Citation for published version

Ekobo, Atanga (1995) Conservation of the African forest elephant (Loxodonta africana) in the Lobeke, south-east Cameroon. Doctor of Philosophy (PhD) thesis, University of Kent.

DOI

uk.bl.ethos.262645

Link to record in KAR

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CONSERVATION OF THE AFRICAN FOREST ELEPHANT

(*LOXODONTA AFRICANA*)

IN

THE LOBEKE, SOUTH-EAST CAMEROON

Atanga EKOBO

Thesis submitted for the degree of Doctor of Philosophy

in Conservation Biology

University of Kent at Canterbury

1995

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ABSTRACT

The Lobeke forest contains not only the largest elephant population of Cameroon, but also the highest density of elephant surveyed in the Central African rainforest. This study aimed at providing the information needed for the creation of a reserve in the Lobeke forest. Data were collected on the ecology of elephants as well as on the ecology of the indigenous peoples living in close proximity to the proposed reserve.

The study reviews the status of elephants in Africa and in Cameroon and describes the Lobeke forest. Dropping counts along line transects were used for the study of the distribution and numbers of elephants in the proposed reserve. Daily activities and aspects of the population dynamics, such as the age structure, sex ratio and reproductive performance were studied by direct observations. The diet and crop depredation by elephant were also studied. The ecology of the indigenous peoples was assessed using data collected by direct observations in villages and in the forest, in conjunction with a questionnaire. The study focused on their demography, food restrictions and traditional activities such as hunting, fishing, gathering and farming.

It was found that: the Lobeke forest is an elephant refuge during the dry season; there are important movement of elephants in and out of the area over the seasons; the Sangha drainage system is important for elephants in the Lobeke forest; the distribution of elephants is more related to food availability; the defecation rate does not vary over the seasons; forest elephant tend to associate in small groups; bark and leaves make up the bulk of their food and crop raiding is negligible in the Lobeke forest. For the indigenous peoples, the forest contributes to their daily subsistence needs as well as providing the means of earning cash income. It also provide them with medicine, building materials, fuel wood and materials for all sort of household articles.

Throughout the discussion, comparisons to other elephant populations as well as other indigenous peoples are made. Aspects of the design of the future reserve are also discussed. The study concludes with a set of recommendations for the conservation of the elephant population in the Lobeke forest.

ACKNOWLEDGMENTS

I am very grateful to Dr Steve Gartlan, Country Representative WWF- Cameroon, to have given me the opportunity to undertake this study and for his encouragement and guidance.

I am also very grateful to the World Wildlife Fund for Nature (WWF-US) and the Durrell Institute of Conservation and Ecology (DICE), University of Kent for funding this research.

I would like to thank my supervisor Dr Mike Walkey, Executive Director of DICE for his encouragement and guidance.

I owe a special debt to Dr Richard Barnes for his useful comments, critics and suggestions. My special thanks extend to: Dr Elizabeth Rath, Dr Andy Smart and Dr Richard Griffiths for going through this thesis.

I owe special thanks for my research assistants Azombo Dieudonné, Mbondja Dieudonné, Mokoguya Valentin, Dekou Daveran, Mbissa Denis, Ayaya Joseph, Popode Pierre and Kallo. They played a key role in the success of this project.

In addition, I would like to thank the following people:

Dr Andrew Allo Allo, Mr John Hazam, Dr John Tanlaka Bansar, Mr Balinga Victor Sunday and Mrs Beryl Fofung for their support; Prof. Ian Swingland for his encouragement; Mrs Joan England for her help with administration of this project; my wife Rose Atanga, my children Enyegue Atanga Marie Jeanne, Badang Atanga Laurent Georges and Ekobo Atanga Rose Suzanne for their love and encouragement.

Chapter 1

INTRODUCTION

1.1 Elephants

There are two living species of elephants: the African elephant (*Loxodonta africana*) and the Asian elephant (*Elephas maximus*). Shoshani (1991a), in his review of the origins and evolution of elephants, pointed out that these two species are the end results of over 50 million years of evolution and the only living representative of the mammalian order Proboscidea, belonging to the family Elephantidae that was established in 1821 by J. E. Gray. He also mentioned that the term "Proboscidea" that comes from the Greek words *pro* for "forward" or "in front" and *boskein* meaning 'to feed' or 'mouth' was introduced by the naturalist Carl D. Illiger at the beginning of the nineteenth century. According to the same author, both species evolved in Africa but the Asian species migrated later to Eurasia.

Shoshani (1991b) reviewed the anatomy and physiology of the two species. Some of the external characters that differ between the two species are given in **Table 1-1**.

Table 1-1: Some differences between the African and the Asian elephant based mostly on external characters (source: Shoshani, 1991b).

	Asian elephant	African elephant
Ears	smaller, do not exceed height of neck	larger, exceed height of neck
Weight	3-5 tonnes	4-7 tonnes
Trunk	tip of trunk has one "finger"	tip of trunk has two "fingers"
Tusks	absent or reduced in females	present in both sexes; larger in males
Teeth	narrow compressed loops on chewing surface	Lozenge-shaped loops on chewing surface
Back	Convex or level	Concave

1.2 The African Elephant

There are two living sub-species of African elephant scientifically recognized: The open habitat (savanna) subspecies (*Loxodonta africana africana* Blumenbach, 1797) and the forest subspecies (*Loxodonta africana cyclotis* Matshie, 1900). Some characters that differ between the two sub-species are given in **Table 1-2**. The *Loxodonta a. africana* sub-species is the biggest living terrestrial mammal (Laws, 1966).

Table 1-2: Some differences between the two African sub-species based mostly on external characters (source: Shoshani, 1991b).

	Subspecies within Africa	
	Loxodonta a. africana	*Loxodonta a. cyclotis*
Weight	4-7 tonnes	2-4 tonnes
Height at shoulder	3-4 metres	2-3 metres
Shape of ears	triangular or trapezoidal	rounder
Tusks	curved, thicker	straighter, slender

1.3 Distribution of the African elephant

Douglas-Hamilton (1987) observed that the range of the African elephant that at one time extended throughout Africa (except for the Sahara) has been dramatically reduced by a large scale ivory poaching. The same author pointed out that ivory poachers exterminated elephant populations in North Africa in the early Middle Ages, in most of South Africa in the eighteenth and nineteenth centuries, and in most of West Africa in the late nineteenth and early twentieth century. In 1989, the African elephant population was estimated at 609,000 individuals; (277,000 in Central Africa, 204,000 in Southern Africa, 110,000 in East Africa and 19,000 in West Africa) by the Ivory Trade Review Group. These estimates are updated whenever new data are acquired or with improved methods of analysis. **Figure 1-1** shows the current estimated distribution of the African Elephant population.

1.3.1 West Africa

West Africa has witnessed a gradual reduction of its elephant population in the early part of the present century due to ivory poaching and a loss of habitat (Douglas-Hamilton, 1987). The same author pointed out that the West African elephant

Figure 1-1: Current estimated distribution of African elephants (source: Ivory Trade Review Group, 1989).

population is now fragmented into small isolated pockets, none of which contains more than a few hundred animals.

1.3.2 Central Africa

Central Africa is thought to harbour the bulk of the African elephant population (Ivory Trade Review Group, 1989; Pfeffer, 1990) which is concentrated mainly in the rainforests that cover large part (about 1.75 million km^2) of six countries: Cameroon, Equatorial Guinea, Gabon, Congo, Central African Republic and Zaire (Barnes *et al.* 1995b). It is not possible at the present to gauge the number present with any great degree of precision. Michelmore *et al.* (1994) used a Geographic Information System (GIS) to analyse field data on the abundance of elephant dung-piles. They came to the conclusion that the total forest elephant population in Central Africa was reduced from about 306,000 in the mid-1970s to 171,000 individuals in 1989 (about 44% in "dung-piles" population) as a result of ivory poaching. The same study showed a reduction in range from 1,892,956 to 1,472,280 km^2 (22%). Barnes *et al.* (1995b) estimated elephant population of Central Africa to be 230,400 individuals, of which 172,400 are forest elephants. About 2/3 of the forest elephant population is to be found in Zaire and Gabon and the other 1/3 in Cameroon, Central African Republic, Congo and Equatorial Guinea (Barnes *et al.*, 1993).

1.3.3 East Africa

Tanzania is the East African country with the highest elephant population estimated to be 61,000 (Ivory Trade Review Group, 1989). Kenya's population is currently estimated at about 24,000 individuals (Kiiru, 1995). The same author pointed out that the elephant range in Kenya has greatly been reduced by the expanding human population. According to the Ivory Trade Review Group (1989), Uganda is estimated to contain 1,600 elephants, Ethiopia 8,000 elephants, Somalia 2,000 elephants, Sudan 22,000 elephants and Rwanda 50 elephants.

1.3.4 Southern Africa

The elephant population in Zimbabwe has increased from an estimated 5,000 in 1900 to over 60,000 in 1992 (Environmental Consultants, 1992). Large numbers of elephants are also found in Botswana (68,000), Zambia (32,000), Angola (18,000) and Mozambique (17,000) (Ivory Trade Review Group, 1989). Namibia's population is estimated at about 8,000 individuals for a total range of 80,000 km^2 (Lindeque, 1995). The Malawi's population was reported to be secured and stable with 2,800 individuals (Ivory Trade Review Group, 1989). According to the same report, the bulk of South Africa population is concentrated in the Kruger National Park where their number is held stable through culling. The population is estimated at about 7,800 individuals.

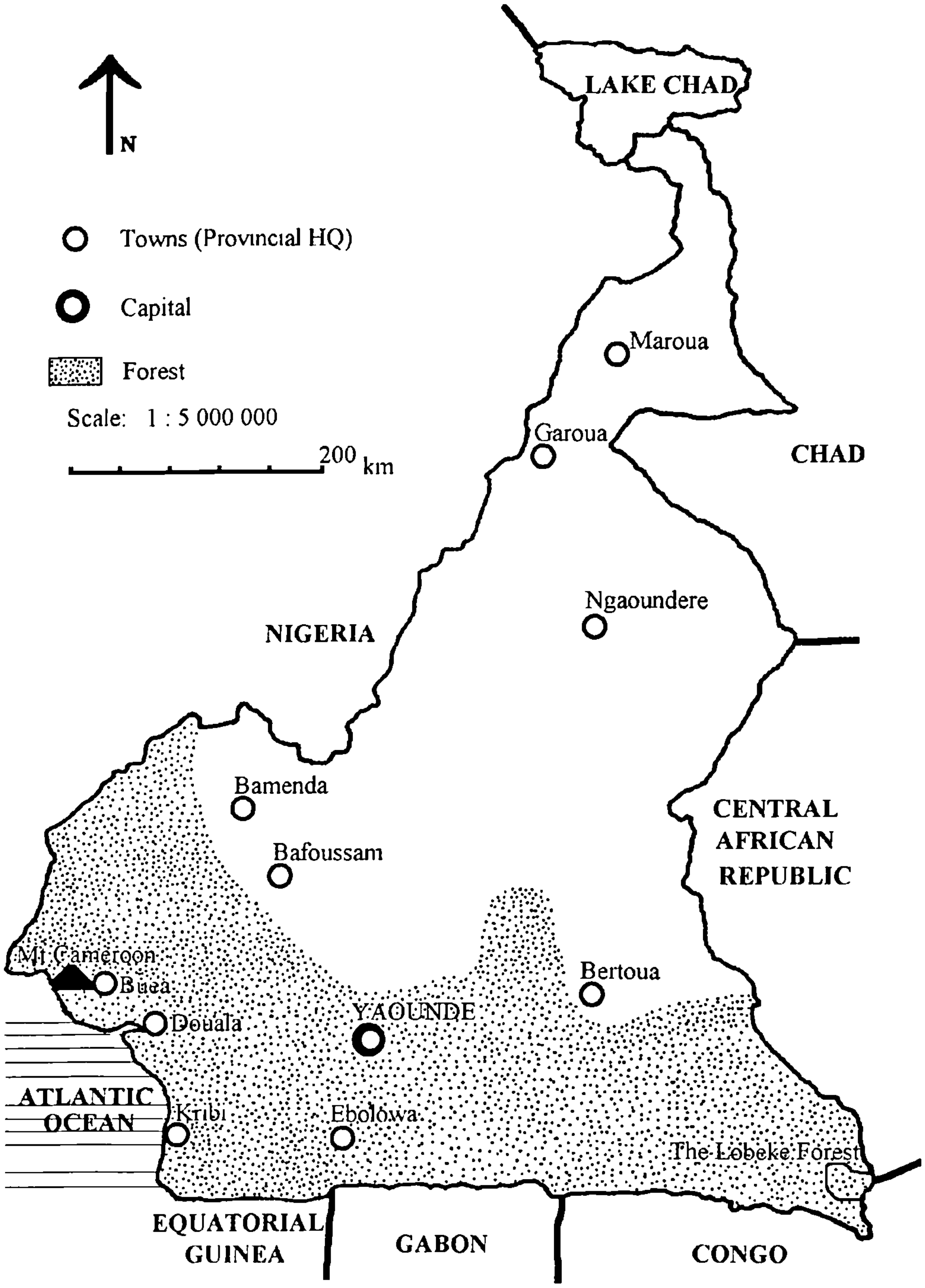


Figure 1-2: Map of Cameroon. Also shown are the six neigbouring countries and the proposed Lobeke forest reserve.

