;

1. To determine the rate of dung decay in two different habitats (the bamboo and the shrub) of Aberdare National Park;

2. To identify the climatic, environmental and biological factors that influence the rate of dung decay and determine how they differ between the bamboo and the shrub habitats and
3. To use the results obtained from 1 and 2 above to estimate elephant densities and numbers in each of the two habitats of the park.

CHAPTER 2
THE STUDY AREA

2.1.0 INTRODUCTION

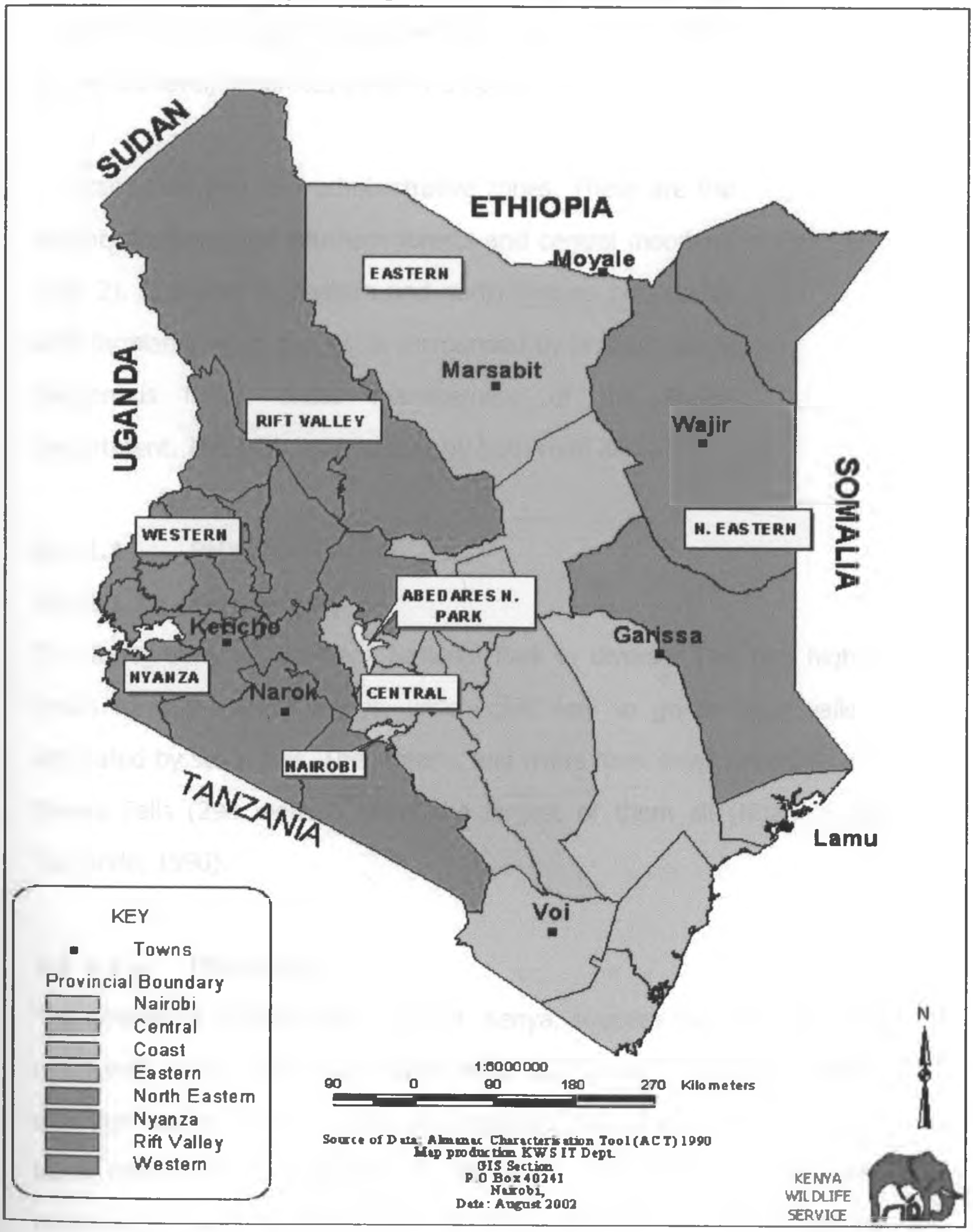
The Aberdare National Park is classified under Management Category II - National Parks (IUCN, 1982). A variety of flora and fauna is protected in this park. The vegetation types range from sub-montane forest to unique alpine plant communities which in turn provide habitats for a number of wildlife, including some endangered species, such as, the black rhinoceros (*Diceros bicornis* L.) and the bongo antelope (*Tragelaphus euryceros* Ogilby). Other than protecting the flora and fauna, the park also imparts a unique combination of scenic and recreational values and it is also an important catchment area (Schmitt, 1991).

2.1.1 GEOGRAPHY AND ADMINISTRATION

The Aberdare National Park is in Central Province of Kenya, with park boundaries extending into Nyeri, Murang'a and Nyandarua districts (Fig. 1). The park, covering a total area of 767 km^2, lies between latitudes 0^o 08' and 0^o 42' South and longitudes 36^o 31'- 36^o 55' East. The park headquarter is situated in Mweiga, which is 17 km from Nyeri town (approx. 171 km north of Nairobi) on the Nyahururu road (KWS, 1991). The study area lies within the Aberdares mountain range, which forms part of the Central Highlands of Kenya (Ngang'a *et al*, 1990).

The highest peaks are Oldonyo Lesatima (4,001 m) and Il Kinagop (3,906 m). Oldonyo Lesatima marks the highest moorland peak in the north while Il Kinagop is the highest

Figure 1: A Map of Kenya Showing the Location of Aberdares National Park



point in the southern moorland (Schmitt, 1991). The moorland, whose height is approximately 3,000 m – 3,300 m above sea level, separates these two peaks.

The park falls into four administrative zones. These are the salient, northern and southern forests and central moorland (Fig. 2). It shares its eastern and north-eastern boundaries with farmland, while the rest is surrounded by predominantly indigenous forest under management of the Forest Department. The park is accessible by both road and air.

2.1.1.1 PHYSIOGRAPHY

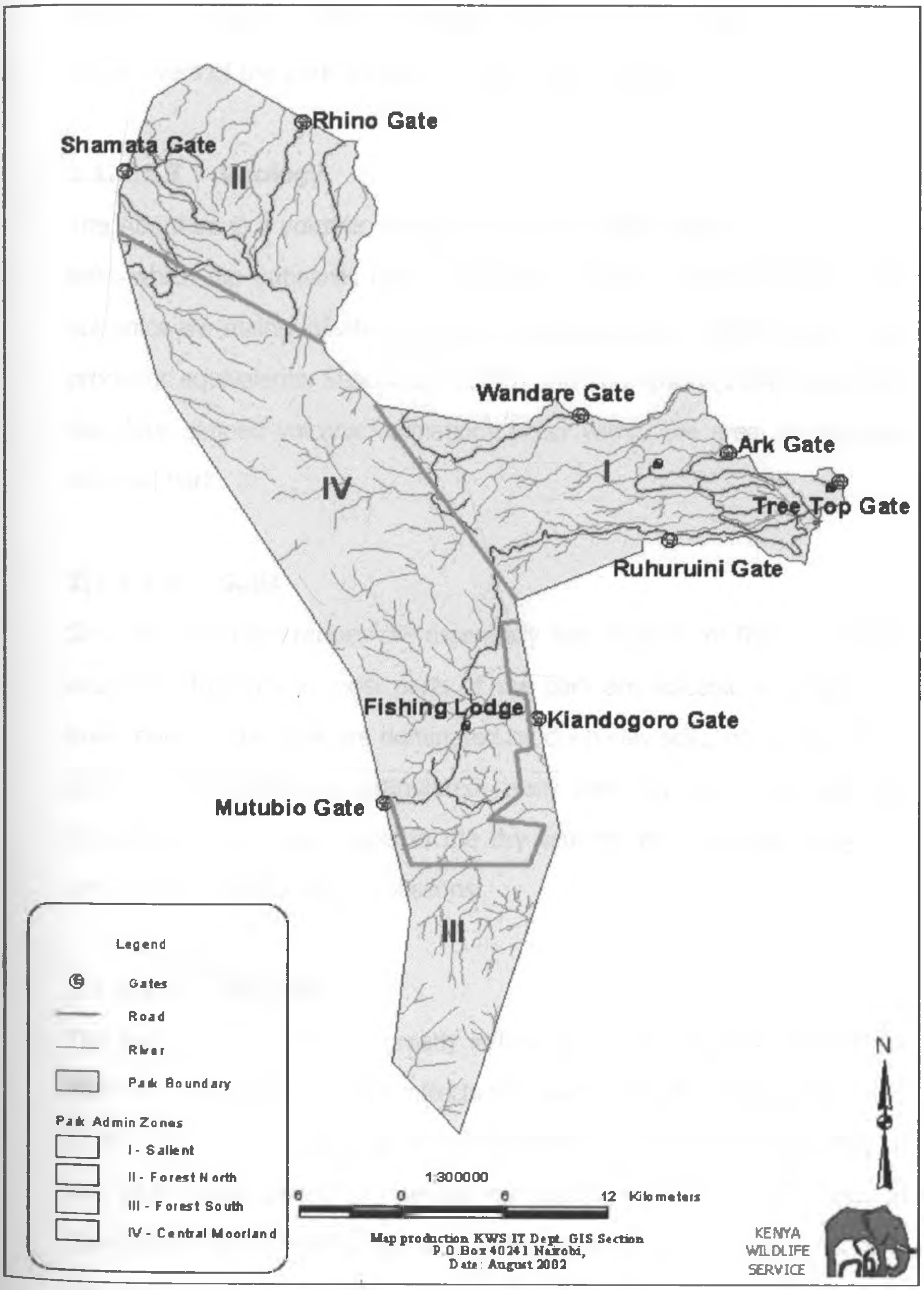
2.1.1.1.1 Topography

The topography of Aberdare National Park is diverse. The two highest peaks form V-shaped valleys, which give way to gentle river valleys, separated by steep hills. The streams and rivers form small waterfalls with Karura Falls (298 metres) being the largest of them all (Ngang'a and Kamande, 1990).