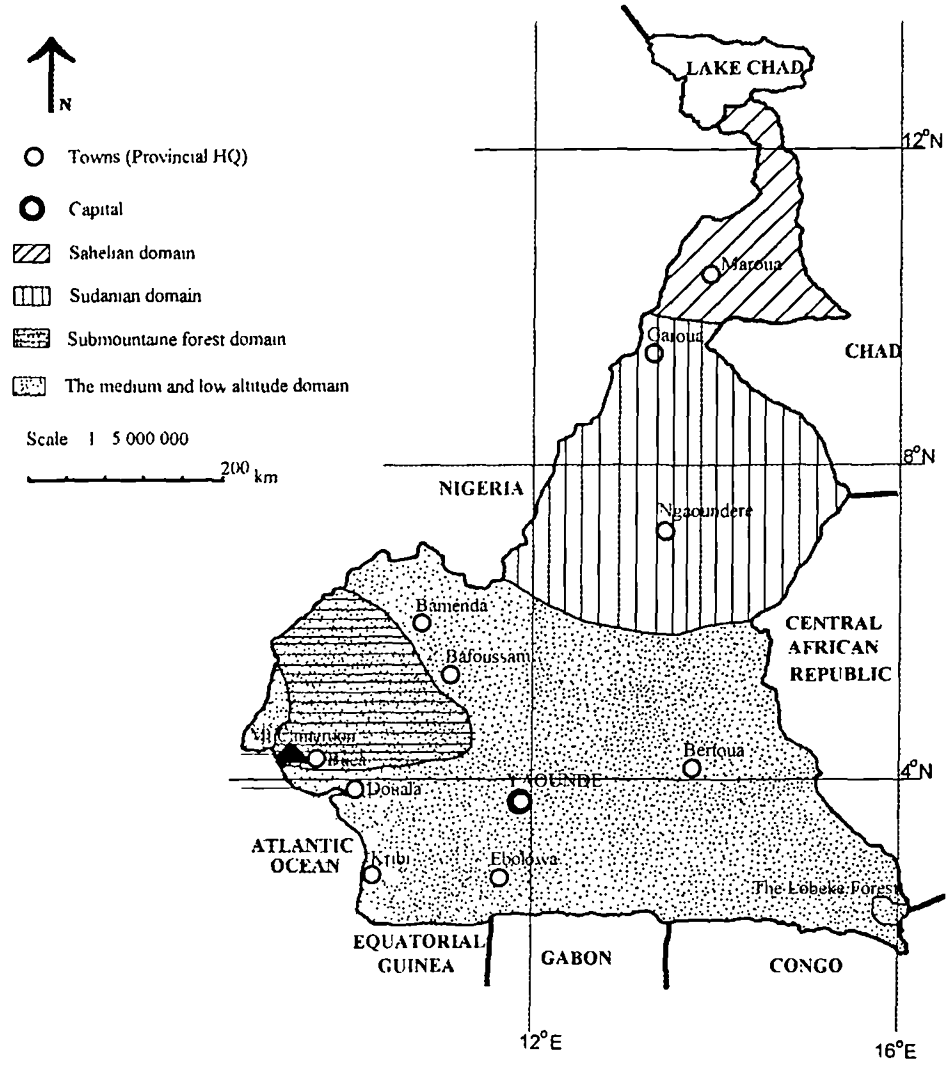


Figure 1-3: Map of Cameroon showing the different vegetation domains

1.4 Elephants in Cameroon

The Republic of Cameroon (**Figure 1-2**) is located in West-Central Africa and lies between longitudes 8^0 and 16^0 East of the Greenwich meridian and latitudes 2^0 and 13^0 North of the Equator. It is 475,000 km^2 and has an unevenly distributed human population of about 11.6×10^6.

The mean national elephant density in 1991 was estimated to be 0.05 elephants km^{-2} of which the total estimated number of savanna dwelling elephants was 2,986 individuals (Ministry of Tourism, 1991). Michelmore *et al.* (1994) estimated that 23,579 elephants live in Cameroon forests. These figures gave a grand total of 26,565 elephants for the whole country. Barnes *et al.* (1995b) revised those estimates down to 12,000 for forest elephants and up to 6,000 for savanna elephants. This represents a population density of 0.04 elephants km^{-2} in 1995.

The two sub-species of the African elephant occur in Cameroon. *Loxodonta a. africana* is found in open habitats and both sub-species occur in some forest zones such as Korup National Park and the Lobeke forest (pers. obs.). The two sub-species occur also in the forest of Central African Republic and Gabon (Carroll, 1988; Barnes *et al.* 1995b). Letouzey in 1975 and 1985 described in detail the vegetation of Cameroon. Two biogeographical regions contain elephants (Ministry of Tourism, 1991) (**Figure 1-3**) .

1.4.1 The Sudano-Sahelian region

The Sudano-Sahelian region is 198,000 km^2 and comprises the Sahelian and the Sudanian domains (Ministry of Tourism, 1991).

- The Sahelian domain extends from Lake Chad south as far as latitude 10^0 North and is 36,000 km^2. It includes two distinct vegetation communities: the thorny grasslands with *Acacia spp.*, *Balanites aegyptica, Tamarindus indica, Calotropis procera, Ziziphus spp.*, and periodically flooded grasslands of the Logone-Chari and the Lake Chad flood plains with *Echinochloa pyramidalis, Hyparrhenia rufa, Oryza longistaminata* and *Pennisetum ramosum*. The Waza-Logone floodplain including Waza and Kalamaloué National Parks contains one of the largest elephant population of the Sudano-sahelian region estimated at 1,100 elephants (Ministry of Tourism, 1991).

- The Sudanian domain extends South from latitude 10^0 North to the southern slopes of the Adamaoua plateau at 800 m. This domain is about 162,000 km^2. The Faro (60 elephants), Benoué (540 elephants) and Boubandjidah (640 elephants) National Parks are part of it (Ministry of Tourism, 1991).

1.4.2 The Guinea-Congolian region

The Guinea-Congolian region encompasses the fringing savannas and various types of forests including submountains (800-1,200 m to 1,800-2,000 m). It is divided into two major domains.

a) The submountaine domain

The submountaine forest domain is found mainly on Mount Cameroon, the Rumpi hills and the highland massif that extends from Mount Kupé and Nlonako to Nkambé with outliers towards Akwaya and Banganté and Ndikinimeki. This area is used by elephants, particularly in the south (Ministry of Tourism, 1991).

b) The medium and low altitude domain

The medium and low altitude forest domain (between 0 and 800 m in the south and 1,200 m in the north) comprises two sectors namely, the semi-deciduous forest and the evergreen forest.

1) The sector of the semi-deciduous forest

The sector of semi-deciduous forest is 75,000 km^2. This sector is made of Guinea-Sudanian savanna on forest margins and Guinea-Congolian semi-deciduous forest often very fragmented. Part of the proposed Mbam and Djerem National Park (420 elephants) lies in this region (Ministry of Tourism, 1991).

2) The sector of evergreen forest

The sector of evergreen forest is 188,000 km^2 and comprises the evergreen Cameroon-Congolese zone of medium altitude and the evergreen Atlantic zone of low and medium altitude.

i) The evergreen Cameroon-Congolese zone of medium altitude.

The evergreen Cameroon-Congolese zone of medium altitude forest is 118,000 km^2. It is estimated to harbour the bulk of the elephant population of the country. It includes the Lobeke Forest that contains the highest density of forest elephant (4.64 elephants km^{-2}) ever recorded in Africa (Stromayer & Ekobo 1991). This zone is considered to be a priority for national and international elephant conservation (Ministry of Tourism 1991).

ii) The evergreen Atlantic zone of low and medium altitude

The evergreen Atlantic zone of low and medium altitude forest is 70,000 km^2. This zone is characterised by a marked endemism and high diversity of fauna and flora that are endangered by logging and human population pressure. The Korup National Park (378 elephants) is within this zone (Ministry of Tourism 1991).

Major changes in the distribution and density of elephants in Cameroon date from the colonial era. Information from that period indicates a much wider distribution than is presently the case (**Figure 1-4**). One of the main reason behind German colonisation was trade in ivory as one of the most important products of Cameroon. This commerce was so devastating that the German governor imposed a minimum export tusk weight of 5 kg to try to control it. However, this did not work as under-sized tusks were smuggled out to Nigeria or south to French Equatorial Africa. Ivory was by far a more important trade item than tropical timber until just before the first world war, coinciding with the end of German colonial era in the country (Ministry of Tourism 1991). International pressure on the Cameroon elephant population is therefore over a century old.

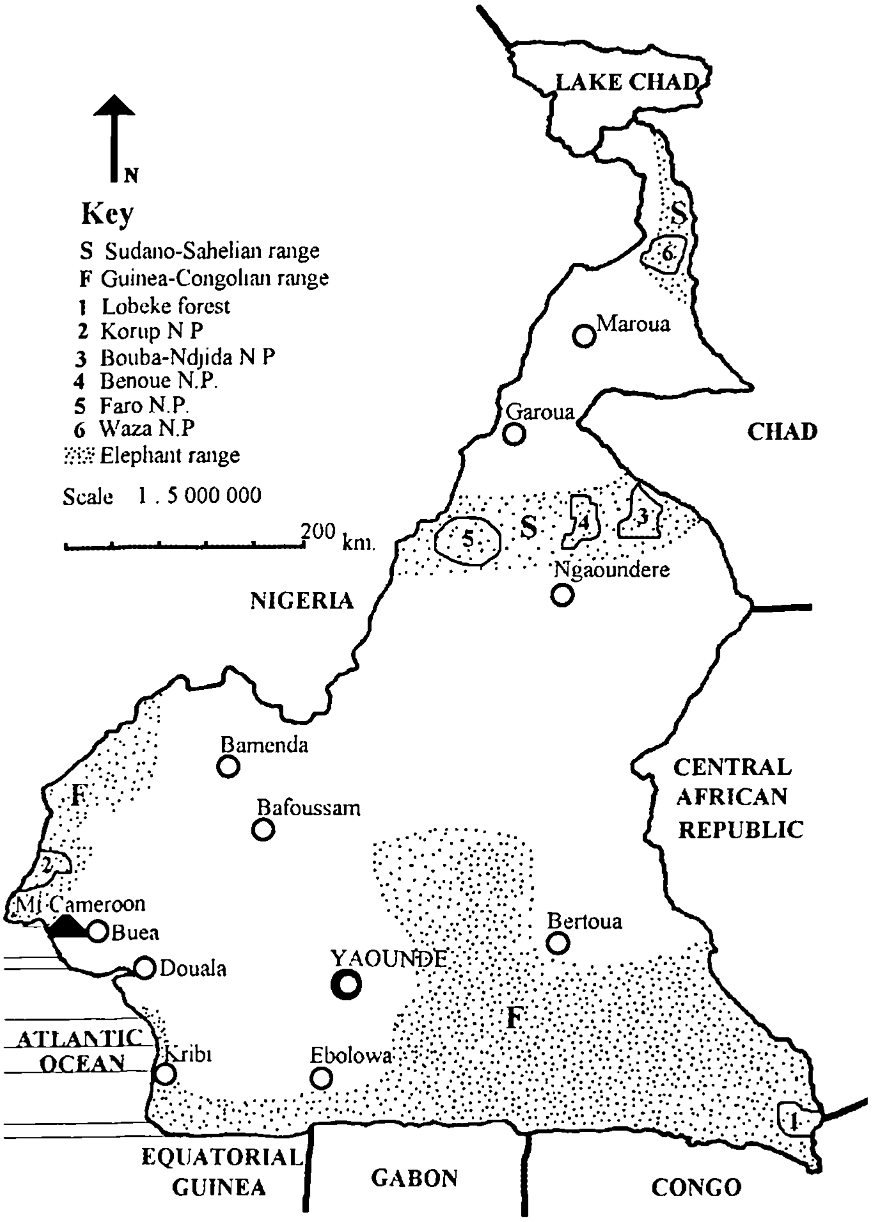


Figure 1-4: Elephant distribution in Cameroon in 1995. National Parks and the Lobeke forest are also shown.

1.5 Research on African elephant ecology

1.5.1 Savanna

Systematic elephant research in Africa is of recent origin and most projects have been undertaken within the past three decades mainly in the savanna ecosystems of Eastern and Southern Africa.

During the 1960s and 1970s, the main concern of many National Park authorities in Eastern and Southern Africa was coping with the dramatic vegetation changes caused by increasing elephant densities (e.g. Buechner & Dawkins, 1961; Laws, 1970; Field, 1971; Douglas-Hamilton, 1973; Laws, Parker & Johnstone, 1975; Caughley, 1976). This situation stimulated a controversy about whether elephant should be culled or not.

Barnes (1980) assessed the impact of elephants on baobab (*Adansonia digitata*) in Ruaha National Park, Tanzania. His work showed that elephants (which eat baobab trees) were causing a decline in the baobab population. In one year, they killed 3% of the baobab trees. Barnes (1983a) studied the impact of elephant browsing on three tree species (*Acacia albida*, *Commiphora ugogensis* and *Andansonia digitata*) in the same National Park and showed a dramatic decline of these tree species because elephants were killing adult trees and preventing regeneration. His models describing the effect of elephants on trees suggested that very large numbers of elephants needed to be culled to stabilise or reverse the woodland decline.

With the catastrophic decline in elephant numbers in East Africa (e.g. Eltringham & Malpas, 1980) the necessity of exploring management practices other than elephant culling became critical. Pellew in 1983 presented a prediction model incorporating the impact of browsing ungulates and fire upon the population structure of *Acacia tortilis* woodlands in the Serengeti National Park, Tanzania. This model suggested that measures to promote regeneration development (fire protection and/or giraffe culling) were more effective in the long-term to encourage mature canopy recovery than elephant culling. In 1984, Bell & Jachmann put forward the hypothesis that the distribution of elephants and the impact by elephants on woodland can be manipulated by burning. McShane (1987) supported that hypothesis. The utilisation of woodlands by elephants was reduced in areas that were burnt early in the dry season in both

Mopane woodlands and *Brachystegia* woodlands. Jachmann & Bell (1985) investigated the utilisation by elephants of *Brachystegia* woodlands in the Kasungu National Park, Malawi. They suggested the pushing over and uprooting of trees by elephants to be part of a feeding strategy that improves the availability of food for elephants during the dry season. In an attempt to predict how woodland will respond to foraging pressures of elephants, Lewis (1991) in Luangwa Valley, Zambia, monitored six samples of tagged *Colophospermum mopane* for five years in locations with varying soil characteristics but with similar elephant densities. His works showed that the influence of soils and elephants on *Colophospermum mopane* alter successional transitions from grassland to woodland. Soils that promoted coppicing of *Colophospermum mopane* yielded less stable woodlands when associated with elephants than soils promoting woodlands with non-coppicing trees.

Laws (1966) undertook one of the most extensive studies of the determination of age criteria for the savanna elephant. He studied a collection of 385 elephant mandibles and developed criteria for estimating the age from them. He described and illustrated thirty age groups, based on the eruption and wear of the six teeth in each side of the lower jaw. Jachmann (1988) revised the Laws' method and showed that between the ages of about 5 and 35 years, estimates assigned by Laws' technique are too high. In 1967, Laws suggested the use of eye lens dry-weight to estimate the age of the African elephant. His works were based on a sample of 543 animals. Laws & Parker (1968) stated that the straight shoulder height of elephants, because of its small variance, could be used to estimate the ages of living elephants in the field.

Knowledge of food habits of elephants is vital to wildlife management and research (Talbot, 1965). One of the most important studies of elephant food habits was undertaken by Buss (1961) in the Murchison Falls National Park region of Uganda. He showed that grass comprised 88% of the total food material in the stomachs of 71 elephants collected during the dry season of 1958-1959 near the Park. Only 10% of the food material utilised by the 71 elephants consisted of leaves, twigs, fruits of trees and shrubs. These findings were confirmed later by Laws & Parker (1968) who observed that grass comprised between 80 and 90% of the stomach fill of elephants in Western Uganda.

The social organisation of savanna elephants has also been extensively studied. The results suggest a social organisation based around the "family unit", consisting of one or more related adult females and their offspring (Buss, 1961; Glover 1963; Laws & Parker, 1968; Douglas-Hamilton, 1973; Moss & Poole, 1983; Moss 1988). Family units are stable but aggregate to form "kin" or bond groups, clans, subpopulations and populations (Laws *et al.* 1975; Moss & Poole, 1983; Moss, 1988). In Ambosseli National Park, Kenya, the mean family unit size was 9.4 individuals (range 2-29), typically 2-3 adult females (range 1-9) (Moss & Poole, 1983; Moss, 1988). Leuthold (1976a), Barnes (1983b) and Moss (1988) showed that the mean group size of elephants in savanna varies over time and between areas and some of these variations can be related to food availability. Moss (1988) found that the mean group size in Amboseli National Park was 15.1 in a year during which there was a serious drought and food was scarce, but was 45.9 in a year when good rains fell and food was abundant, with maximum group sizes of up to 550 individuals. Males were found singly, in temporary all-male groups (mean group size 3.8, range 2-25) or in association with females (Moss & Poole, 1983; Moss 1988).

Wyatt & Eltrigham (1974) undertook the most quantitative behavioural study of wild elephants in the Rwenzori National Park, Uganda. Seven elephants were observed over the full 24 hours' period and spent about 75% of the total time feeding. Three feeding peaks were recorded; one in the morning, another in the afternoon and the third around midnight. Walking activity was observed mainly at dusk and sleeping period during the small hours of the morning with a shorter rest period in the early afternoon. Guy's works in 1976 showed no sex differences in activity patterns of elephants in Sengwa area, Rhodesia (now Zimbabwe) but elephants spent less time feeding (between 36% and 57%). He argued that elephants spent less time feeding because they fed mainly on browse, which is richer in fat and protein than grass. In Mikumi National Park, elephants spent between 56% and 85% of their time feeding, depending on the season (Barnes, 1983b). The percentage of time spent on feeding activity was estimated to be 69% in Ngorongoro Crater, Tanzania (Kabigumila, 1993) and 71% in Manovo-Gounda-St Floris National Park, Central African Republic (Ruggiero, 1992).

Another important aspect of the study of elephant ecology is the human-elephant conflict. The most common conflict between humans and elephants appears to be crop depredation, generally leading to deaths and injuries of both people and elephants. Research in savanna (Ngure, 1992; Damiba & Ables, 1993; Thouless, 1994; Kiiru, 1995; Tchamba, 1995; Smith *et al.*, 1995) as well as in forest (Lahm, 1994; Barnes, Azika & Asamoah-Boateng (1995a) show human encroachment into elephant range as the main cause of crop depredation. Hoare (1995) suggested a series of approaches to dealing with the human-elephant conflict. These approaches included direct non-fatal methods (disturbance shooting, translocation, non-fatal deterrents, etc.), direct and fatal methods (killing) and indirect methods (monetary compensation schemes, electric fencing, land use and settlement planning).

1.5.2 Forest

Research on forest elephant has lagged behind, although recently, there has been a surge of interest in these animals.

The lack of data on the numbers and status of forest elephant is a major obstacle to assessing the impact of ivory exploitation on the continental elephant population (Barnes & Jensen 1987). The determination of numbers and distribution of elephants present in forest has been a persistent problem because both access and visibility are limited. Direct observation, which provides the basis of behavioural and ecological studies in savanna ecosystems is difficult in forest and population studies rely mainly on elephant signs. For the estimation of elephant numbers, dropping counts were used in quadrats (Short, 1983) and strip transects (Wing & Buss, 1970; Merz, 1986a & 1986c; Carroll, 1988) in the early stage of forest elephant research. Barnes & Jensen (1987) found that the dropping count methods used for these previous works were impractical because of the difficulty of making repeat visits to permanent transects located in remote forest where access is difficult, time-consuming and expensive. They suggested two methods: the line transect method (Burham, Anderson & Laake 1980, Buckland *et al.*, 1993) and the shortcut method. For the line transect sampling, an observer walks along the centre-line of the transect. When a dropping is seen, its perpendicular distance from the observer is measured. The perpendicular distances are used to estimate the number of droppings per km^2. This method was used later by

Barnes *et al.* (1991) in Gabon and Ekobo (1995) in the Lobeke forest. The short cut method derived from the standard line-transect method. Although this method is less accurate than the line-transect one, it is faster and better suited for reconnaissance survey (Barnes & Jensen, 1987; Alers *et al.*, 1992). While walking on a more-or-less straight compass bearing, the observer stops every 500 m to record the number of droppings seen since the last stop. Researchers who used this method include Fay & Agnagna (1991) in northern Congo, Stromayer & Ekobo (1991) in south-east Cameroon and Alers *et al.* (1992) in Zaire.

For the dung count technique, two other important parameters must be estimated in order to determine the elephant density. They are: the number of droppings produced per elephant per day (defecation rate) and the rate of decay of droppings. The most extensive research on the defecation rate was undertaken by Tchamba (1992) in the Santchou forest, Cameroon. He estimated a defecation rate of 20 dung-piles per day, with no significant variation over the season. His estimates came from elephant groups that were followed for 24 hours or more. Wing & Buss (1970) obtained a defecation rate 17 dung-piles per day in the Kibale forest reserve, Uganda, and Merz (1986a) computed a figure of 18 defecation per day in Tai National Park, Ivory Coast. All these estimates were shown by Tchamba (1992) not to be significantly different. Barnes *et al.* (1994) undertook a multinational survey on dung decay rate in six sites in Ghana and Cameroon. Their results suggested, when considering only those points from humid areas that rainfall and temperature explained 81% of the variance in decay rate. However, White (in press) showed that the most important factor affecting dung duration was the fruit content of the diet in any given month in the Lopé forest reserve, Gabon.

Another important aspect of elephant ecology that has been studied in forest is the diet. Short (1981) working in Bai National Park, Ghana, showed that woody material (mainly leaves and stems) formed the bulk of elephant diet. Fruit was also an important component of the diet as 93% of all dung-piles examined showed some trace of fruits (either seeds or fruits' fragments). White *et al.*, (1993) observed in the Lopé forest reserve, Gabon, that the bulk of the diet, in terms of number of species and quantities eaten by elephants, came from leaves and bark (70% of all items).

Trees represented 73% of the species fed upon and fruit was an important part of the diet. In contrast to all these results, Tchamba & Seme (1993) found that elephant diet in the Santchou forest reserve, Cameroon, consisted primarily of grass.

White *et al* (1993) observed in the Lopé forest, Gabon, that adult females were generally encountered with one or more offspring, and adult males were generally solitary. The mean group size was 2.8 individuals and the mean size of a family unit was 3.5 individuals. Association of more than eight elephants were exceptional. Previous works by Merz (1986b) in Tai National Park, Ivory Coast estimated a mean group size of all elephants to be 2.44 ± 1.7 but if single elephant, comprising 40% of all observations were ignored, the mean group size became 3.4 ± 1.6.

1.6 The indigenous peoples of the Central African rainforest

Cavalli-Sforza (1986b) reported two major causes of destruction of the Central African rainforest: the drying up of the climate and the arrival of early farming, swidden, slash-and-burn type of horticulture, causing a rapid and often irreversible conversion of the forest to savanna. In recent times logging, mining and technological developments have started adding their effect to those of drying climate and slash-and-burn farming. The same report mentioned that major migrations of Central African farmers originated 3,000 years ago and generated the Bantu expansion, which reached all Central and South Africa in the next 2000-3000 years. The Bantu farmers' expansion probably made early contact with pygmies in the tropical forest or at its margins, 2000 years ago. The socioeconomic relationship between these two groups is fairly similar over the whole Central African rainforest, and consists of the exchange of forest products (e.g. wild game, mushrooms, honey), plantation work, and other services provided by pygmies in exchange for iron and pottery artifacts as well as village products (e.g. banana (*Musa sp*), cassava (*Manihot esculenta*), alcohol, tobacco) provided by the Bantu farmers. Althabe (1965) reported that the south-eastern Cameroon was subject to an important economic change due to the introduction of cash crop (cocoa and coffee) and money in the 1950s. This period marked the beginning of change of the Baka pygmies' life style from nomadic to sedentary.

Cavalli-Sforza (1996a) identified four main pygmy clusters in the Central African rainforest which are: the western cluster called "Binga" estimated at about 33,000 individuals found in north-eastern Congo, south-western Central African Republic, south Cameroon, Gabon and near Libenge (Zaire); the central cluster called "Twa" or "Cwa" estimated at about 100,000 people found north of Lake Leopold, Zaire; the eastern cluster called "Mbutis" estimated at about 40,000 people found in the Ituri forest, Zaire; the south-eastern cluster called "Gesera" or "Zigaba" estimated to 9,000 and found in Rwanda and Burundi.

Curran (1993) in his preliminary assessment of issues affecting the human populations of the Lobeke forest, Cameroon, reported that Baka and Bangando are the closest indigenous peoples to the Lobeke forest. The 1987 census estimated them at 3,000 people. A previous report by Stromayer & Ekobo (1991) mentioned the Lobeke forest as part of Moloundou subdivision that is 15,567 km^2, with a human population estimated to be 24,000 (1.54 inhabitants km^{-2}) in 1987 and composed of 8 important ethnic groups: Baka pygmies (60%) and 7 Bantu groups (40%). The same report listed these 7 Bantu groups by principal occupation: Agriculturalists (Bangando, Boman, Essel, Mbimou), fishermen (Bakwele, Sangha-Sangha, Mopwaelli).

Hart & Hart in 1986 assessed forest food resources (plant and animals) to determine their adequacy to support a hunting gathering economy of the Mbuti pygmies in eastern Zaire. They observed that calorically important forest fruits and seeds were not available for five months of the year and honey was not abundant during that period of scarcity. Although wild game meat was available year round, the main animal species caught had low fat content, making them a poor substitute for starch-dense agricultural plants. Wild edible plants were more abundant in agriculturally derived secondary forest than in primary forest and even more common in savanna and gallery forest. They concluded that it is unlikely that hunter-gatherers would have lived independently in the forest interior with its precarious resource base when many food species they exploit are more abundant toward the savanna border. Previous works by Ichikawa in 1983 had already shown that without the symbiotic partners providing the Mbuti pygmies with farm food, a hunting-dependent life in the Ituri Forest would be quite hard although not impossible from a calorific viewpoint.

Ichikawa (1987) observed that while the Mbuti utilise more than 300 animal and plant species as food, only 60% were eaten without restriction. The remaining 40% were avoided for various reasons (e.g. they may cause diseases to the person who eats them, to their small child or even the unborn baby).

Bahuchet in 1990, studied food sharing among the pygmies of the Central African rainforest. Food sharing was not isolated from other types of exchange such as the circulation of goods and the acquisition of spouses. He pointed out that sharing among African pygmies "is a function in the wider system of exchange and cooperation that perpetuates the society". The same author in 1991, compared the different groups of pygmies in Central Africa. He pointed out the identical evolution of their life style patterns, despite the dispersion factor and differences.

This thesis is a contribution towards research on elephant ecology. The results produced indicate that human ecology is also a critical feature of forest elephant management in the Central African rainforest.

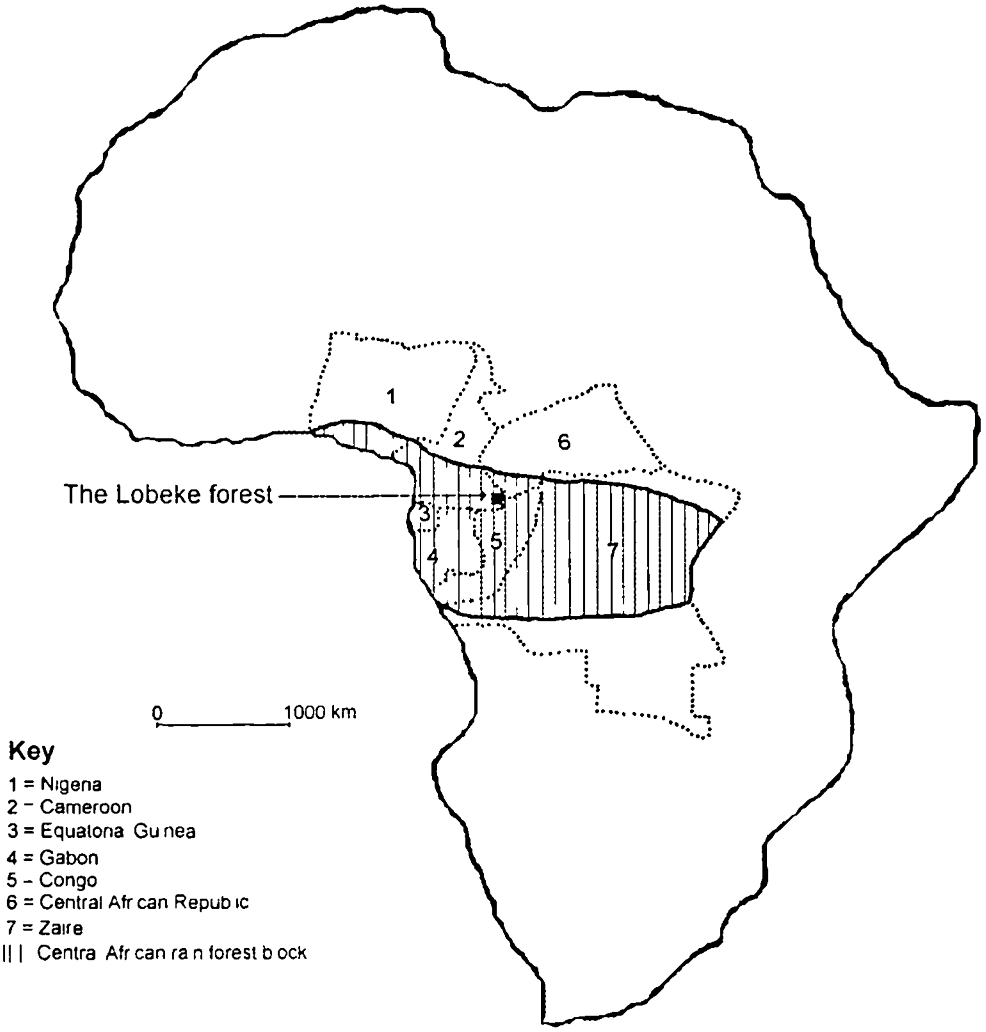


Figure 1-5: Outline of the map of Africa showing the Central African rainforest block and the Lobeke study site.