2.1.1.1.2 Hydrology

The Aberdares Range, along with Mt. Kenya, supplies the Tana and Athi rivers with water. They also provide water to the central rift and northern drainage basins. The park thus encompasses one of the most important water catchment zones in the country (KWS, 1991). Some of the major rivers whose source is within the park include; Tana River, flowing into the Indian Ocean, Malewa, flowing into Lake Naivasha and the Ewaso Nyiro,

Fig 2: Aberdare National Park Showing the Park Administrative Zones and Gates



which drains into northern Kenya through underground seepage. Numerous feeder streams also exist. These feeder streams flow into the major rivers of the park and add to their sizes downstream.

2.1.1.1.3 Geology

The Aberdare is a volcanic range made up of tertiary to recent lavas and tufts which dip outwards from the volcanic centre (Schmitt, 1991). The volcanics are mainly of alkaline type including basalts, rhyolites and their proclastic equivalents. Shackleton (1945) and Thompson (1964) suggested that four defined volcanic formations occur within the area of Aberdare National Park.

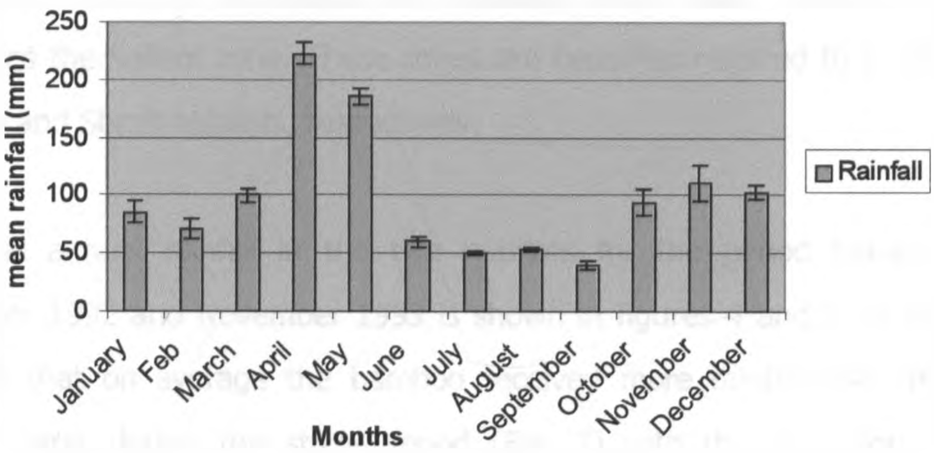
2.1.1.1.4 Soils

Since the Aberdare ranges are essentially the products of fissure volcanic eruptions, the soils in most parts of the park are volcanic in origin. The lower parts of the park are dominated by deep clay soils, while the higher parts are dominated by granulated sandy and clay soils. The soils are characterised by wide cracks in the dry seasons and become sticky and waterlogged during the wet seasons.

2.1.1.1.5 Climate

The climate of Aberdare is greatly influenced by the varying relief of the park. This altitudinal variation affects the rainfall, which increases from the lower slops to the peak. Rainfall varies from around 900 mm annually at the park headquarters in Mweiga, to slightly more than 2,000mm at Kiandogoro Gate, close to central moorlands (Blom *et al*, 1990). Generally, the rainfall distribution depicts a bi-modal distribution (Fig 3) with the two

Fig 3: Mean monthly rainfall (mm) in Aberdare National Park between January 1973 and Dcember 1992 (source: Aberdare National Park)



peaks (wet seasons) in April-May and October-December. However, the Aberdare is never completely dry and animals can usually find water.

2.1. 2 LOCATION OF STUDY SITES

Due to logistics, this study was carried out in only two zones of the Park: the Bamboo and the Salient zones. The study sites selected have a large number of elephants (Blom *et al.*, 1990); thus, abundant fresh dung was available. There is a 1,600 metres difference in the altitude between the two zones. Bamboo dominates the Bamboo zone while shrub/forest dominates the Salient zone. These zones are hereafter referred to as the Bamboo and Shrub habitats, respectively.

The total annual rainfall in the two habitats for the period between December 1992 and November 1993 is shown in figures 4 and 5. It can be seen that on average the bamboo received more rainfall than the shrub habitat during the study period (Fig. 3) with the exception of January. Although the amount of rainfall differed in the two habitats, the wet and dry seasons were observed in the months of October to November and March to September respectively. There was a sudden increase in rainfall in both habitats in the month of May.

The mean monthly maximum humidity for the two habitats did not seem to differ much in the two habitats but the mean monthly minimum humidity differed very much (Figs 6 and 7). The same case applied for the mean monthly temperature (Figs 8 and 9).

Fig 4: The total monthly rainfall in the bamboo habitat, Aberdare National Park, between December 1992 and November 1993

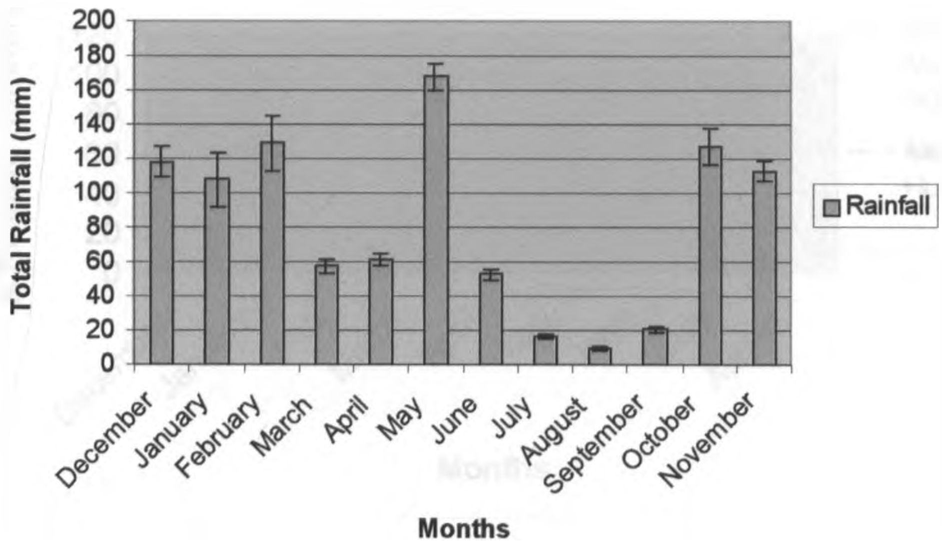
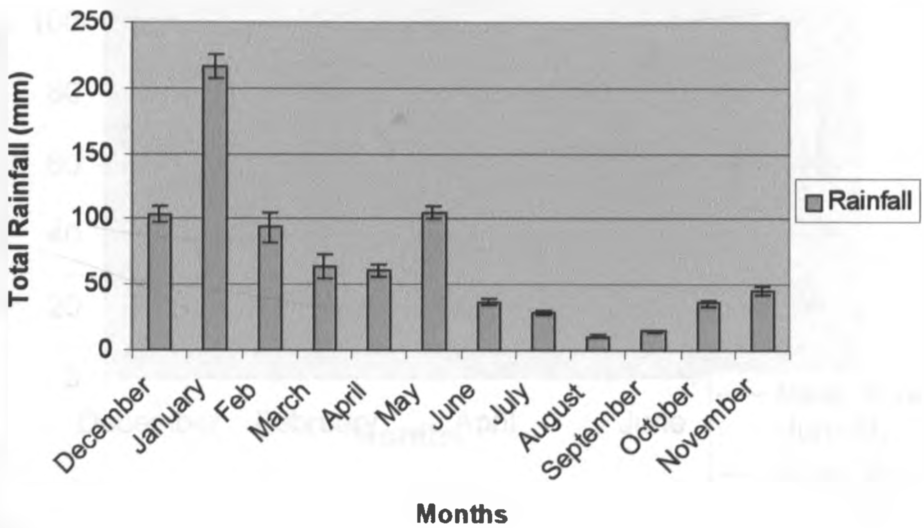


Fig 5: The total monthly rainfall in the shrub habitat, Aberdare National Park, between December 1992 and November 1993



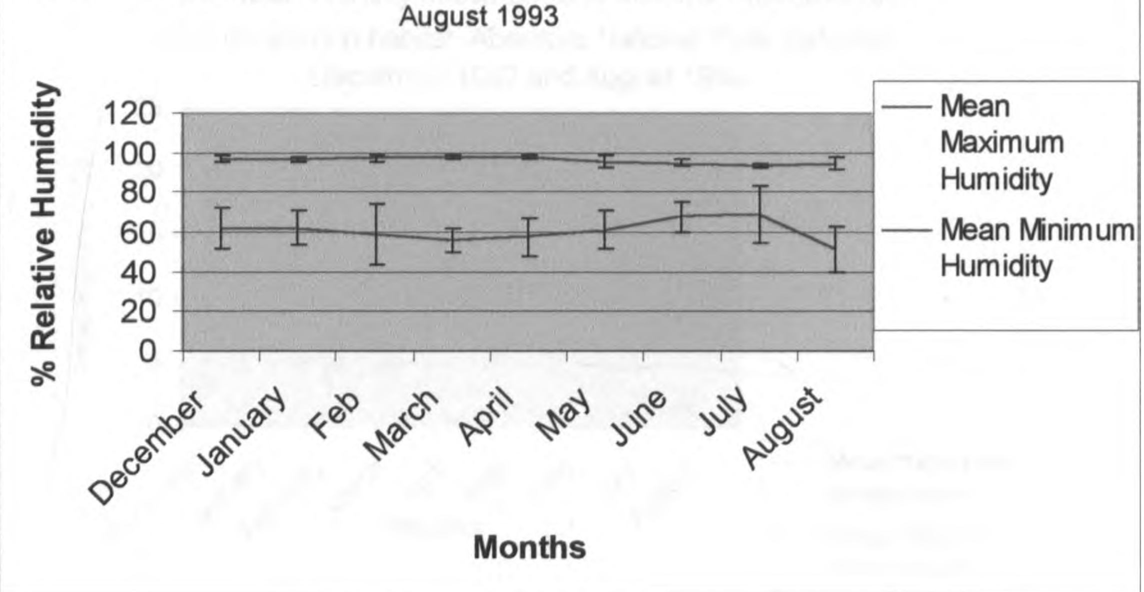


Fig 6: Mean montly maximum and minimum relative humidity (%) in bamboo habitat, Aberdare National Park, between December 1992 and August 1993