1.7 Objectives

This study aimed to provide information needed for the creation of a reserve for the conservation of elephants in the Lobeke Forest

There has been no previous detailed study of the ecology of elephant in the Central African rainforest of which Lobeke is part (**Figure 1-5**). This study addresses issues of basic importance to the ecology and conservation of the African forest elephant. The primary objectives were as follows:

1) To study and establish elephant distributions, densities, numbers and movements in relation to the environment, human activities and the seasonal cycle in the Lobeke forest;

2) To study the structure and population dynamics of the forest elephant;

3) To study forest elephant daily activities and diet;

4) To assess crop depredation by elephants,

5) To study the ecology of the indigenous peoples and their relationship with the south-eastern rainforest of Cameroon

1.7.1 Densities, numbers, distribution and movements in relation to human activities, environment and seasonal cycle.

The conservation and management of elephant in the Lobeke forest requires information on numbers, distributions, densities and movements. This information does not exist for the Lobeke forest

The aims here were

1) To determine important areas for elephants in the Lobeke forest.

2) To determine distribution patterns to the nearest 25 km^2 and how they relate to human activities (hunting, logging), main vegetation types (primary and logged forest) and water.

3) To estimate elephant numbers in the proposed reserve over a seasonal cycle.

4) To estimate elephant defecation and dung-pile decay rates, two key parameters for an estimate of elephant numbers.

1.7.2 The structure and population dynamics of elephants in the Lobeke forest.

Although based on approximate visual height/age assessments, this part of the study was essential in understanding the ecological status of elephants in the proposed reserve and making management and conservation decisions.

The aim here was to estimate the sex ratio of adult elephants (when they could be sexed with certainty), to estimate the birth rate and age structure.

1.7.3 Forest elephant daily activities and diet

The study of the diet and daily activities are important for management and conservation as it determines which plant species are important for forest dwelling elephants and how they use their habitat. It can also help to anticipate elephant movements.

The aim here was therefore to determine the plant species eaten by elephants over the seasons.

1.7.4 Crop depredation by elephants

Crop raiding causes hostile relations between park management and local communities. In Cameroon, many villagers consider elephants as crop raiders (Ministry of Tourism 1991). It was therefore important to assess crop depredation as the results could help to find solutions to minimise conflicts between indigenous peoples and conservation. Such data could also be used in the study of elephant movements.

The aims here were therefore

1) To assess crop damage as this could be used as an index to evaluate the state of the relation between elephants and indigenous peoples

2) To map all places where crop-raiding by elephants was reported for the study of seasonal patterns of elephants' movements from of the Lobeke forest.

1.7.5 The ecology of the indigenous peoples.

If the Lobeke reserve is to survive, it must have local support or at least acceptance. The study of indigenous peoples who are also part of the ecosystem was focused on their demography and traditional activities (hunting, fishing, gathering, farming). This helped to determine the extent to which the local people exploit the forest, what natural resources they gather and how much they depend on the proposed reserve for their survival. The results were also used in the design of the reserve. The overall aim here was to minimise conflicts between conservation and the indigenous peoples. Such a study has never been undertaken in the area.

The field work for this project was carried out in the Lobeke forest from September 1992 to June 1994.

Chapter 2

THE STUDY AREA

2.1 Location

The proposed Lobeke forest reserve is located in the south-east of Cameroon (**Figure 1-2**). It is 2,125 km^2 and lies between the latitudes 2° 05' and 2^0 30' N and the longitudes 15^0 33' and 16^0 11' E. It is bounded (**Figure 2-1**)

- To the east by the Sangha river that serves also as the international border between Cameroon, Central African Republic (C.A.R.) and Congo.

- To the north by the Lobeke and Longue Rivers

- To the west by the Djombi River

- To the south by the Moko Paka River.

The total boundary length is about 184 km.

2.2 Climate.

The climate of the Lobeke forest was described by Harrison & Agland in 1987 as being a four-season equatorial climate, with the major rainfall in September-November, and high rainfall in March-June. The long dry season is during December-February and the short dry season in July-August. They reported a rainfall of 1500 mm per annum and a mean annual temperature of 24^0 C.

2.3 Geology and soils.

The Lobeke forest is a plateau belonging to the Sangha basin. The region is of Precambrian origin, consisting of a crystalline base of granites and metamorphic rocks overlain with schists, limestone and sandstone quartzite. It is a flat relief with few hills, few steep slopes and an altitude rising from 400 m in the valleys to 700 m on the

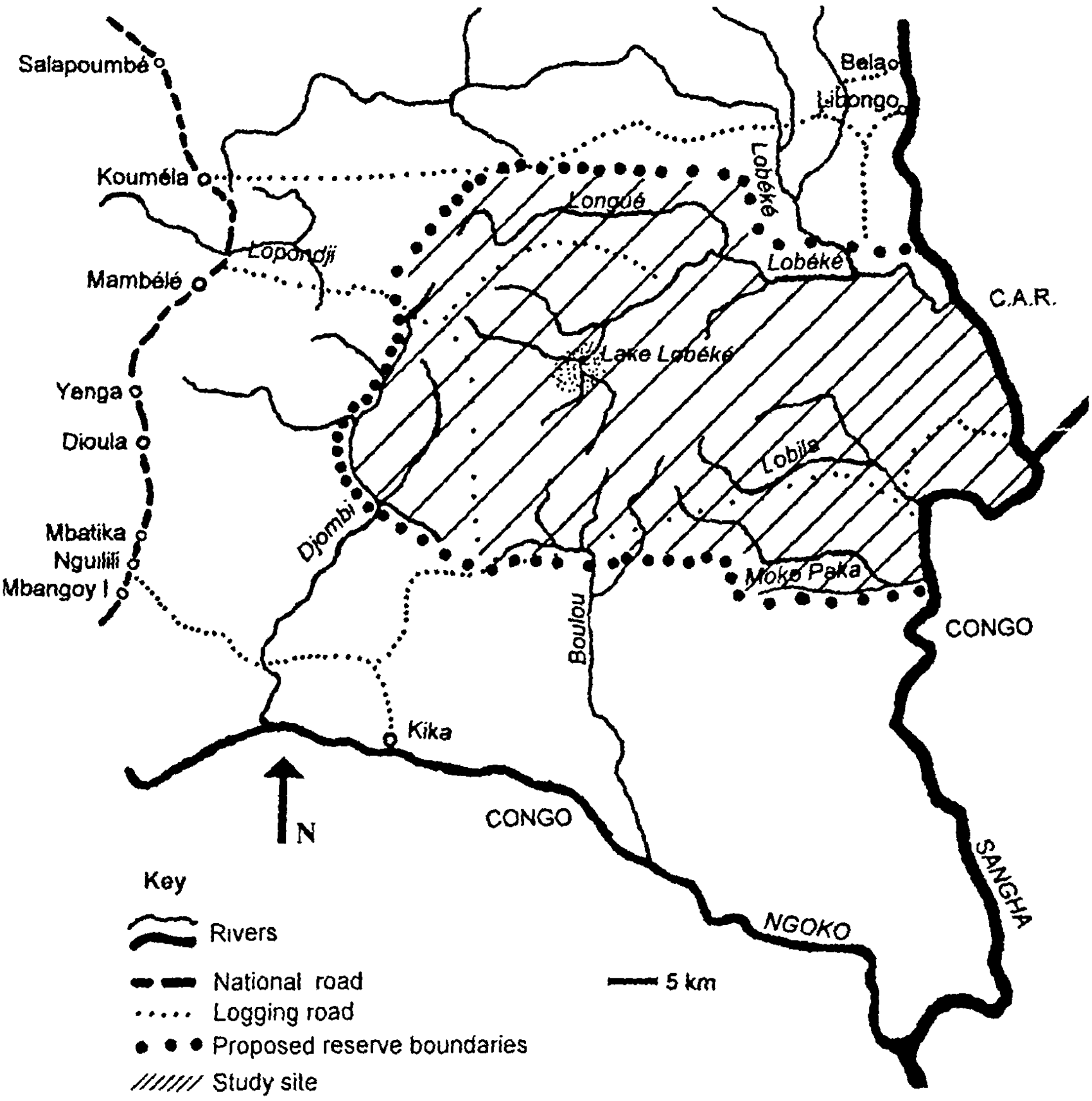


Figure 2-1: The proposed Lobeke forest reserve and the study site.

three hills that have a south-west/north-east alignment in the proposed reserve. Lake Lobeke is a large shallow swampy clearing.

Soils in the Lobeke forest are, as with many soils supporting tropical rain forest, acid, clayey, the humic layer thin and bearing little organic material, and low in nitrogen and exchangeable bases. They are ferralitic, red or red-brown in color and are derived from the ancient metamorphic bedrock. In many parts of the Lobeke forest and in some areas bordering the Sangha river, soils are hydromorphous and rich in organic material. This is due to permanent ground water.

2.4 Drainage

The Lobeke forest is well drained. There are two major drainage systems within the proposed reserve: The Sangha drainage system with the Lobeke, Longue, Lobila and Moko Paka Rivers as tributary and the Ngoko drainage system with the Djombi and Boulou Rivers as tributary (**Figure 2-1**).

2.5 Vegetation

The vegetation of the area was mapped and described by Letouzey (1985). It has three predominant floristic formations: two types of transitional forest and a semi-deciduous forest. Letouzey (1985) estimated that Lobeke has 19% of transitional forest rich in Dja evergreen with semi-deciduous elements, 21% of transitional forest rich in semi-deciduous with elements of Dja evergreen and 60% of semi-deciduous forest. There is also a series of "islands" of marshy grassland within the forest.

2.5.1 The Dja evergreen forest

The Dja evergreen forest has red clay soils that derives from chlorite schist of the bedrock. No plant family is predominant and most trees have evergreen foliage. This forest, unlike the coastal region is marked by a lack of Caesalpinaceae with the exception of *Gilbertiodendron dewevrei*, a Caesalpinaceae that grows in extended single-species stands. Harrison and Agland (1987) noticed that these stands form large islands dotted throughout the forest. They believed this species was once widespread but is now disappearing due to decreasing overall water availability, leaving only relict populations in closed valleys and basin refuges. Species that characterize evergreen forest are *Desbordesia glaucescens, Gilbertiodendron* *dewevrei, Irvingia sp., Klainedoxa gabonensis, Panda oleoza, Pentaclethra macrophylla, Scorodophloeus zenkeri, Strombosiopsis tetrandra, Uapaca guineensis.* Other species such as *Cleistanthus polystachyus, Funtumia elastica, Musanga cecropioides, Petersianthus macrocarpus* and *Pterocarpus soyauxii* are also present.

2.5.2 The semi-deciduous forest

The semi-deciduous forest here grows on sandy clay soils. The vegetation is dominated by the families of Sterculiaceae and Ulmaceae. Many of the dominant tree species are leafless for several weeks of the year. Species that characterize this forest are *Celtis adolfi-frideri, Celtis mildbraedi, Celtis zenkeri, Celtis sp., Diospyros simulans, Entandrophragma cylindricum, Mansonia altissima, Pericopsis elata, Phyllanthus discoideus* and *Triplochiton scleroxylon.* Other species are well represented. This is the case of *Angylocalyx pynaertii, Eribroma oblongum, Holoptelea grandis, Musanga cecropioides* and *Terminalia superba* which is a colonizing species found deep into the evergreen forest zone. Stands of *Gilbertiodendron dewevrei* are rare or absent.

2.5.3 The transitional forest

The transitional forest owes its name to the fact that it shows elements of both evergreen (*Gilbertiodendron dewevrei, Strombosiopsis tetrandra*) and semi-deciduous (*Entandrophragma cylindricum, Triplochiton scleroxylon* and species of *Celtis*). Other species such as *Albizia adianthifolia, Macaranga hurifolia, Pausinistalia macroceras* and *Ricinodendron heudelotii* are also present.

2.5.4 Marshy grassland

The Lobeke forest has a series of clearings of marshy grassland. These are a vital focus for the large mammals of the forest. Animals seek out such areas as rich sources of essential minerals and nutrients, found in the water and the herbaceous vegetation. The grasslands are small basins of heavy clay soils which are dry in the dry season except for permanent streams, and inundated in the wet season. There is no tree cover, and abundant herbaceous ground-cover grows in the full light, principally sedges, grasses, and low shrubs.

2.5 The Fauna

Stromayer and Ekobo (1991) surveyed the Lobeke forest to assess its conservation potential. They used non-randomly distributed strip transects of 4 m width. A total of 156.0 km of strip transect and 57.0 km of logging roads were surveyed. Overall dung density was estimated to be 4,479 dung-piles km^{-2}. This density yielded an extrapolated elephant density of 4.64 km^{-2}. They found that dung densities were significantly greater on logging roads.

Stromayer and Ekobo (1991) compared gorilla and chimpanzee densities estimated in the Lobeke forest to those of other sites in Central African rain forest. This comparative study revealed that the Lobeke forest contains the highest density of lowland gorilla and the second highest density of chimpanzees in Central Africa. The authors believed that their results significantly underestimate chimpanzee density due to the difficulty in accurately counting chimpanzee nests (often high in trees or partially concealed in vegetation) while scanning the ground for signs of elephant and other mammals' signs. During their study, the most common species of primate encountered by the authors were the grey-cheeked mangabey (*Cercocebus albigena*), the white-nosed guenon (*Cercopithecus nictitans*) and the black and white colobus (*Colobus guereza*). Mixed groups were made of *Cercocebus albigena* with one of the three *Cercopithecus* species, most often *Cercopithecus nictitans*. The crested mangabey (*Cercocebus galeritus*) was encountered on three occasions and the De Brazza's guenon (*Cercopithecus neglectus*) only twice.

For other large mammals, Stromayer and Ekobo (1991) presented the Lobeke forest as being very rich and largely intact. This observation was backed by the relatively high densities of "indicator species" such as the yellow-backed duiker (*Cephalophus sylvicultor*), the giant pangolin (*Manis gigantea*) and the leopard (*Panthera pardus*), whose populations are usually the first to crash when hunting pressure exceeds low intensities (Gartlan, personal communication).

2.6 Human impact

There are no permanent settlements within the Lobeke Forest. Although one of the most remote and sparsely populated forest regions in Cameroon, no part is over 30.0 km from a driveable road or navigable river. Despite this apparent accessibility, large areas of forest are seldom visited by the indigenous peoples. Populations are concentrated along the main national road that runs 215 km due south (from Yokadouma, the headquarters of the Division, to Moloundou, the headquarters of the Subdivision), in logging company towns and along the logging roads that link these towns to the main highway. Small permanent settlements also exist along the Sangha river.

The principal subsistence crops are plantain (*Musa paradisiaca*), peanuts (*Arachis hypogea*), maize (*Zea mays*) and cassava (*Manihot esculenta*). Small cocoa (*Theobroma cacao*) and coffee (*Coffea sp.*) plantations provide the main cash income.

2.6.1 Logging

The impact of logging companies on the Lobeke forest and in the adjacent areas has been and continues to be great. About only 1,000 km^2 of the proposed reserve remain unlogged. This activity has been going on for the last 30 years. Five European timber companies operate in the area. They export raw and partially processed lumber. Species exploited are: assamela (*Pericopsis elata*), sapelli (*Entandrophragma cylindricum*), ayous (*Triplochiton scleroxylon*), kossipo (*Entandrophragma candollei*), tiama (*Entandrophragma angolense*), sipo (*Entandrophragma utile*), azobe (*Lophira alata*) and iroko (*Chlorophora exelsa*). Surveys (Stromayer & Ekobo 1991; Curran 1993) reported that the local population considers logging exploitation as having a very negative impact on the forest and its dwellers. By facilitating access, they fragment and endanger the potential core areas. Hunting pressure becomes high on the forest for, it has not only to provide meat for the local people, but also to timber company employees and main population centers. Another aspect of the problem is that some of the species exploited are used by the indigenous peoples as medicine, building material and source of food.

2.6.2 Poaching

Poacher refers here to those who hunt large quantities of animals for the express purpose of sale in logging towns or elsewhere. Curran (1993) observed that although both the local people (Baka and Bangando) are engaged in poaching activity, a much greater impact is caused by outsiders. Baka in particular are given rifles by outsiders and sent into the forest, often for ivory. This activity involves Cameroonians from other regions who sell bush meat to logging company employees or markets elsewhere in the country. People from Congo and Central African Republic are also involved in the commercialization of bush meat. They easily cross the unpatrolled international boundary marked by the Sangha river. In addition to bush meat, live animals, particularly young gorillas and chimpanzees, leopard (*Panthera pardus*) skins, bongo (*Tragelaphus scriptus*) skins and ivory constitute products of high market value.

2.6.3 Parrot trade

The trade in African grey parrot (*Psittacus erithacus*) is a seasonal occupation in the Lobeke forest. Permits for the capture of up to 1,000 birds are currently issued by the Ministry of Environment.

2.6.4 Sport hunting

There are no clearly-defined hunting concessions in the Lobeke forest. However, four hunting camps in the area are used by professional hunters. The Ministry of Environment grants permits to operate from December to June each year. Such hunting brings in wealthy foreign clients interested in animal trophies. They generally seek bongo (*Tragelaphus scriptus*), buffalo (*Syncerus caffer nanus*), sitatunga (*Tragelaphus spekei*) and elephant (*Loxodonta africana*). There are always problems between indigenous peoples and safari-hunters. The hunters burn local dwelling people's hunting huts and often threaten to shoot them in the forest (Curran, 1993).

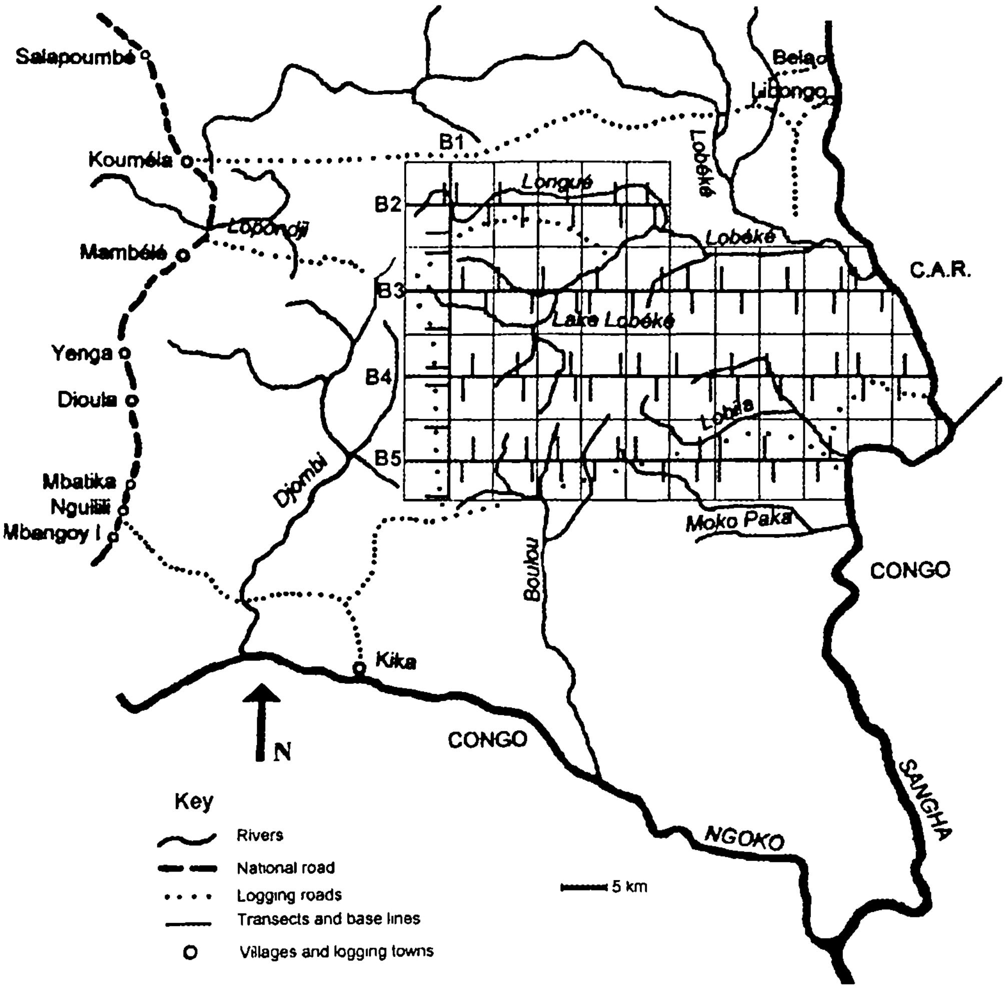


Figure 3-1: Stratification of the study area into cells of 25 km^2 each. Also shown are the five base lines (B1, B2, B3, B4, B5) and the 78 transects.

Chapter 3

METHODS

3.1 Meteorological records

A meteorological station was set up in the forest underneath the tree canopy near the Mambele village (**Figure 3-1**) because its purpose was to measure the microclimate within the forest. The station consisted of a shelter with a sloping roof. The shelter protected the instruments from rain and any sunlight that penetrated the tree canopy, but allowed air to circulate freely around the instruments. It contained a max-min thermometer and a wet and dry bulb thermometer. The rain gauge was established in the village because standard rainfall measurements have to be made in clearings (Cole, 1970). Measurements were made once a week, at 1200 hours.

3.2 Elephant Ecology

3.2.1 Densities, numbers and distributions.

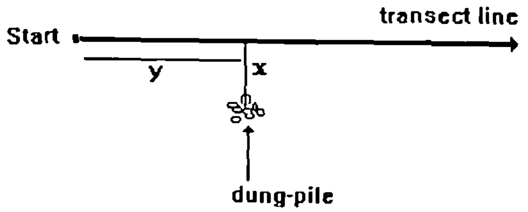
1) Stratification and distribution of transects in the study area

The study area was divided into 78 cells of 25 km^2 (5 km × 5 km) each. One 2.5 km transect was surveyed in each cell. For a practical reason, each transect had to start from one of the existing five base-lines (**Figure 3-1**). The starting point of each transect was randomly generated (using a table of random numbers). A total length of 195 km of transects was cut along 235 km of base-line.

2) Transects

The 78 transects were surveyed 3 times each by the same team (of 5 persons) in January-March 1993 (dry season), in May-August 1993 (short rainy season and short dry season) and in November 1993 (long rainy season). The short duration of the November 1993 survey is due to the fact that base-lines and transects were previously cut. It was planned at the beginning of the study to undertake 4 surveys of each transect (one in each season) but the total distance to cover along transects and base-lines (a minimum of 860 km was covered on foot per survey) made it impossible for one team. Trees were followed along a compass bearing. The line itself was determined by a 50 m steel tape that also helped in measuring the length of transects. The team consisted of a leader, two labourers and two assistants. The leader was responsible for reading the bearing, searching for dung-piles and recording data. The two labourers cut the transect ahead along the compass bearing. The two assistants helped with distance measurements, dung searching and making sure that the measuring tape lay straight on the ground. Care was taken during the data collection that dung-piles on or near lines were never missed and that all the measurements of distances were accurately recorded with steel tapes to the nearest centimetre. Often, elephants defecate while walking. The colour, the shape, the estimated age and distances separating boli were taken into account in defining a dung-pile and its central point.

The following data were recorded for each dung-pile: The distance (y) along the transect (in km); the perpendicular distance (x) from the line to the centre of the dung-pile (in m) (**Figure 3-2**); the dung-pile grade (as defined in the decay rate experiment, page 37), its location and the vegetation type. Distances of dung-piles of stage E (see decay rate, page 38) were not recorded as they were assumed to have "disappeared" (Barnes & Jensen, 1987). In addition, information on other elephant signs (feeding, footprints, digging), vegetation change (primary forest, logged forest, swampy forest, clearing), human activities (logging, hunting, fishing, farming), streams and swamps were also recorded.



Key

x Perpendicular distance from the line to the centre of the dung-pile
y Distance along the transect from the starting point to the dung-pile

Figure 3-2: Illustration of a transect line and the measurements recorded.

Plate 1: Measurements along a transect line.

3) Data analysis

The *x* values (perpendicular distances from the line-transect to the centre of dung-piles) for all the droppings located at a distance of 1.2 m or less (truncation point) (Buckland *et al.*, 1993) were used by the programme DISTANCE (Laake *et al.*, 1994) to estimate the detection function *g(x)*.This is the probability of detecting a dung-pile, given that it is at distance *x* from the random transect (Buckland *et al.* 1993). The DISTANCE programme uses *g(x)* to estimate the probability density function (pdf) f(x) of the perpendicular distance data, conditional on the dung-pile being detected (Buckland *et al.*, 1993). From the probability density function, the DISTANCE programme calculates an estimate for f(0), which is an estimate of the frequency with which dung-piles occur on the centre-line (Barnes & Jensen, 1987) as well as its 95% confidence interval.

The detection function *g(x)* is not known in advance and it varies with factors like the environment and observer effectiveness to detect dung-piles. Several models of *g(x)* are implemented in the programme DISTANCE. Three different statistical tests can be used in selecting the best model that fits the data. These tests are: the likelihood ratio test, the goodness of fit test and the Akaike's Information Criterion (AIC) test. However, Buckland *et al.* (1993) advise the use of the AIC test because, unlike the likelihood ratio test that works only for nested models and the goodness of fit test that provides only the warning that the model might be poor, the AIC test allows to test all the models implimented in the programme DISTANCE at the same time and the best model is the one with the lowest AIC. The AIC test was therefore chosen for data analysis. For the first and second surveys (January-March and May-August 1993), a three-term Fourier series model was selected. Their respective AIC values were 3672.2 and 2896.1. The mathematical formula of the model is:

$$g(x) = \frac{1}{w}\left[1 + \sum_{j=1}^{3} A_j \cos\left(\frac{j\pi x}{w}\right)\right] \qquad \textbf{(Equation 3-1)}$$

where w is the is a perpendicular distance (here 1.2 metres) such that all x_i greater than w are discarded (truncation point). A_j is the *j*-th parameter in the estimated probability density function (pdf). Their values are calculated by the programme DISTANCE.

For the third survey (November 1993), the hazard rate model was selected (AIC = 1275.9). Its mathematical formula is:

$$g(x) = 1 - \exp(-x / A_1)^{A_2} \quad \textbf{(Equation 3-2)}$$

A_1 and A_2 were calculated by the DISTANCE programme.

For this survey, dung densities calculated using the Hazard rate model were compared with dung densities calculated using three-term Fourier series (as for the first two surveys).