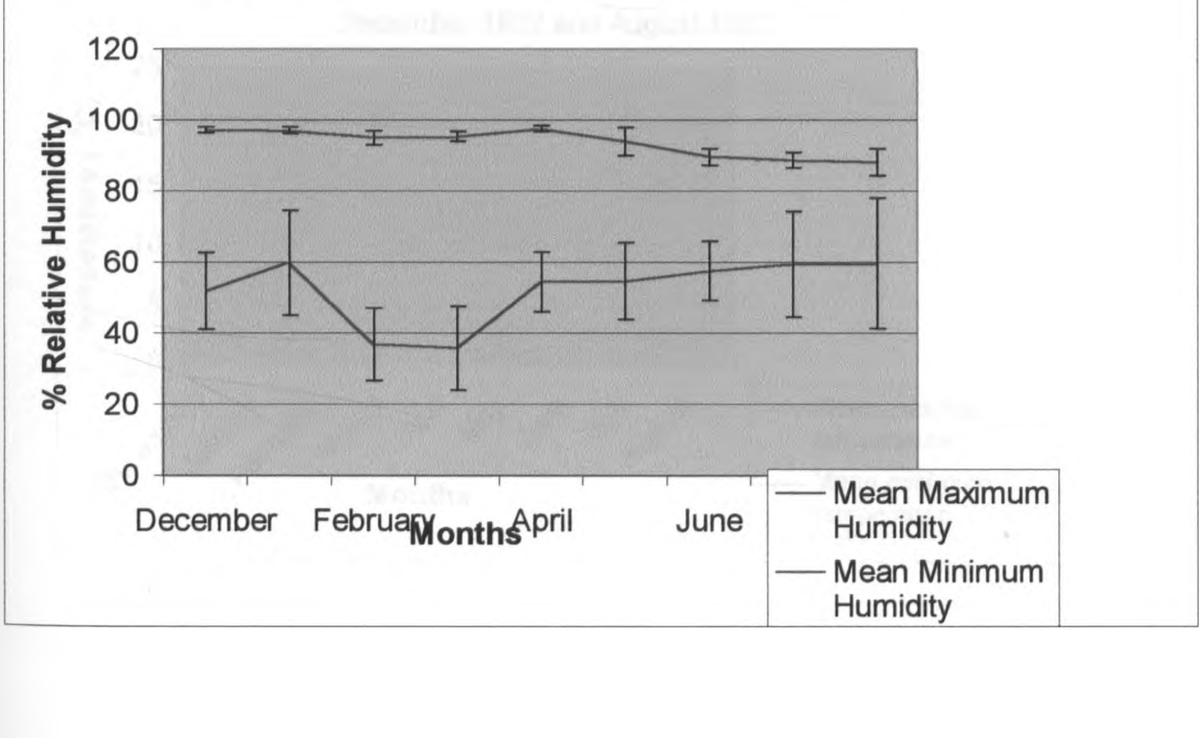


Fig 7: Mean monthly maximum and minimum relative humidity (%) in the shrub habitat , Aberdare National Park, between December 1992 and August 1993

Fig 8: Mean monthly maximum and minimum temperature (°C) in bamboo habitat, Aberdare National Park, between December 1992 and August 1993

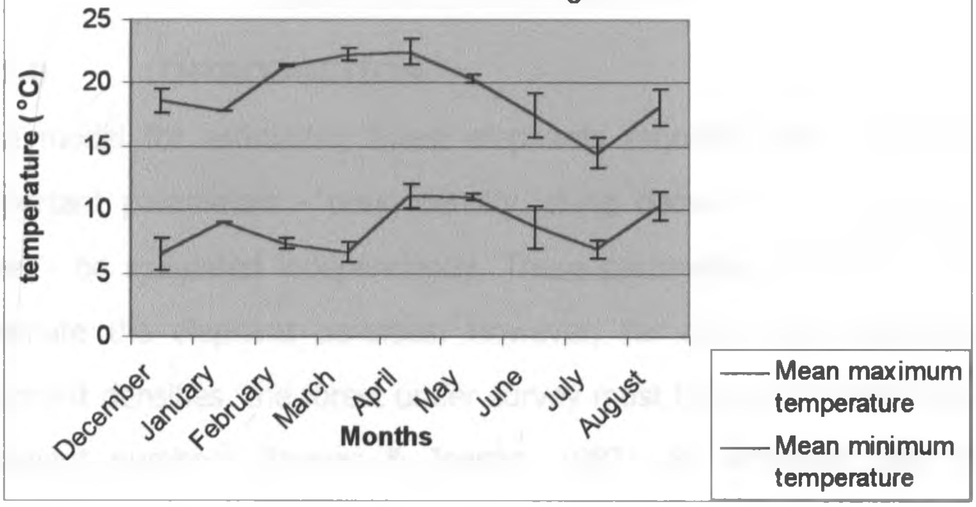
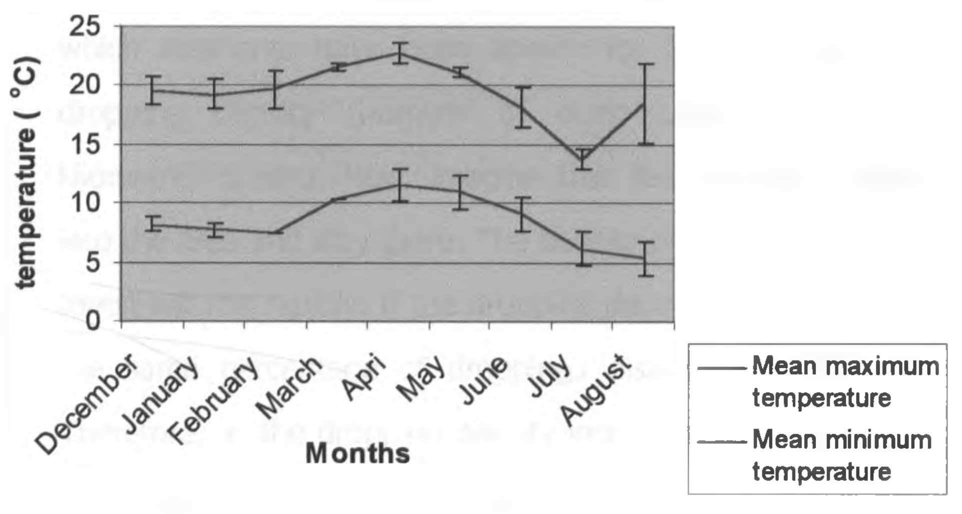


Fig 9: Mean monthly maximum and minimum temperature (°C) in shrub habitat, Aberdare National Park, between December 1992 and August 1993



CHAPTER 3
ESTIMATING POPULATION OF FOREST ELEPHANTS

3.1.0 INTRODUCTION

The model for estimating forest elephants requires that three equally important parameters - dung density, dung decay rate and defecation rate, - be estimated independently. These parameters are then used to estimate the elephant densities. However, for meaningful estimate of elephant densities, the forest under survey must be at a "steady state" of elephant numbers (Barnes & Jensen, 1987). By achieving this state, equilibrium between dung deposition and dung decay will exist. The following example, which is an extract from Barnes & Jensen (1987), illustrates the steady state assumption.

> "Consider a block of forest, which is 100km^2 in area, from which elephants have been absent for a long time. The dropping density (number of dung piles per square kilometre) is zero. Now, imagine that ten elephants move into the area and stay there. The density of droppings in this forest will rise rapidly. If the dropping decay rate is constant, the same percentage of droppings disappears each day. Therefore, as the dropping density increases, the number of dung piles disappearing each day will rise until it equals the number of dung piles deposited each day. At this stage, the system is in equilibrium and the number of droppings per square kilometre remains constant from day to day. The system is in a steady state. The assumption that a steady

state has been reached gives a simple method of converting an estimate of dung piles per square kilometre (Y) to elephants per square kilometre (E) (McClanahan, 1986)".

When this is the case, the number of dung piles produced per day (D) equals the number that is lost through decay (r), that is:

$$E \times D = Y \times r$$

Alternatively, $$E = Y \times r / D$$

Where **E** is the number of elephants per square kilometre (elephant density), **D** is the defecation rate, **Y** is the number of droppings per square kilometre (dung density) and **r** is the daily dung decay rate. The above equation gives the model for estimating forest elephants and is applied to the bamboo and shrub habitats of Aberdare National Park, in this study. A steady state was not determined for this study but it was assumed that the forest was/is in a steady state.

3.2.0 MATERIALS AND METHODS

Data collection was done in the two habitats, namely the Bamboo and the Shrub habitats. Data was collected on dung decay, factors influencing the rate of dung decay and dung density using similar methods in each habitat and season.

3.2.1 DUNG DECAY

Dung decay study was obtained by marking fresh (< 1 day old) dung and monitoring it at a regular interval until it completely disappeared. The fresh dung was obtained by locating and monitoring elephant herds during the day, and when they left an area all fresh dung piles voided were then marked. The marking was done with an aluminium tag which had a number engraved on it. After marking, the dung was not disturbed. Once marked, the fresh dung was monitored at an interval of seven to ten days. Dung pile that was < 1 day old was mainly determined from its physical condition as categorised below. In cases where elephant herds could not be located, fresh dung piles were located by following fresh tracks of elephants and looking for dung piles along the tracks. A total of two hundred and thirty one dung piles were marked and monitored at an interval of seven to ten days until they disappeared. Out of this, one hundred and nine were marked in the wet season and one hundred and twenty two in the dry season.