For each transect, the programme DISTANCE estimated the dropping density km^{-2} ($\hat{Y}$) using **Equation 3-3** (Buckland *et al.*, 1993).

$$\hat{Y} = \frac{n.\hat{f}(0)}{2L} \quad \textbf{(Equation 3-3)}$$

where n in the number of dung-piles in the transect, and L is the total length of the transect.

Estimation summary of dung-pile densities calculated for each transect and for each survey are given in the **Appendix 1**.

After estimating dung-pile densities for each transect and for each of the three surveys, the programme pooled the data over the 78 replicate transects for the estimation of the dung-pile density of the Lobeke forest for each of the three surveys. The coefficient of variation and confidence limits were also calculated by the programme DISTANCE.

4) The Defecation rate

Whenever elephants were located, they were followed by four observers: two experienced trackers, an assistant and the principal investigator. Direct observations of defecation rates of single individuals or members of small groups were made, recorded to the nearest minute, throughout the observations period. Observations were stopped immediately whenever the observers were detected by the elephant.

Plate 2: Defecation rate study in an extended single-species stand of *Gilbertiodendron dewevrei*. A bull can be seen in the background.

For data analysis, each observation was converted to elephant hours (group size multiplied by the duration of the observation). The number of defecations per hour and then per 24 hours were estimated. The observations were then divided into two groups: the dry period (long dry season and short dry season) and the wet period (long rainy season and short rainy season) according to the repartion of seasons of Harrison & Agland (1987). Students' t-test was used to test the null hypothesis (H_0) that there is no significant difference between average daily defecation rate in the dry period and in the wet period. The relationship between the defecation rate and the rainfall of the same month and preceding three months was tested using regression analysis.

5) The decay rate

One sample of 39 fresh dung-piles (initially less than one day old) was studied in the Lobeke forest, from May to September 1993. The dung-piles were marked and graded according to their appearance, following the grades used by Barnes and Jensen (1987) as follows:

Stage A: Boli intact, very fresh, moist with odour.

Stage B: Boli intact, fresh but dry, no odour.

Stage C1: Some of the boli are disintegrated, but more than half are distinguishable as boli.

Stage C2: Less than half of the boli are distinguishable, the rest are disintegrated.

Stage D: All boli form an amorphous flat mass

Stage E: It is impossible to detect the dung-pile at 2 metres range in the undergrowth.

Dung-piles were monitored at regular intervals of 7 days until they had all disappeared (reached stage E). At each visit, notes were made of the appearance of the dung-pile (morphological change), presence of fungi or insects, and whether the dung-pile had been disturbed by other animals or birds looking for seeds. When a dung-pile passed from stage D (visible) to stage E (unlikely to be detected at a distance of 2 m), it was deemed to have "died", that is disappeared and observations were discontinued.

For data analysis, Barnes *et al.* (1994) method and programme were used. The mean decay rate for each dung-pile was calculated using the date of deposition (t_d), the date when the dung-pile was last recorded as stage D (t_D) and the date when it was first recorded at stage E (t_E). The interval between the two last dates was not more than 7 days. Since the exact date when the dung-pile passed from grade D to grade E was not known, a date had to be assigned to it. That date was defined as $t_D + R$, where R is a random number between 0 and 7. The life span of a dung-pile was then the time that elapsed between t_d and $t_D + R$.

If x is the median life span (duration time) of a dung-pile (the mean was not used here since the duration times were not normally distributed (see **Chapter 4**, Section 4.1.1)) and supposing Y is the number of dung-piles, D the defecation rate and E the number of elephants to be estimated. Assuming that the system is in a steady state, Y is the number of dung-piles that have accumulated during the preceding x days. This means that the number of dung-piles laid per day was Y/x. With E elephants living in the area and each producing D dung-piles per day, the total number of dung-piles produced by the population was $E \times D$. Thus

$$E \times D = \frac{Y}{x}$$

and

$$E = \frac{Y}{D} \times \frac{1}{x}$$

This equation is similar in form to the one derived by Barnes & Jensen (1987), where $E = Y \times r/D$ with r being the mean rate of decay. These two equations are interchangeable if one sets $r = 1/x$. This relationship is very important as it means that the decay rate is equal to the reciprocal of the median duration time (that is, the time for half the dung-piles to decay) (Barnes *et al.*, 1994).

The median duration was therefore calculated for the sample and the estimate of the decay rate was estimated as the reciprocal of the median duration time (Barnes *et al.*, 1994). Although this provides a simple method for estimating the decay rate, there remains the problem of calculating the confidence limits. This is solved by resorting to the bootstrap technique (Krebs, 1989). Bootstrap estimates of parameters are biased (Krebs, 1989) and the bias adjusted estimate, *Vadj* is calculated as:

$$Vadj = 2Vs - Vb \qquad \textbf{(Equation 3-4)}$$

were *Vs* is the estimate of decay rate from the original sample and *Vb* is the estimate from the bootstrap.

A computer programme, MEDECAY3.BAS (Barnes *et al.*, 1994), checks the data-file containing the duration times for the sample and calculates its mean decay rate, standard error, confidence limits and the bias adjusted estimate. It is the bias-adjusted estimate which is used in elephant density estimates (Barnes *et al.*, 1994).

6) Elephant density.

It was assumed that dung-piles in the study area were in a steady state (number of dung-piles disappearing each day were equal to the number of dung-piles being deposited). The densities of elephants (*E*) per square kilometre were therefore estimated using the three variables (McClanahan 1986; Barnes & Jensen 1987): dung-piles density (Y), elephant defecation rate (*D*) and dung decay rate (r).

$$E = \frac{Y.r}{D} \qquad \textbf{(Equation 3-5)}$$

Each of the variables (*Y*, *r*, *D*) is an estimate with its own variance. The variance of each of the three variables will contribute to the variance of E, which is estimated by:

$$Var(E) = Var(D) \times \frac{(Y \times r)^2}{D^4} + \frac{Var(Y \times r)}{D^2}$$ **(Equation 3-6)** (Barnes, 1993)

where

$$Var(Y \times r) = Var(Y) \times Var(r) + Y^2 \times Var(r) + r^2 \times Var(y)$$

The 95% confidence interval was estimated as

$$E \pm 1.98 \times SE$$ **(Equation 3-7)**

because, with a sample size $n = 78$, $t_{0.05}$ is about 1.98 (Zar, 1984)

3.2.2 Movements and distribution in relation to the environment and human activities.

As previously stated, one random transect was cut in each cell. It was assumed that each transect was representative of its cell. This means that if the vegetation type observed along a transect was, for example, a logged forest, the cell in which the transect was cut was automatically classified as a cell with logged forest (**Appendix 5**). The same consideration was valid for dung-pile densities (**Appendix 1**) and elephant densities (**Appendix 4**). The variation of elephant densities in each cell over the three surveys allowed the determination of movement patterns. The estimated density of elephants in a cell for the second survey was subtracted from the density of elephants in that specific cell estimated for the first survey. A positive result indicated a migration of elephants into the cell and a negative result indicated that elephants moved away from the cell during the period separating the two surveys. The same method was used to determine elephant movements during the period separating the second and third survey.

For the resolution of surveys, the 5 × 5 km grid was used to determine density distributions accurate to the nearest 25 km^2 and therefore be able to match them with particular habitat types within each grid. The environmental variables selected were the vegetation type (primary and logged forest), water, relief (hilly or flat) and swamp. Human activities (hunting, logging road in use) were also selected as variables. For each of the three surveys, each of the 78 cells was placed into two groups, one with the environmental variable or human activity (e. g. cells with logged forest) and one without that specific environmental variable or human activity (e.g. cells without logged forest) and then, the analysis of variance was used to test the significance of differences in mean elephant density between the two groups. Then, the 78 cells were recast into two new groups for the analysis of variance with a different environmental variable or human activity.

The regression analysis was carried out to test the relationship between elephant densities in cells and distance to the Sangha river, the main highway the nearest village and nearest logging road in use for each of the three surveys.

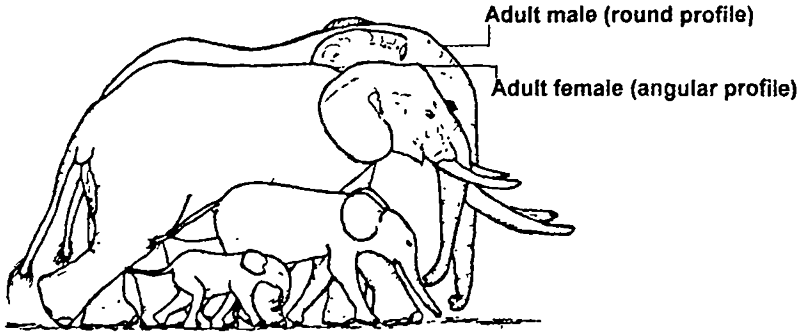


Figure 3-3: Field age criteria used in the Lobeke forest. A calf (< 1 year old), an immature, a cow and one adult bull are shown.

3.2.3 Age structure, sex ratio and group sizes

Because of low visibility in the forest undergrowth, it was only possible to make approximate visual height age assessments for population-structure estimates. Elephants were classified into three main groups; adults, immatures and calves of less than one year old. Calves of less than one year old were those that could stand between their mother's forefeet (Laws, 1966). To distinguish between the sexes, elephants heads were observed in side view. That of a female has an angular profile, while that of male is round (**Figure 3-3**). Immature and babies were not sexed because of a very low visibility. From the total number of individuals whose ages were determined, the proportion classified as calves less than a year old was taken as representing the percentage of young born into the population during the study period.

3.2.4 Daily activities

A day was divided into three unequal periods: morning (6:01 am-11:00 am), noon (11:01 am-01:00 pm) and afternoon (1:01 pm-6:00 pm). Each time elephants were seen, the activity they were engaged in as well as the period (morning, noon, afternoon) were recorded. In other words, groups were instantaneously sampled. The recorded activities were drinking, feeding, lying, standing, walking and digging.

3.2.5 Diet

Fresh elephant feeding signs were recorded along transects. These signs are conspicuous; plants are broken, climbers are pulled down, leaves are stripped from branches and they are generally associated with footprints or dung-piles. Less conspicuous signs were ignored as they could not be attributed with certainty to elephants. A single observation could reflect consumption of one elephant or a group of elephants. Plants were identified via Baka names and Letouzey (1976) or by reference to the national herbarium. Each plant eaten was recorded as an observation. Parts eaten were leaves, barks, roots, fruits, twigs and tubers.

The percentage of a species in the diet (r_i) was calculated as

$$r_i = \frac{n \times 100}{N} \quad \textbf{(Equation 3-8)}$$

where n is number of observations of the species in the diet and N the total number of observations.

For the estimation of the percentage of the same species of food plants in the environment, 40 of the 78 transects were selected at random. An observer and two

Plate 3: Elephant feeding sign on barks of ayous (*Scleroxylon triplochiton*).

Plate 4: A hole dug by elephants in the Lobeke forest.

assistants walked along each of the selected transects. Each sighting of any of these species was recorded as an observation.

The percentage of a species in the environment (n_i) was calculated as

$$n_i = \frac{x \times 100}{X} \quad \textbf{(Equation 3-9)}$$

where x is the number of observations of the species in the environment and X the total number of observations.

An electivity index (Krebs, 1989) which is a measure of preference was estimated as

$$E_i = \frac{r_i - n_i}{r_i + n_i} \quad \textbf{(Equation 3-10)}$$

where E_i is the Ivlev's electivity measure (Krebs, 1989) for the species i; r_i is the percentage of species i in the diet and n_i is the percentage of species i in the environment. The Ivlev's electivity index varies from -1.0 to +1.0. For the order of preference, each E_i was compared to 0 as follows:

$E_i > 0$: Preferred species

$E_i = 0$: Species eaten because of its high frequency of occurrence in the forest

$E_i < 0$: Species eaten from time to time, low frequency of occurrence in the forest.

3.2.6 Crop depredation

The study of crop raiding was made simultaneously with the human ecology survey (see **Section 3.2.1**). Interviews were conducted in all the villages and logging towns in the Lobeke area (**Figure 2-1**). The owner or any other adult person (above 15 years old) met in every second household was asked if they were experiencing crop-raiding in their farms. In the case of a positive answer, the informant was asked to give names of crop-raiders and the period of the year crop-depredation was much more intense. A questionnaire was used but all interviews were informal and the informant was given the opportunity to develop their answer outside the structured format. More than one species were generally cited by informants.

For data analysis, a total number of "complaints" (C) was calculated as the summation of the number of times each species was cited as crop-raider.

$$C = \sum_{i=1}^{n} X_i \qquad \textbf{(Equation 3-11)}$$

where X_i is the number of times the species i was cited as crop-raider.

The impact (I_i) of a species i on agriculture in the Lobeke forest was estimated as

$$I_i = \frac{X_i}{C} \times 100 \qquad \textbf{(Equation 3-12)}$$

Where X_i is the number of times the species was cited as crop-raider and C the total number of "complaints".

Villages where elephant crop damage was reported were mapped. These data were used to determine the seasonal patterns of elephants' movements out of the Lobeke forest and to evaluate the state of relations between elephant and local people.

3.3 Human ecology

The study was focused on the Baka and Bangando and their relationships with the natural environment because they are the closest indigenous peoples to the proposed Lobeke forest reserve. The main research methods were: interviews and participant observation.

3.3.1 Interviews

Individual interviews were conducted by a trained Bangando that spoke both Baka and Bangando languages fluently. All interviews were started opportunistically and questions were asked in the course of a conversation. This approach gave informants the opportunity to develop their answers outside the structured format and therefore provide useful information. The set of topics investigated were: social organisation, demography, logging experience, importance of the Lobeke forest for the indigenous population, food restriction, gathering, fishing, plant cultivation and livestock farming (see **Appendix 6** for details).

3.3.2 Participant observation

Participation in agriculture, resource collection (fishing, hunting, gathering) and processing activities was the second approach in data collection. Observations were made opportunistically in hunting camps, farms and fishing camps. Visits lasted from 1 day to 1 week. Data were recorded on methods used to harvest natural resources, the type or species of natural resource harvested, the distance from the village (in number of days of walk), the ethnic group, the number of persons involved in the activity and the period of the year the activity was undertaken.

3.3.3 Data analysis

Each individual observation in the sample was classified into two separate categories: Baka and Bangando. The comparative analysis was undertaken using the Chi-squared test for non parametric analysis and one-way analysis of variance for parametric analysis.

The indigenous population was estimated by multiplying the total number of households in each tribe by the corresponding mean number of persons per household. Different household definitions may be relevant in different societies, including for example a common source of the major part of income, sleeping under one roof or in one compound, a common source of food, or answerable to the same head (Casley & Lury, 1981). In villages involved in this study, unmarried men tend to live with their parents. In some cases, households temporarily merged with others for food consumption. It appeared therefore most appropriate to define households as sleeping under one roof. A complete census of households simultaneously with the questionnaire survey was made of each study village. These data were analysed by the statistical programme Minitab for windows version 10 (Minitab Inc, 1994).

Chapter 4

RESULTS

4.1 Meteorological records

4.1.1 Rainfall, temperature and humidity

In 1993, the climate of the Lobeke forest was characterised by rains covering virtually the whole year although marked by relatively dry period from December to March and a sharp decrease of rain in September. The monthly rainfall that reached 245 mm in April dropped to 31 mm in September (**Figure 4-1**). The annual rainfall was 1476.5 mm. The mean annual temperature was 25^0 C with fluctuations of about 10^0 C between minimum and maximum temperatures (**Figure 4-2**). The relative humidity remained high the whole year with a mean of about 75% (**Figure 4-3**).

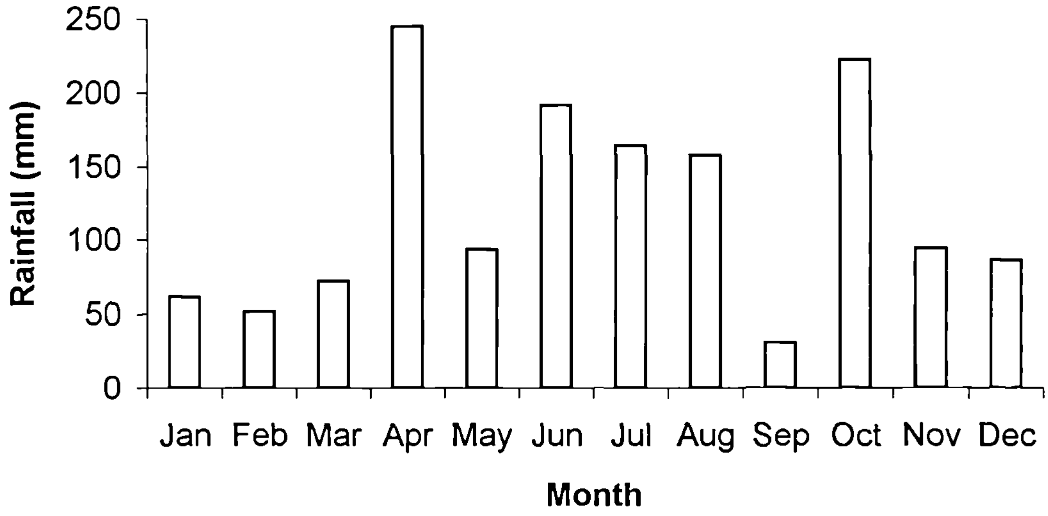


Figure 4-1: Monthly rainfall in the Lobeke forest, 1993.

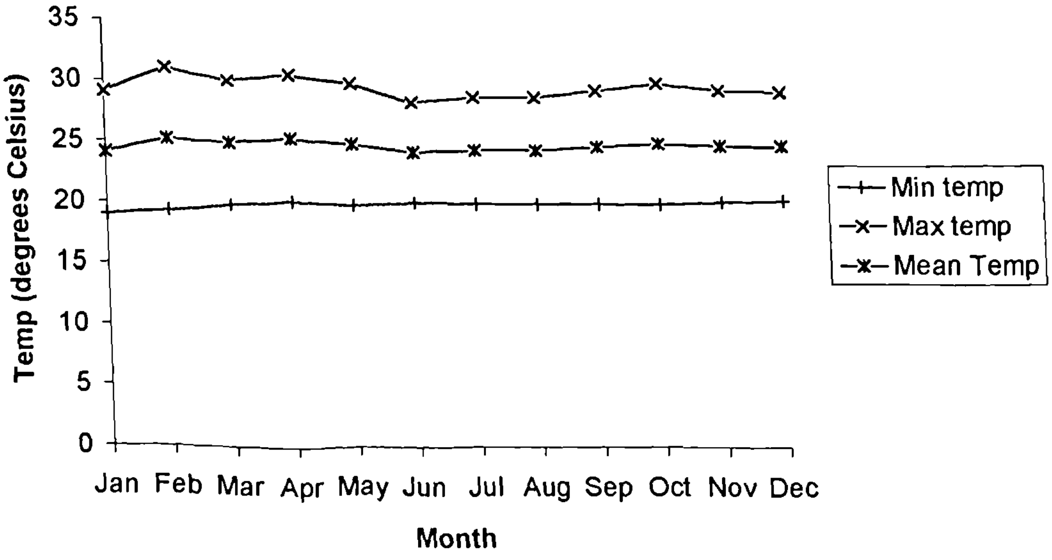


Figure 4-2: Maximum, mean and minimum temperatures in the Lobeke forest, 1993.

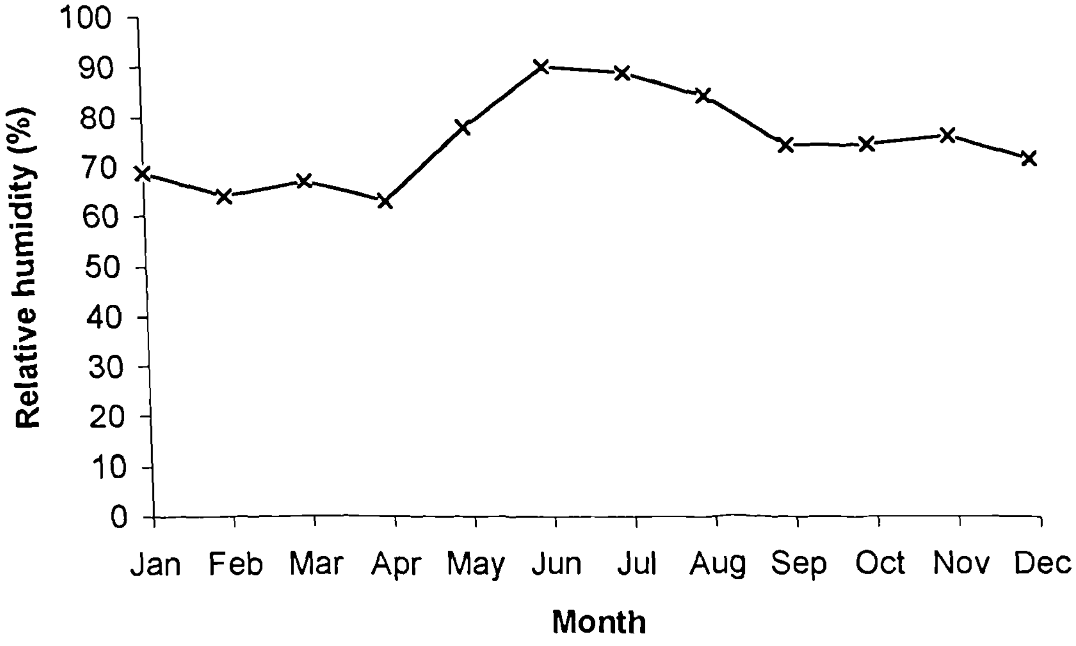


Figure 4-3: Relative Humidity in the Lobeke forest, 1993.

The repartition of seasons for this study refers to that of Harrison & Agland (1987) as defined in **Chapter 2 Section 2.2**, which is widely used in the Central African rainforest. Rainy and dry seasons (short and long) correspond only loosely to actual rainfall.

4.2 Elephant Ecology

4.2.1 Densities, numbers and distributions

1) Dung-pile densities

The total length of transects for each of the 3 surveys was 195 km (585 km for the 3 surveys). The major vegetation types represented were primary and logged forest. The total number of dung-piles detected during each survey is shown in **Table 4-1**.

Table 4-1: Total number of dung-piles detected along transects for each of the three surveys.

Period	Number of dung-piles detected for the survey
January-March 1993	1469
May-August 1993	1152
November 1993	500

The apparent reduced number of dung-piles detected during the November 1993 survey suggests that a great number of elephants had left the area by that time.

Frequency histograms and probability density functions of the perpendicular distances from the centre line of all detected droppings were constructed by the computer programme DISTANCE. They are presented in **Figure 4-4**, **Figure 4-5** and **Figure 4-6**. Parameters calculated by the programme DISTANCE for each survey of the 3 surveys are presented in **Table 4-2**, **Table 4-3** and **Table 4-4**.

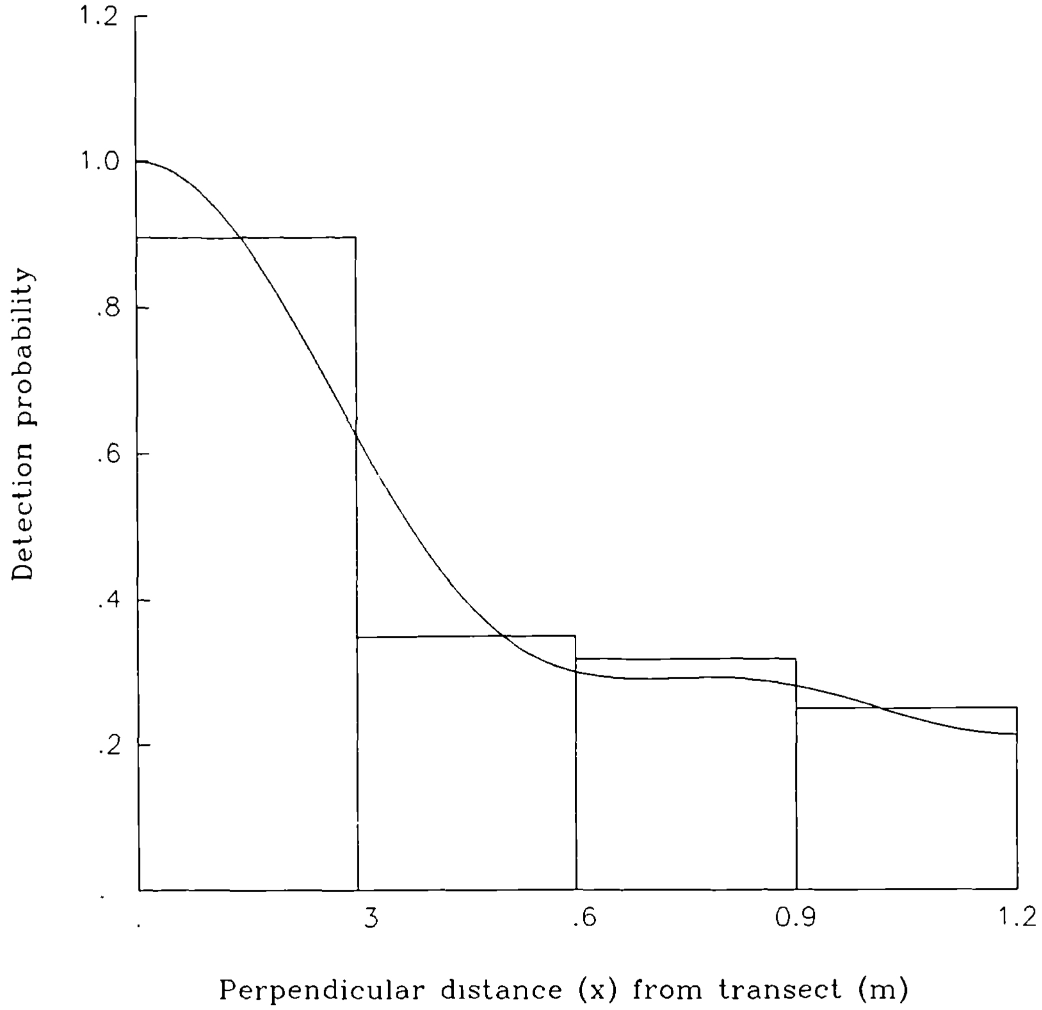


Figure 4-4: Histogram of the survey of January-March 1993, using 0.3 m cut points, and truncated at 1.2 m. A three-term Fourier series detection function is fitted to the data.