When a fresh dung pile was encountered, a minimum of three boli from this pile was marked for monitoring while the rest of the boli in the pile were used for insect collection and succession study. The general location and the microhabitat of the dung were noted. The microhabitat was categorised into three, based on the percentage of the canopy cover:

100%	: Fully covered by canopy or in undergrowth where sunlight cannot penetrate.
50%	: Partially covered by canopy or receives sunlight for part of the day.
0%	: No canopy cover, that is, receives sunlight for most part of the day.

Each dung was assigned to one of the following decay stages (Barnes and Jensen, 1987):

Stage A	: Boli intact, very fresh (<1 day old); moist with odour.
Stage B	: Boli intact, fresh but dry, no odour.
Stage C_1	: Some of the boli have disintegrated, but more than 50% are still distinguishable as boli.
Stage C_2	: Less than 50% of the boli are still distinguishable as boli.
Stage D	: All boli completely disintegrated, dung pile now forms an amorphous, flat mass.
Stage E	: Decayed to the stage where it would not be seen at 2m range in the undergrowth; it would not be seen on a transect unless directly underneath.

NB. This categorisation is based on the relative physical condition of the dung and not the age.

When the marked dung piles were revisited (every seven to ten days), each was reassigned to another stage if its physical appearance had changed. A dung pile was deemed to have fully decayed once it passed from stage D to E. As dung was being monitored at an interval of approximately seven to ten days, there is a possibility that dung decayed in between the interval. To correct for this error, it was assumed that dung - pile decayed half-way between the day it was last recorded as stage D and the first time it was recorded at stage E (Barnes & Barnes, 1991). In the dry season, it was observed that there was a considerable delay in the onset of decay due to termite activity. Termites attack the boli from within; thus, breakdown of the boli is not readily evident. A different categorization of the above decay stages as redefined by Dawson (1990) was thus adopted for the dry season. These stages are defined below:

B	: Termite activity had commenced from beneath (detected by the fact that dung was cemented to the substrate) but all boli still intact.
C_1	: Less than 50% of the boli consumed by the termites.
C_2	: More than 50% of the boli consumed by the termites.
D	: All boli disintegrated as a result of termite activity but not necessarily a flat amorphous mass.
E	: Only mud left (in the shape of boli); no dung left except for a few fibres.

3.2.2 FACTORS INFLUENCING THE RATE OF DUNG DECAY

The rate at which dung decay takes place is determined by many factors such as, the type of decomposers, the quality of the decomposing material and the physicochemical environment. This study examined the role of climatic factors and invertebrate fauna in determining the rate of decay of elephant dung. The climatic factors considered were rainfall, temperature and humidity. Rainfall was collected daily while the temperature and humidity though recorded daily, the record cards were collected weekly.

3.2.2.1 Climatic Factors

In each habitat, a thermohygrograph and a rain gauge were used to obtain daily information on temperature, relative humidity and rainfall. A thermohygrograph is an automatic instrument that records temperature and relative humidity simultaneously. The blank record cards were placed in the thermohygrograph, which has a calibrated clock and a pen. The clock was then wound to the maximum. As the clock unwound, the pen automatically inscribed on the record cards the humidity and temperature. The record cards used in the thermohygrograph were divided laterally into two equal halves. The upper half was for temperature while the lower half was for relative humidity. The record cards were further subdivided horizontally into seven days. At the end of the seventh day, a graph of the weeks' (on daily basis) temperature and relative humidity was obtained on the record cards. The record cards were changed weekly through out the study period. Since the rain gauge was manual, it was checked daily at 9:00 am for the amount of rainfall collected. This was measured in millimetres with the measuring cylinder provided with the rain gauge and recorded in the notebook.

3.2. 2.2 Invertebrate Fauna

The rest of the boli that were not used for decay study as were used for insect collection and succession study. This aspect of the study was achieved by destructive sampling of the boli, where the bolus was broken or dissected and all the large insects were picked either by forceps or hand depending on the size and preserved in ethyl acetate or 70% alcohol and then labelled for later identification.

Dung that had been colonized by insects for a known period was put in emergency traps and the date of emergence of a new insect was recorded. The basic principle of the emergence trap is that a newly-emerged insect, being positively phototactic, will make its way into the collecting vial (trap) which is emptied regularly (Southwood, 1980). However, only flying insects were trapped in the collecting vial. The vial was then opened up and the other insects were hand picked and preserved for later specific identification. Dung colonised for one, three, five, seven, eleven, fifteen and twenty one days was put in the traps.

Tullgren funnel was used to obtain additional information. This was done by placing fresh dung in it and collecting the insects from underneath. The principle of the Tullgren funnel is that, when dung is heated from above, various insects tend to move away from the hot zone to the cooler conditions below (Southwood, 1980). Since dung is placed suspended in a perforated tray over a funnel, progressive heating will cause the insects to move into a jar (containing 70% alcohol) underneath. Dung that was put in the Tullgren funnel was also colonized for one, three, five, seven, eleven, fifteen and twenty one days The Tullgren funnel thus supplemented the emergence traps by providing the smaller insects that otherwise would not have been hand picked, and information on insect succession was obtained. Dung in different decay stages, as categorized by Barnes & Jensen (1987), was broken and investigated for insects colonizing it. This was done for stages A - D (Section 3.2.1).

It was observed that some dung beetles dig holes underneath the dung piles. The beetles roll dung into these holes, where they eventually lay their eggs. It was, therefore, planned that, when dung was picked (for the Tullgren funnel and emergence traps), the space below would be investigated by using a quadrat of known size to sample the holes below the dung, and the stage of development - egg, larvae, pupae, adult - of the beetle noted. Unfortunately, this was not possible as it was only observed on the roads, which at the time of data collection, were under major repair. This does not mean that dung beetles do not dig holes off the roads, but possibly due to the undergrowth, it was not quite evident. This information was expected to supplement the results of emergence traps on ageing dung.

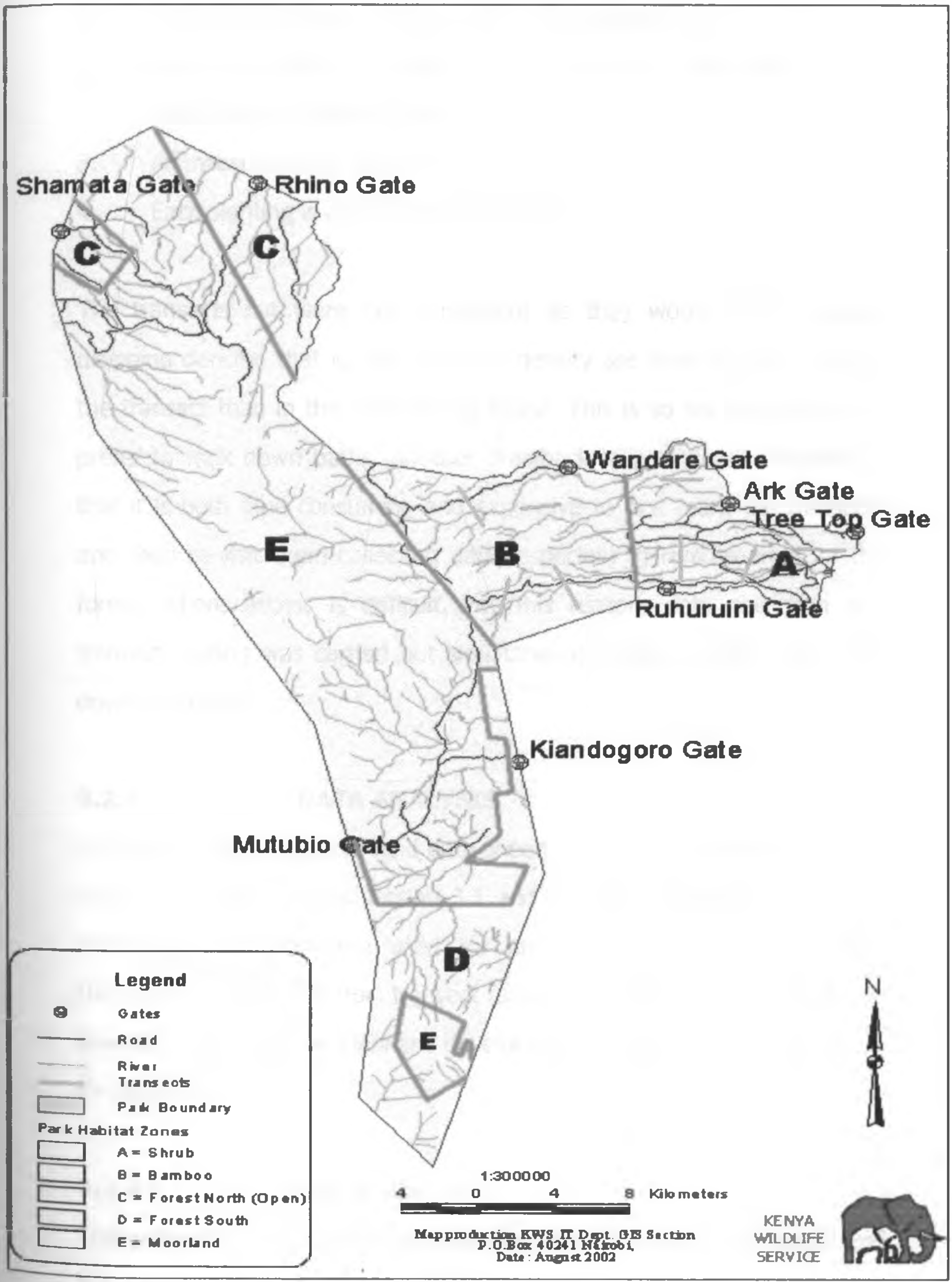
3.2.3 DUNG DENSITY

Barnes and Jensen (1987) recommend that dung density sampling by quadrats should be avoided in forest elephant censuses. They observed that in situations where the distribution of the target object (in this case dung) is clumped, the use of quadrats would result in a large sample error. For this reason, transects are a more efficient way of sampling forest elephants as opposed to quadrates. Although most censuses of large mammals in Africa have used transects of a predetermined fixed width (Barnes and Jensen, 1987) it is however not appropriate in situations where there is a sharp drop in visibility on either side of the transect, as is usually the case in forests. Transects of variable width are therefore preferred to fixed width transects in forest surveys.

Dung density is generally estimated by both line and short-cut transects (Barnes & Jensen, 1987). As compared to the line transects, the short cut transects do not folow a straight line, rather, one can choose to follow animal tracks. For this study, only line transects of variable width was used. Transect cutting was carried out in late March and early September. A total of sixteen transects, each approximately 2km, were cut in the two seasons and habitats. Eight transects were cut in each season and habitat. The transects were set in a way that they crossed the main drainage lines (Fig 10). For each transect, a recorder and two "cutters" (to clear the way for the recorder) were required. It involved walking slowly down a straight line (transect) on a certain compass bearing scanning the forest floor on either sides. As dung was encountered along the transect, the distance of the dung down the transect line was measured with the help of a "hip-chain". This is a device for measuring the length of a transect. It is a box containing a reel of cotton thread. The loose end of the thread is tied to a peg at the beginning of the transect. As one proceeds down the transect, the thread unwinds and passes over a spindle attached to a meter which shows the distance walked. The perpendicular distance of the dung pile from the transect line was measured by a steel tape. The decay stage of each dung pile measured as well as the vegetation type was recorded.

Although the line transect method is robust and rarely affected by differences between vegetation type and observer, it is important that the transect line be absolutely straight and its centre accurately determined (Burnham *et al.* 1980; Barnes *et al.*, 1987). As is required for the line transect method, the following assumptions were made in this study to achieve valid results.

Fig 10: Habitat Zones of Aberdare National Park showing areas where transects were cut



1. Dung on the transect line is seen with probability one;
2. All objects (dung) are fixed, do not move until they are counted and there is no double counting;
3. All measurements are done accurately and
4. Each sighting is an independent event.

The transects cut were not permanent as they would give a biased dropping density, that is, the dropping density are likely to be higher on the transect than in the surrounding forest. This is so because elephants prefer to walk down paths. Another drawback to permanent transects is that it is both time consuming and expensive to first mark the transects and then re-visit them collecting data, especially in remote areas of the forest, where access is difficult. For this reason, data collection and transect cutting was carried out simultaneously, thus passing only once down a transect.

3.2.4 DATA ANALYSIS

Data was transferred from field data sheets into an IBM laptop computer. This was stored in lotus version 3.1 and MS excel spreadsheets. Three computer programs were used for analysis; Fourier series program (Burnham *et al.* 1980) for transect analysis, statview for multivariate analysis and programe Elephant developed by Dekker & Dawson (1992) for dung decay.

3.2.4.1 DUNG DECAY

The analysis of the dung decay data was done using the exponential and the survival methods. The exponential method assumes that dung decays exponentially and, therefore, the equation of exponential decay is used to estimate the mean daily rate of decay. Monitoring is stopped once two thirds of the dung marked has disappeared (Barnes & Jensen, 1987). The exponential equation is given by:

$$Nt = N0\ e^{-rt}$$

Where **N0** = initial number of droppings; **Nt** = number left after **t** days; **r** = rate of decay. Taking natural logarithms (In or $\log_e$), the equation becomes:

$$\ln(Nt) = \ln(N0) - rt;$$

Alternatively, $$r = (\ln(N0) - \ln(Nt)) / t$$

On the other hand, the survival method does not assume any relationship of dung decay to time (Dawson, 1990) and derives the "life expectancy" of a dung pile from a simple life table of dung surviving at the end of each week (Amitage & Berry, 1987 cited in Dawson (1990)). In this method, dung is monitored until the last dung pile disappears and the mean expected survival time is calculated. The reciprocal of this survival time gives the decay rate (**r**). This means that:

$$r = 1 / T$$

And **T** is the mean survival time per dung pile.

3.2.4.2 FACTORS INFLUENCING THE RATE OF DUNG DECAY

3.2.4.2.1 Climatic Factors

The record cards from the thermohygrograph containing daily temperature and relative humidity were collected and used for the calculation of mean monthly maximum and minimum temperature and relative humidity for each habitat. Similarly, the monthly total rainfall for bamboo and shrub habitats was calculated from the rainfall notebook that contained the daily rainfall. For each dung pile marked, the mean maximum and minimum temperature and relative humidity as well as the total rainfall for the entire period that the dung lasted was calculated. These variables were then regressed against the time taken by the dung to decay. Multiple regression (stepwise regression) analysis was preferred to correlation analysis since the decay rate was assumed to be a function of temperature, relative humidity and rainfall.

3.2.4.2.2 Invertebrate Fauna

The preserved insects were then forwarded to the National Museums of Kenya (NMK) for specific identification. Since not all the insects could be identified to species level as they had been collected and preserved incorrectly, the identification was limited to the order level. For this reason and the fact that the sample size was not large enough to allow for statistical testing, ageing of dung was not done and is therefore not presented in the results or discussed.

3.2.4.3 ELEPHANT DENSITIES AND NUMBERS

To obtain elephant density, the three parameters dung density (Y), dung decay rate (r) and defecation rate (D) (section 3.1.0) must be measured. Once the elephant density (elephant numbers/km^2) is obtained, the estimate of the elephant numbers is achieved by multiplying this density with the area of the study site in square kilometres.

3.2.4.3.1 Dung Density

Data recorded from the transects was stored in MS excel spreadsheet. The Fourier series computer program was then used to analysis these data. This program calculates the dung density (**Y**) per square kilometre metre for each transect. Similarly, the program also provides the variance and the 95% confidence limit of the dung density, and the number of dung piles.

3.2.4.3.2 Estimate of Elephant Numbers

Elephant numbers were then estimated by applying the equation for estimating forest elephants since the dung density (**Y**) and decay rate (**r**) had now been calculated. The equation is represented by:

$$E = Y \times r / D$$

Since the defecation rate (**D**) of the two habitats under consideration was not estimated in this study, the widely used value of D = 17 droppings/elephant/day (Wing & Buss, 1970) was/has been adopted.

3.3.0 RESULTS

3.3.1 DUNG DECAY

The results of the dung decay experiments are summarised in table 1. Of the total dung marked in wet season, fifty-two were in the bamboo habitat and fifty-seven in the salient area. In the dry season, sixty dung piles were marked in the bamboo habitat and sixty-two in the salient area. A students t-test was used to analyse for seasonal and habitat differences. In the wet season, there was no significant difference in the rate of dung decay between bamboo and shrub habitat ($t = 0.263$, $p > 0.05$, $df = 107$) whereas in the dry season, the dung decay rate in these two habitats was significantly different ($t = 10.94$, $p < 0.05$, $df = 120$). Since the decay rates from the two habitats were not significantly different in the wet season, data for this season from both habitats were pooled to give a wet season decay rate of 0.0130 (95% CL = 0.0032) dung piles/day. In dry season the decay rates from the two habitats showed a significant difference.

Table 1: A comparison of the exponential and survival methods in estimating dung decay rates between the Bamboo and Shrub habitats during the dry and wet seasons.

Season & habitat	Sample size	Decay rate (dungpile/day) From exponential method	Decay rate (dungpile/day) From survival method
Wet bamboo	52	0.012 (+/-0.0009)	0.0130 (+/-0.0032)
Wet shrub	57	0.013 (+/-0.0032)	0.0140 (+/-0.0032)
Dry bamboo	60	0.008 (+/-0.0006)	0.0092 (+/-0.0006)
Dry shrub	62	0.014 (+/-0.0032)	0.0144 (+/-0.0017)

The numbers in parenthesis in the survival method column represents the 95% confidence limits attached to the dung decay rate.

It is clear from the dung decay results obtained that, in the dry season, dung decays much slower in the bamboo habitat as compared to the shrub habitat. While in the wet season the difference is not significant although slightly faster in the shrub habitat, which is at a lower altitude compared to the bamboo habitat.

The decay rates calculated from the exponential method compared closely to the ones calculated from the survival method, though slightly slower except for bamboo habitat in dry season. It is therefore, not necessary to set up different decay studies for wet and dry seasons in the shrub habitat and a decay rate from any one season can be used in the equation for the model of estimating forest elephants. This is, however, not the case in the bamboo habitat, where two separate decay rates for wet and dry season must be estimated.

Figures 11 and 12 represent the dung survivorship curves for the two seasons and habitats, which were obtained by plotting the number of dung piles persisting per week. There was a delay in the onset of dung decay in the two habitats in each season. In the dry season, the delay in both habitats was twice as long as that observed in the wet season. This delay was due to the absence of fungi that were observed in the wet season and a drop in the abundance of the dung beetles in the dry season, leaving only termites as main agent of decay. In the wet season, the delay in the onset of dung decay despite the presence of beetles was attributed to the sensitivity of the method used to estimate decay (section 3.2.1). Decay was determined largely by visual observation of the physical appearance of the dung. The activities of

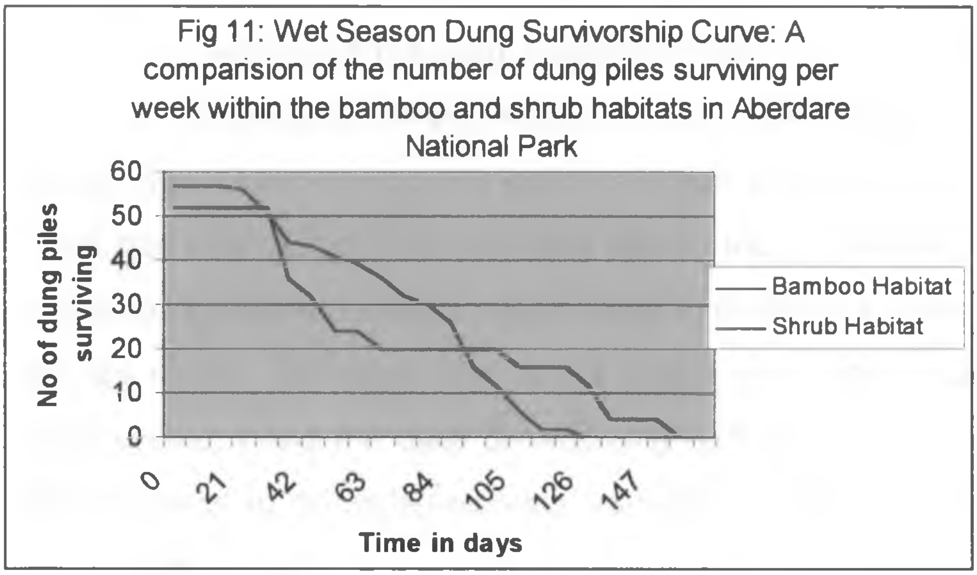


Fig 11: Wet Season Dung Survivorship Curve: A comparision of the number of dung piles surviving per week within the bamboo and shrub habitats in Aberdare National Park
60
50
40
30
20
10
0
No of dung piles surviving
0
21
42
63
84
105
126
147
Time in days
Bamboo Habitat
Shrub Habitat

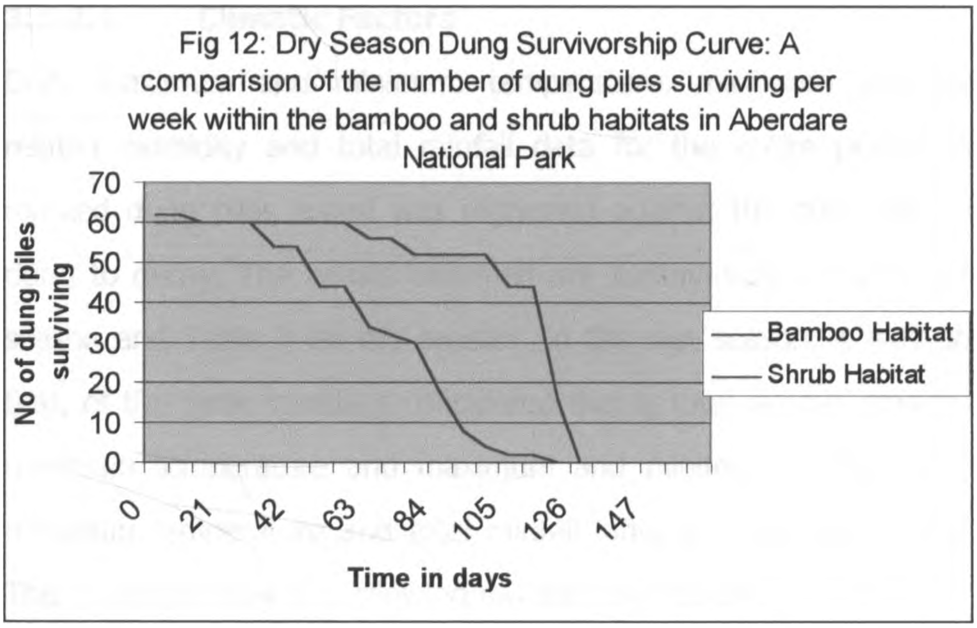


Fig 12: Dry Season Dung Survivorship Curve: A comparision of the number of dung piles surviving per week within the bamboo and shrub habitats in Aberdare National Park
70
60
50
40
30
20
10
0
No of dung piles surviving
0
21
42
63
84
105
126
147
Time in days
Bamboo Habitat
Shrub Habitat

the dung beetles were not evident on the surface of the dung in the first two to four weeks and the dung appeared stable, that is not decaying. However, the presence of the beetles in this period (first two to four weeks) was confirmed from the insect collection study (section 3.2.2.2). Fungi that were observed on the dung piles in the wet season probably had an added influence on the rate of decay thus making it faster than in the dry season. The decay rate in wet season was faster because the dung beetles, being the main decomposing agents in the wet season, found it easier to dig underneath the dung piles as the ground was soft and consistently wet.

3.3. 2 FACTORS INFLUENCING THE DECAY RATE

3.3.2.1 Climatic Factors

Daily maximum and minimum temperature, maximum and minimum relative humidity and total rainfall data for the entire period that the marked dung piles lasted was regressed against the time taken for the dung to decay. The results obtained are summarised in Table 2 for wet season and Table 3 for dry season. In the wet season, it was observed that, of the three variables considered that is total rainfall, maximum and minimum temperature and maximum and minimum humidity, only the minimum temperature and total rainfall influenced the dung decay rate. This is indicated by the following multiple regression equation:

$$Y = a + b_1X_1 + b_3X_3$$

where; $a = -117.27$, $b_1 = 0.179$, $b_3 = 18.281$, X_1 = total rainfall and X_3 = minimum temperature. Alternatively the equation can be expressed as

$$Y = -117.27 + 0.179X_1 + 18.281X_3$$

Table 2: Results of the stepwise regression of the climatic variables affecting dung decay rate in wet season

Variables in equation

Variable	coefficient	Std error	Std coeff	F to Remove
INTERCEPT	-117.27			
Mini Temp-Wet	18.281	1.376	0.499	176.61
Total rain-wet	0.179	0.011	0.603	257.611

Variables not in equation

Variable	Par. Corr:	F to Enter
Maxi Temp - Wet	-0.087	0.793
Maxi Hum - Wet	-0.123	1.596
Mini Hum - Wet	0.091	0.869

Table 3: Results of the stepwise regression of the climatic variables affecting dung decay rate in dry season

Variables in equation

Variable	**coefficient**	**Std error**	**Std coeff**	**F to Remove**
INTERCEPT	-2013.074			
Maxi Temp-Dry	70.505	9.447	1.189	55.703
Mini Temp-Dry	-16.648	8.01	-0.27	4.319
Mini Hum-Dry	19.045	2.404	0.588	62.771
Total rain-Dry	0.102	0.011	0.351	82.863

Variables not in equation

Variable	**Par. Corr:**	**F to Enter**
Maxi Hum - Dry	-0.91	0.966

The above equation further indicates that although the two variables both have a positive effect on the decay rate, the minimum temperature has a more pronounced effect.

In the dry season, the decay rate is affected by all except one of the variables considered, that is, the maximum humidity. The multiple regression equation in the dry season thus takes the following form:

$$Y = a + b_2X_2 - b_1X_1 + b_4X_4 + b_5X_5$$

where; a = -2013.074, b1 = -16.648, b2 = 70.505, b4 = 19.045, b5 = 0.102, X1 = minimum temperature, X2 = maximum temperature, X4 = minimum humidity, X5 = total rainfall. This equation can also be expressed as

$$Y = -2013.074 + 70.505X_2 - 16.648X_1 + 19.045X_4 + 0.102X_5$$

This indicates that the dung decay rate is affected positively by maximum temperature, minimum humidity and total rainfall, but negatively by the minimum temperature.

3.3. 2.2 Invertebrate Fauna

Insects collected were identified at the National Museums of Kenya (Entomology Section). Forty-two insect specimens were identified (Table 4), with eighteen of them to the species level. The collected insects fell into three main orders namely; Coleoptera, Diptera and Isoptera. Out of the forty-two specimen, it was observed that the order Coleoptera where dung beetles belong dominated the wet season while the order Isoptera where termites belong were abundant in the dry season. The order Diptera where flies belong was represented equally in the seasons. When dung is deposited, flies (order Diptera) and dung beetles were the first to be attracted possibly for food and in the process deposits their eggs. It was therefore observed that in wet season, dung is colonised by flies and beetles in the first, second and third weeks while in the dry season, the second weeks' composition is termites and very few beetles and that of the third week is almost purely termites. Similarly, a lot of beetle larvae were observed in the dung during the second and third weeks in wet season while in the dry season it is the larvae of the termites that were observed in the third week.

Table 4: Variation of insect abundance in dry and wet seasons

Order	No. in wet season	No. in dry season	Total no. identified
Coleoptera	16	4	20
Diptera	6	6	12
Isoptera	0	10	10
Total	22	20	42

3.3.3 ESTIMATES OF ELEPHANT DENSITIES AND NUMBERS

The elephant density was ere calculated using the equation for the model of estimating forest elephants, that is:

$$E = Y \times r / D,$$

where E is the estimated density of elephants, Y is the estimated dung density, r is the estimated dung decay rate and D is the estimated elephant defecation rate. Once the elephant density was obtained it was used to calculate the elephant numbers. Since a defecation rate was not estimated for this study, the widely used rate of 17 droppings per elephant per day (Wing & Buss, 1970) was adopted.

3.3.3. 1 DUNG DENSITY

Eight transects were cut in each season, that is, four per habitat, giving a total of sixteen (approximately 2km each) transects. Estimates of dung and elephant densities in each habitat and season are shown in Table 5. Although there were more dung piles (203) in the shrub habitat in wet season compared to the bamboo habitat (147), the mean dung density for the wet season in these two habitats did not differ significantly ($t = 0.99$, $p > 0.05$ $n = 6$). The dung density data for these two habitats was therefore pooled. Similarly, the number of dung piles in the two habitats in dry season did not differ significantly ($t = 0.15$, $p > 0.05$, $n = 6$) and the dry season dung density data for these two habitats was similarly pooled. The seasonal difference in dung density was investigated by pooling the dung density data in each season.

Table 5: A comparison of seasonal changes in dung and elephant density between the bamboo and shrub habitats in Aberdare National Park

	Wet season Bamboo	Wet season shrub	Dry season bamboo	Wet season shrub
No. of transects cut	4	4	4	4
Total length in km	9.07	9.90	10.13	10.99
Total no. of dung piles	147	203	227	229
Mean dung density/km^2	5332.98	6636.41	5696.33	6044.42
Elephant density km^2	4.078	5.465	2.681	4.978

Data from wet season bamboo and shrub was pooled to obtain a wet season mean dung density of 5984.69 (std dev. 1859.33, n = 8). Similarly a mean dung density of 5870.37 (std dev. 3115.50, n = 8) was obtained for dry season (Table 6). These two mean dung densities were not statistically ($t = 0.09$, $p > 0.05$, $n = 14$) despite differences in transect length and total number of dung piles encountered between the two seasons. The distance/length covered in wet season was less than the dry season but with more dung piles encountered as compared to the dry season. These results therefore allow for pooling of all the dung density data irrespective of habitat and season to obtain a mean dung density (for the two habitats & seasons) of 5927.5 3 (std dev. 2479.2, n = 16) and elephant density of 4.184 elephants per km^2

Table 6: Pooling dung density data for habitat within each season

	Wet season	Dry season
No. of transects cut	8	8
Total length in km	18.97	21.12
Total no. of dung Piles	350	227
Mean dung density per km^2	5,984.69	5,870.37

3.3.3. 2 ELEPHANT NUMBERS

Elephant number for each habitat and season were estimated by multiplying the elephant density in each habitat and season with the area of the habitat. The results are summarised in table 7. The elephant numbers ranged between 334 and 693. A total of 693 elephants were estimated in the bamboo habitat in the wet season. This number dropped to 456 in dry season. In the shrub habitat, the elephant numbers did not change much with 366 estimated in the wet season and 334 in the dry season. A total of 1,085 elephants were estimate in the two habitats in wet season and 900 in the dry season (Table 8). All in all, 992 elephants were estimated for the two habitats irrespective of the season. This was obtained by multiplying the mean elephant density with the total area of the two habitats. That is: $4.184 \times 237 km^2 = 992$ elephants. Table 9 indicates that, like the decay rates, the number of elephants in the two habitats as estimated using the exponential and survival methods compared closely.

Table 7: Elephant densities and numbers in Bamboo and Shrub Habitats in each season

	Wet season bamboo	Wet season shrub	Dry season bamboo	Dry season shrub
Elephant density per km^2	4.078	5.465	2.794	4.978
Habitat area in km^2	170	67	170	67
Estimated no. elephants	693	366	475	334

Table 8: Overall seasonal differences in elephant densities and numbers

	Wet season	Dry season
Elephant density per km2	4.577	3.799
Habitat area in km^2	237	237
Estimated no. of elephants	1,085	900

Table 9: Seasonal differences in elephant numbers between the Bamboo and Shrub habitats as estimated using the Exponential and Survival dung decay methods.

	Wet season Bamboo	Wet season Shrub	Dry season bamboo	Dry season shrub
Exponential method	640	340	513	334
Survival method	693	366	456	334

3.5.0 DISCUSSION

3.5.1 GENERAL OBSERVATIONS

The amount of data collected, especially the marking of dung, was limited by heavy rainfall and elephant movement. Dung was located easily in wet season in the salient habitat as opposed to the bamboo habitat. This could be due to the fact that elephants occupy the lower altitude salient during the rains and move up to the bamboo during the dry season. The dung beetle activity was observed to achieve a peak at the height of the rains. In the drier months, however the activity of coprophagous beetles decreased, and that of termites increased.

3.5.2 THE RATE OF DUNG DECAY IN THE HABITATS

Dung was observed to decay much slower in the bamboo habitat during the dry season, as compared to the shrub habitat, which is at a lower altitude than the bamboo habitat. Given this, one would expect a faster decay rate at the lowland forests such as Arabuko Sokoke and Shimba Hills. In their study, Anderson and Coe (1974) though used a different method of estimating dung decomposition also demonstrated that decomposition processes were very rapid in tropical regions with an annual mean temperature of 20^{o}-25^{o}C or above. Re-analysis of the Shimba Hills dung decay data yielded a decay rate of 0.0058 (Mulama, 1994) which is much slower than the slowest decay rate obtained in the present study. The decay rate used to estimate the elephant numbers in Arabuko Sokoke was an adopted one and therefore can not be compared to that of the present study.

This observation may seem to contradict the statement that one expects a faster decay rate at the lowland forests. It is, however, important to note that altitude is just but one of the several variables that influence the decay rate (through temperature, rainfall and humidity) and that each variable has it own influence no matter how small. In 1987, Barnes and Jensen showed that decay rate follows a simple negative exponential model. Data from the present study, however, showed a delay in the onset of decay, which was more pronounced in the bamboo habitat during the dry season.

The dung decay rates obtained in this study may be compared further with other studies conducted in different parts of Africa and Asia. Kingston (1977) found that dung was removed at a rate of 0.155% per day in savannah habitat (Tsavo), while the slowest decay rate from the study on Asian elephants (*Elephus maximus*) by Dawson (1990) was 0.81% per day. Both these rates are slower than the slowest rate obtained in the Aberdare (0.90%). Also studying in Tsavo, Buxton (1979) found that removal of dung by termites took place in a mean of 120 days. This is close to that obtained in the present study except for wet season in bamboo habitat, which stretched up to 154 days. The mean of 120 days is also not very different from that indicated by Dawson (1990) in India. In Kilimanjaro forest the decay rate obtained (0.0060, Grimshaw and Foley, 1990) is slower than the slowest rate obtained in the present study, especially the shrub habitat that is almost at the same altitude with the Kilimanjaro study location.

3.5.2 VARIABLES INFLUENCING THE DUNG DECAY RATE

Studies that have looked at the variables influencing dung decay rate are limited. However those that have looked at these variables have shown that microorganisms, macro-organisms and weather are the key factors involved in dung decay. Although this study did not consider the microorganisms, it showed that both climatic factors and invertebrate fauna play a significant role in the decomposition of dung. Anderson & Coe (1974) observed that in an arid tropical environment, elephant dung is not extensively utilised by dung beetles in dry season, while in wet season, the rate of dung removed by beetles could be extremely high. A similar trend as that observed by Anderson & Coe (1974) was observed in this study with dung beetles dominating the wet season. In dry season, the termites were observed to be the most active decomposers. In this season, the dung beetles are thought to be in a form that can not decompose. Similarly Leakey (1992) also observed that the dung beetle activities were considerably reduced in the dry season and beetles were therefore not the key dung decomposers. Results in this study also showed that there was a significant difference, in dry season, between the decay rate in bamboo and shrub habitats. This is an indication that the habitat also affects the rate of elephant dung decay.

Climatic factors can be considered to have a double effect on the decay rate since they not only contribute directly to the breakdown of the dung through the direct effects of erosion and exposure, but they also control the extent that the other factors, in this case the invertebrate fauna, are involved in break down. In the wet season both total rainfall and minimum temperature influence the dung decay rate. The results here have shown that even though there is rainfall, it is important to have a high minimum temperature for the dung to decay faster. The effect of the minimum temperature is reversed in the dry season. This is because along with the minimum temperature and total rainfall, two other factors come in. These are minimum humidity and maximum temperature, meaning that it is now important to have a very low minimum temperature for the dung to decay faster. This very low minimum temperature is thought to be important to *"balance"* the high maximum temperature thus marking conditions favourable for the other decomposing agents, especially the invertebrate fauna, to act.

3.5.3 ELEPHANT DENSITY AND NUMBERS IN THE TWO HABITATS OF THE PARK

As the defecation rate was not estimated in this study, the adopted rate by Wing & Buss (1970) has an associated error which means that the elephant numbers obtained in this study too have an associated error. They should strictly be looked at as an approximation of the true elephant numbers. The general observation that elephants occupy the low altitude shrub habitat in the wet season and the high altitude bamboo habitat in the dry season can be supported by the number of dung piles encountered, except for dry season bamboo, which showed almost the same number of dung piles as the shrub habitat during the dry season. The reverse should have been true. Although wet season shrub registered the highest mean dung density, statistical analysis showed that the difference between the two habitats was not significant. Similarly the difference between the bamboo and shrub habitats in dry season was not significant. It is also important to point out that, when transects were cut, both old and new (fresh) dung piles were counted. The fresh dung could be restricted to the particular season that the transect was cut but some of the old dung might have been deposited in a different season. As a result, there is a bias in the dung density.

The pooled dung density data indicated that the mean dung density did not change much between the seasons. This actually was the case as the difference was statistically not significant. As dung density is an indicator of elephant numbers/concentration, it can be suggested that elephants are present in these habitats almost on a permanent basis.

Generally the elephant densities are high in the two habitats under consideration. The elephants had a liking for the shrub habitat round the year; that is, the elephant density does not change significantly between the seasons. The impact of these continued elephant pressure (density) in this habitat is beginning to show in areas around Treetops lodge. There is a considerable change of elephant density in the bamboo habitat between seasons showing a one and a half (1.5) lower density in the dry season compared to the wet season. This means that the habitat is relieved of the elephant pressure by a factor of 1.5 in the dry season.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

6.1.0 THE MODEL FOR ESTIMATING FOREST ELEPHANTS

For census in forest habitats, the indirect method using the model for estimating forest elephants as reported in this study has a. practical advantage. The advantage is that one need not necessarily see the elephants to count them, that is, one can actually obtain an estimate of the elephant population without seeing any member of the population. However, the following aspects of the model need to be improved, as they are central in the model:

1. Steady state assumption

The model for estimating forest elephants assumes that the forest under consideration is in a steady state (section 3.1.0). However, in East Africa, there are no "true" forest elephants since the forests are small and usually have several patches of grassland within them as compared to the huge forests of Central and West Africa, where the model was developed. Elephants therefore forage alternatively in the forests and the grassland patches available. This then raises the question - Are there true steady state forests in East Africa? It is recommended that methods that do not assume steady state (Hiby & Lovell, 1991) should be tried.

2. Defecation rate

Defecation rate may be influenced by various factors. Barnes (1979) established significant seasonal and habitat difference in defecation rates of bull elephants of Ruaha National Park, Tanzania. His study also revealed a significant difference in the defecation rates of the two sexes in the wet season while the difference was not significant in the dry season. For optimal results, it is recommended that defecation rates should be estimated in the forests under consideration during the season when the study is conducted.

3. Dung decay

As observed from this study, decay rate is influenced by climatic factors, especially rainfall. It is therefore recommended that climatic factors should be considered whenever a decay study is conducted. The influence by invertebrate fauna needs to be investigated further. Similarly, it is recommended that dung decay rates should be estimated in the forest whose elephant numbers are being estimated.

6.2.0 ELEPHANT DENSITIES AND NUMBERS

In the light of the results obtained from this study, the elephant densities are high in the two habitats studied. This high density could lead into degradation of these habitats. It is recommended here that management strategies to cope with these densities should be sought considering the facts that: (a) these habitats, especially the shrub, are the "heart" of the park in terms of animal diversity and (b), plans to fence the entire park are under way. These strategies should for now centre around redistributing the elephants within the park. The forest in the northern section of the park (Rhino and Shamata areas) is under utilised by elephants. This study has demonstrated that accurate estimation of the decay rate is indeed important as a slight change in this rate has a corresponding effect on the elephant numbers. This study has also shown that while two different decay studies are required, one in each season for the bamboo habitat, this is not the case in the shrub habitat as decay rate of any one season can be used.

This method converts the elephant densities into numbers by multiplying it (the density) with the area of the study site. This tends to give an over estimate as in many cases the elephants do not utilise the entire study site yet the area of the entire study site is used in the calculation of the elephant numbers. This is a common error because transects are mainly in the useable elephant habitat only. It is recommended that where it is not possible to estimate the useable elephant range, the area of this range should be used for calculating the elephant numbers. Otherwise in situations where it is not possible to estimate the area of this range, management considerations should be made based on the elephant densities and not numbers *perse*. In the present case of Aberdare National Park, the elephants not only use the park but also the adjacent Aberdare forest. Hence a survey should be conducted for the entire Aberdare forest ecosystem.

6.3.0 FACTORS INFLUENCING DUNG DECAY RATE

For the factors influencing dung decay rate, it has been shown in this study that all the climatic factors considered except the maximum humidity, have either positive or negative effect on the rate of dung decay. In wet season, it is the total rainfall and minimum temperature that affect the decay rate while in the dry season minimum humidity and maximum temperature supplement the two. The invertebrate fauna observed to compliment the climatic factors are dung beetles in wet season and termites in dry season. Further studies on the influence of the invertebrate fauna are however, recommended as this was not extensively covered in this study.

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Appendix I: Results of the regression analysis for wet season

Stepwise Regression Y_1: Dung decay - wet season 5 X variables

Summary Information

F to enter	4
F to remove	3.996
Number of steps	2
Variables entered	2
Variables forced	0...0

Residual Information Table

SS[e(I)-e(I-1)]	e≥ 0:	e< 0:	DW test:
9944.584	58	50	.558

Note: 138 cases deleted with missing values

Stepwise Regression Y_1: Dung decay - wet 5 X variables

STEP NO 1. VARIABLE ENTERED: X 5: Tot Rain-wet

R:	R-squared	Adj. R-squared:	RMS Residual
.826	.682	.679	21.234

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test
REGRESSION	1	102294.213	102294.213	226.867
RESIDUAL	106	47795.417	450.9	
TOTAL	107	150089.63		

STEP NO. 1: Stepwise Regression Y_1: Dung decay - wet 5 X variables

Variables Equation

Variable	Coefficient	Std. Err:	Std. Coeff:	F to remove
INTERCEPT	18.352			
Tot Rain-wet	.245	.016	.826	226.867

Variables not in Equation

Variable:	Par. Corr:	F to enter
Maxi Temp-wet	.372	16.867
Mini Temp-wet	.792	176.61
Maxi Hum-wet	-.28	8.917
Mini Hum - wet	.151	2.556

Stepwise Y_1: Dung decay - wet season 5 X variables

(LAST STEP) NO. 2 VARIABLE ENTERED. X_2: Mini Temp-wet

R:	R-squared	Adj. R-squared:	RMS Residual
.939	.881	.879	13.028

Analysis of Variance Table

Source	DF:	Sum squares	Mean Square	F-test
REGRESSION	2	132268.844	66134.422	389.664
RESIDUAL	105	17820.786	169.722	
TOTAL	107	150089.63		

STEP NO. 2 Stepwise Regression Y_1: Dung decay-wet season 5 x variables

Variables in Equation

Variable	Coefficient:	Std. Err:	Std. Coeff:	F to remove
INTERCEPT	-117.27			
Mini Temp-wet	18.281	1.376	.499	176.61
Tot Rain-wet	.179	.011	.603	257.611

Variables No in Equation

Variable	Par. Corr:	F to enter
Maxi Temp-wet	- .087	.793
Maxi Hum-wet	- .123	1.596
Mini Hum-wet	.091	.869

Appendix II: Results of the regression analysis of the dry season

Stepwise Regression Y_1: Dung decay - dry season 5 X variables

Summary Information

F to enter	4
F to remove	3.996
Number of Steps	4
Variables Entered	4
Variables Forced	0...0

Residual Information Table

SS[e(i)-e(i-1)]:	e ≥ 0:	e < 0:	DW test:
7578.463	66	56	.521

Note: 124 cases deleted with missing values.

Stepwise Regression Y_1: Dung decay - dry 5 X variables

STEP NO. 1: VARIABLE ENTERED: X_2: Mini Temp-dry

R:	R-squared	Adj. R-Squared	RMS Residual
.805	.648	.645	17.878

Analysis of Variance Table

Source	DF:	Sum Squares	Mean Square	F-test
REGRESSION	1	70503.467	70503.467	220.576
RESIDUAL	120	38356.008	319.633	
TOTAL	121	108859.475		

STEP NO. 1. Stepwise Regression Y_1 Dung decay - dry 5 X variables

Variables in Equation

Variable	Coefficient	Std. Err:	Std. Coeff.	F. to remove:
INTERCEPT	-311.556			
Mini-temp-dry	49.686	3.345	.805	220.576

Variables Not in Equation

Variable	Par. Corr:	F to enter
Maxi Temp-dry	.036	.154
Maxi Hum-dry	.143	2.489
Mini Hum-dry	.254	8.208
Tot Rain dry	.643	83.901

Stepwise Regression Y_1: Dung decay - dry 5 X variables

STEP NO. 2 VARIABLE ENTERED: X_5: Tot Rain dry

R:	R-squared:	Adj: R-squared:	RMS Residual:
.891	.793	.79	13.749

Analysis of Variance Table

Source	DF:	Sum Squares:	Mean Square:	F-test:
REGRESSION	2	86364.001	43182.001	228.431
RESIDUAL	119	22495.474	189.038	
TOTAL	121	108859.475		

STEP 2: Stepwise Regression Y_1: Dung decay - dry 5 X variables

Variables in Equation

Variable	Coefficient	Std. Err:	Std Coeff:	F to Remove
INTERCEPT	-235.04			
Mini Temp-dry	38.527	2.847	.624	183.175
Tot Rain dry	.123	.013	.422	83.901

Variables Not in Equation

Variable	Par. Corr:	F to enter
Maxi temp-dry	.076	.688
Maxi Hum-dry	.188	4.305
Mini Hum-dry	.212	5.545

Stepwise Regression Y_1: Dung decay-dry 5 X variables

STEP 3: VARIABLE ENTERED: X 4: Mini Hum-dry

R:	R-squared	Adj. R-squared	RMS Residual:
.896	.803	.798	13.494

Analysis of Variance Table

Source	DF:	Sum Squares	Mean Square	F-test
REGRESSION	3	87373.675	29124.558	159.952
RESIDUAL	118	21485.801	182.083	
TOTAL	121	108859.475		

STEP NO. 3 Stepwise Regression Y_1: Dung decay-dry 5 X variables

Variables in Equation

Variable:	Coefficient:	Std. Err:	Std. Coeff:	F to remove:
INTERCEPT	-440.531			
Mini Temp-dry	40.391	2.904	.654	193.486
Mini Hum-dry	3.242	1.377	.1	5.545
Tot Rain dry	.118	.013	.407	79.06

Variables No in Equation

Variable:	Par. Corr:	F to enter:
Maxi Tem-dry	.568	55.703
Maxi Hum-dry	.052	.315

Stepwise Regression Y_1: Dung decay - dry 5 X variables

(Last step) STEP NO. 4. VARIABLE ENTERED: X_1: Maxi Tem-dry

R:	R-squared	Adj: R-squared:	RMS Residual
.931	.866	.862	11.154

Analysis of Variance Table

Source	Df:	Sum Squares:	Mean Square	F-test
REGRESSION	4	94303.661	23575.915	189.504
RESIDUAL	117	14555.814	124.409	
TOTAL	121	108859.475		

STEP NO. 4 Stepwise Regression Y_1: Dung decay - dry 5 Xx variables

Variables in Equation

Variable	Coefficient:	Std. Err:	Std. Coeff:	F to remove
INTERCEPT	-2013.074			
Maxi Tem-dry	70.505	9.447	1.189	55.703
Mini Tem-dry	-16.648	8.01	-27	4.319
Mini Hum-dry	19.045	2.404	.588	62.771
Tot Rain dry	.102	.011	.351	82.863

Variables not in Equation

Variable	Par. Corr:	F to enter
Maxi Hum-dry	**-.091**	**.966**

Appendix III: Identification of insects collected from elephant dung in wet and dry seasons, December 1992 to November 1993

Serial No.	Order	Family or sub-family	Genus, species and author	Total No.	Wet season	Dry season
1	Coleoptera	Scarabaeidae /coprinae	*Oniticellus arrowi Bouc*	2	xx	
2	Coleoptera	Scarabaeidae /coprinae	*Onthophagus sp.*	2	xx	
3	Coleoptera	Scarabaeidae /coprinae	*Aphodius sp.*	4	xxxx	
4	Coleoptera	Histeridae	*Hister sp.*	2	xx	
5	Coleoptera	Scarabaeidae /coprinae	*Onitis crenatus, Reiche*	2	xx	
6	Coleoptera	Scarabaeidae /aphodinae	*Aphodius holubi,Dohm*	2	xx	
7	Diptera	Muscidae	*Dichaetomyia sp*	2	xx	
8	Diptera	Muscidae	*Limnophora perfidodes emd*	2	xx	
9	Coleoptera	Staphylinidae		2	xx	
10	Diptera	Muscidae		8	xx	xxxxxx
11	Coleoptera	Scarbaeidiae		4		xxxx
12	Isoptera			10		xxxxxxxx xx