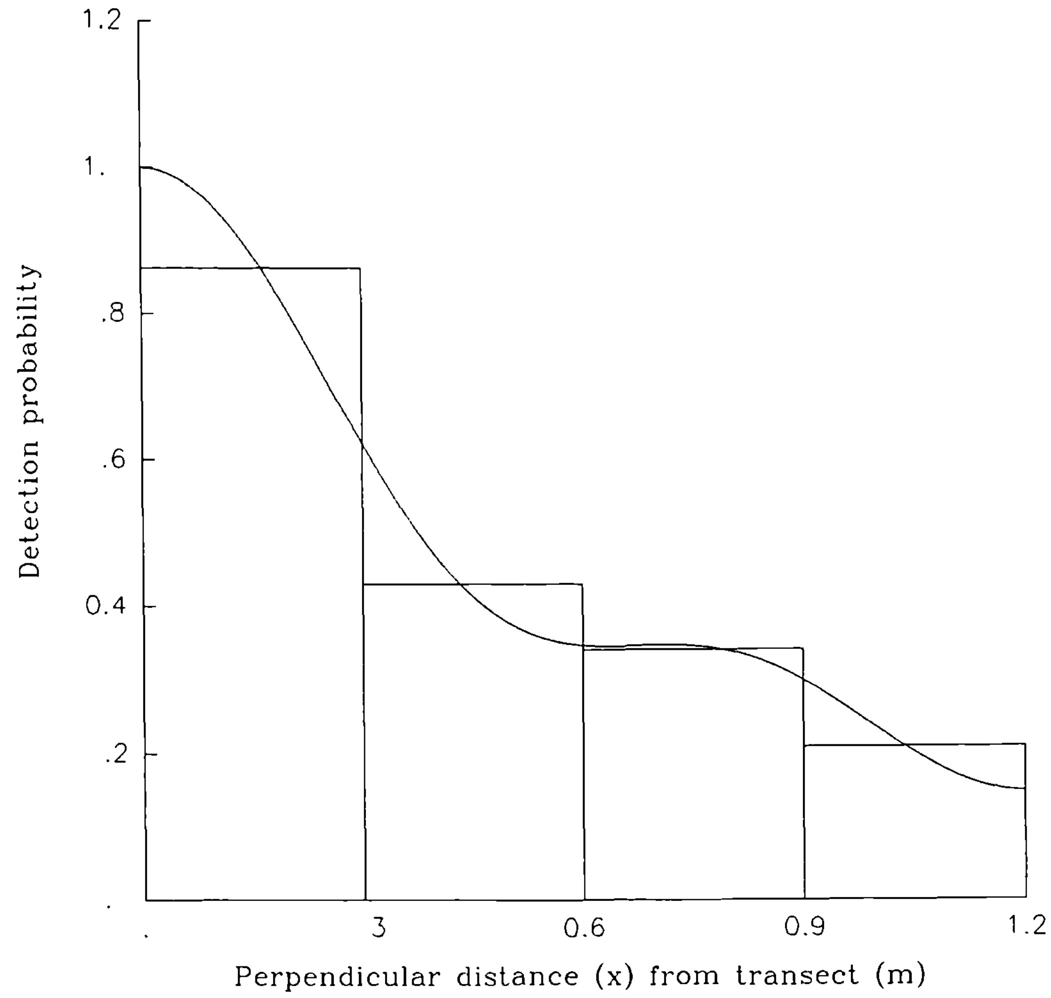


Figure 4-5: Histogram of the survey of May-August 1993, truncated at 1.2 m with cut points at 0.3 m. A three-term Fourier series detection function is fitted to the data.

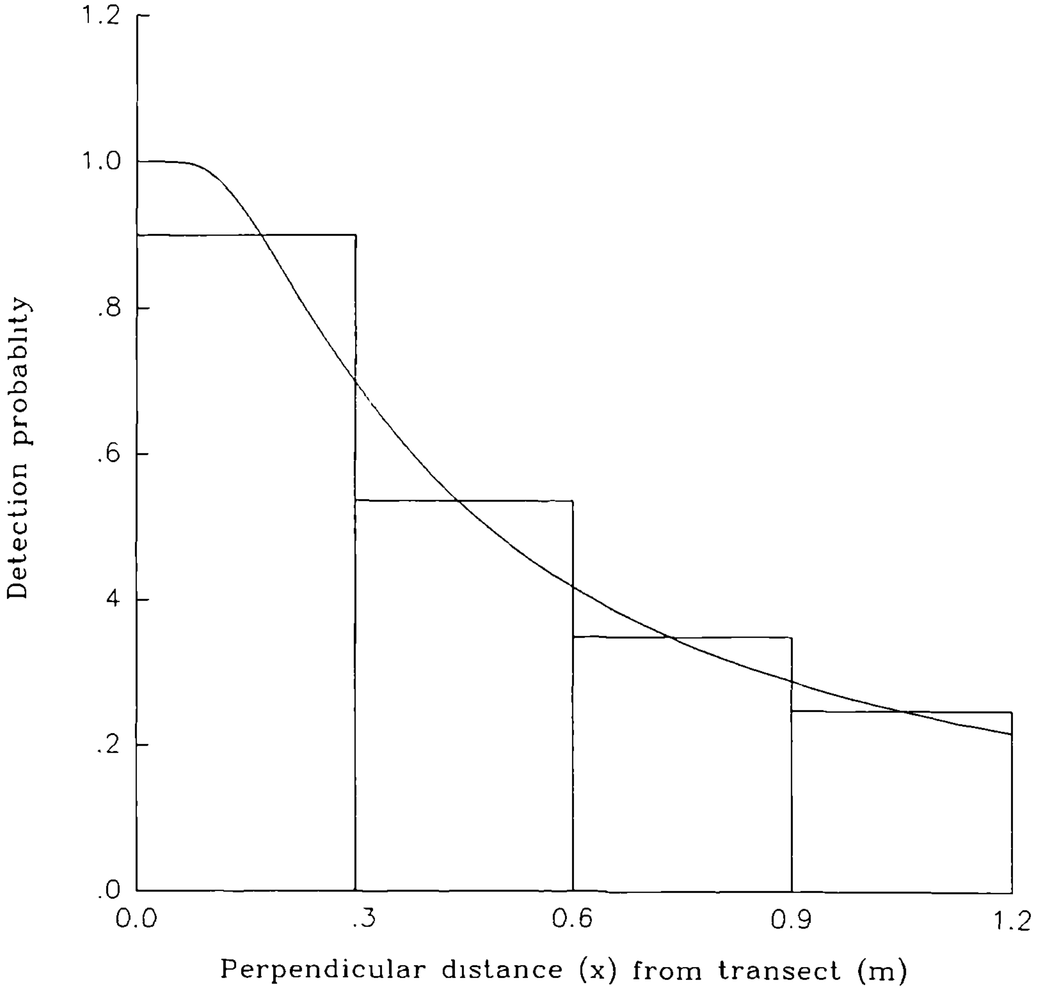


Figure 4-6: Histogram of the survey of November 1993, using 0.3 m cut points and truncated at 1.2 m. A Hazard rate detection function is fitted to the data

Table 4-2: Summary of statistics for January-March 1993 survey (three-term Fourier series detection function).

Parameter	Point estimate	Standard error	Coefficient of variation (%)	95% confidence Interval
A(1)	0.7053	0.3625×10^{-1}	5.14	-
A(2)	0.3395	0.4000×10^{-1}	11.78	-
A(3)	0.1650	0.4307×10^{-1}	26.10	-
f(0)	1.8415	0.70191×10^{-1}	3.81	1.7090 1.9843
P	0.45253	0.17249×10^{-1}	3.81	0.41996 0.48762
ESW	0.54303	0.20698×10^{-1}	3.81	0.50396 0.58514

Table 4-3: Summary of statistics for May-August 1993 survey (three-term Fourier series detection function).

Parameter	Point estimate	Standard error	Coefficient of variation (%)	95% confidence Interval
A(1)	0.7114	0.3991×10-1	5.61	-
A(2)	0.2481	0.4569×10-1	18.41	-
A(3)	0.2142	0.4965×10-1	23.18	-
f(0)	1.8115	0.78984×10-1	4.36	1.6632 1.9730
P	0.46003	0.20058×10-1	4.36	0.42236 0.50105
ESW	0.55203	0.24070×10-1	4.36	0.50684 0.60126

Table 4-4: Summary of statistics for November 1993 survey (Hazard rate detection function).

Parameter	Point estimate	Standard error	Coefficient of variation (%)	95% confidence Interval
A(1)	0.3512	0.1076	30.64	-
A(2)	1.144	0.2680	23.43	-
f(0)	1.6392	0.20986	12.80	1.2767 2.1045
P	0.50839	0.65088×10^{-1}	12.80	0.39597 0.65273
ESW	0.61007	0.78105×10^{-1}	12.80	0.47516 0.78328

A(1) = first parameter in the estimated probability density function (pdf)
A(2) = second parameter in the estimated pdf
A(3) = Third parameter in the estimated pdf
f(0) = The pdf of the perpendicular distances from the line, evaluated at zero distance
P = Probability of detecting a dung-pile
ESW = effective strip width (= w × P) in metres

The programme DISTANCE calculates the estimated dung-pile density of each transect using the general estimator of dung-piles density (**Equation 3-3**). The mean estimates, their standard errors and 95% confidence intervals are presented in **Table 4-5**.

Table 4-5: Mean dung density estimates for each of the three surveys.

Period	Density estimate (km^{-2})	Standard error	95% confidence interval
January-March 1993	6936	823	± 1613
May-August 1993	5351	460	± 902
November 1993	2102	362	± 710

For the survey of November 1993, analysis of variance suggests no significant difference between dung densities estimated using the Hazard rate detection function and dung densities estimated using a three-term Fourier series detection function (*F* (1, 154) = 0.00, NS) (see **Appendix 10**).

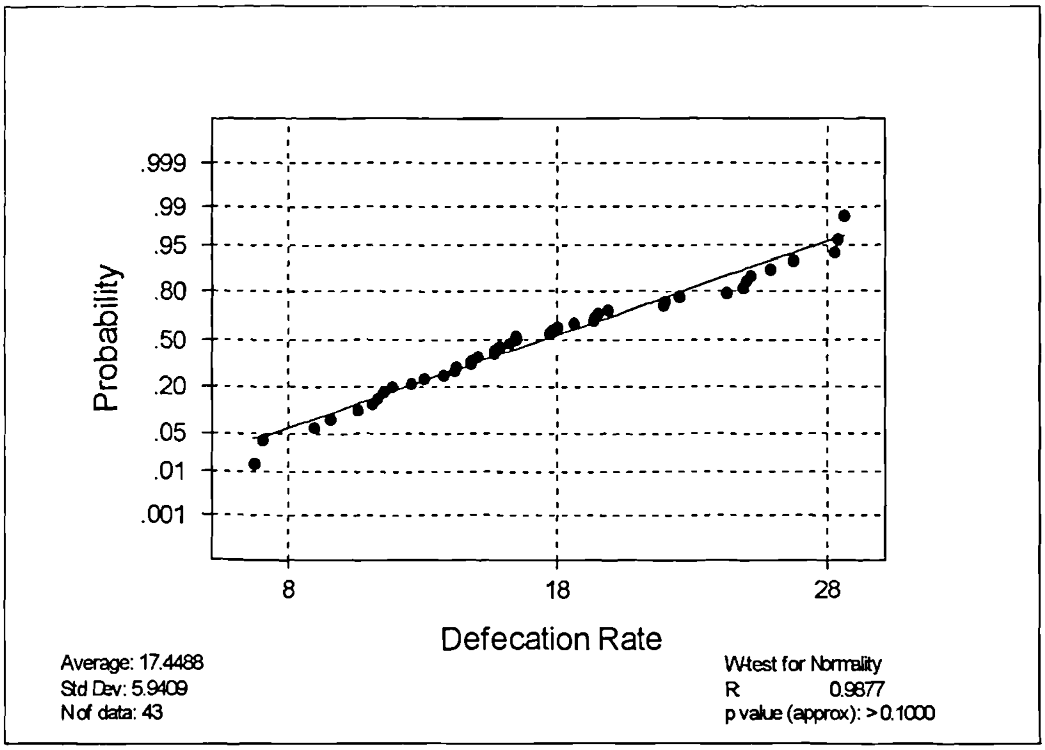


Figure 4-7: The normal probability plot for the defecation rate data.

2) Defecation rate

The total number of observations was 43 for 563.28 elephant hours; 249.96 elephant hours (18 observations) for the wet period (long and short rainy seasons) and 313.32 elephant hours (25 observations) for the dry period (long and short dry seasons). Details of each observation are given in the Appendix 2. The Ryan -Joiner test (**Figure 4-7**) shows the normal probability plot of the defecation rate. This test is similar to the Shapiro-Wilks test (Zar, 1984). The hypothesis of normality cannot be rejected here since the p value displayed is larger than 0.05 (Zar, 1984).

The two-sample t-test suggests that the mean defecation rate does not vary significantly over the wet and dry periods ($t = 0.77$, df = 41, NS). The summary of the results of the defecation rate study for each period, the mean estimate and 95% confidence limits are shown in **Table 4-6**.

Table 4-6: Mean defecation rate of elephants in the Lobeke forest for each period (wet and dry), the mean estimate and 95% confidence intervals.

Period	Point estimate	Standard error	95% confidence intervals
Dry period	16.85	1.14	± 2.35
Wet period	18.27	1.49	± 3.15
Mean	17.45	0.90	± 1.82

Regression analysis did not show a significant relationship between the defecation rate and the rainfall of the same month (F (1, 41) = 1.96, NS), the preceding month (F (1, 41) = 0.96, NS), two months (F (1, 41) = 0.01, NS) or three months (F (1, 41) = 2.24, NS) before the defecation rate data collection (**Figure 4-8**, **Figure 4-9**, **Figure 4-10** and **Figure 4-11**). Hence, it is concluded that there is no relationship between defecation rate and preceding rainfall.

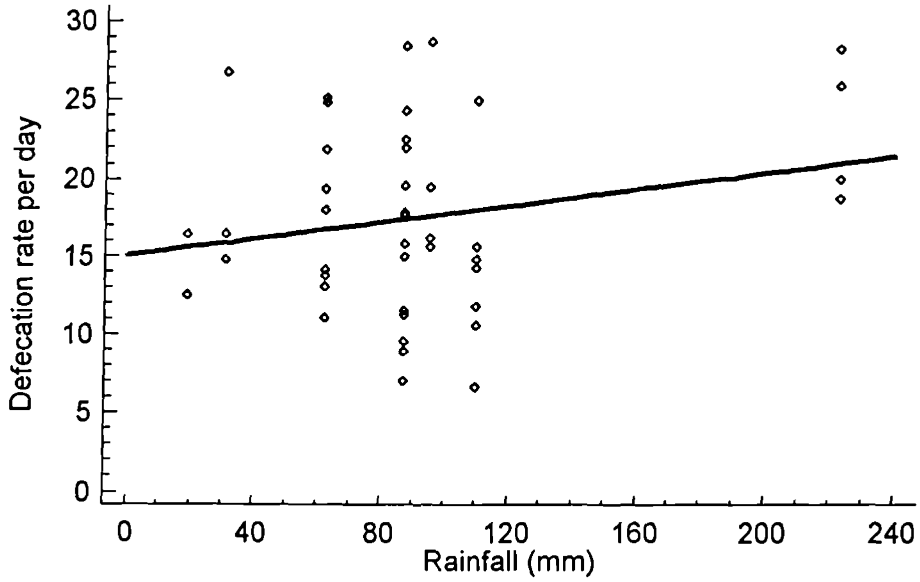


Figure 4-8: Fitted regression line of defecation rate and rainfall of the same month.

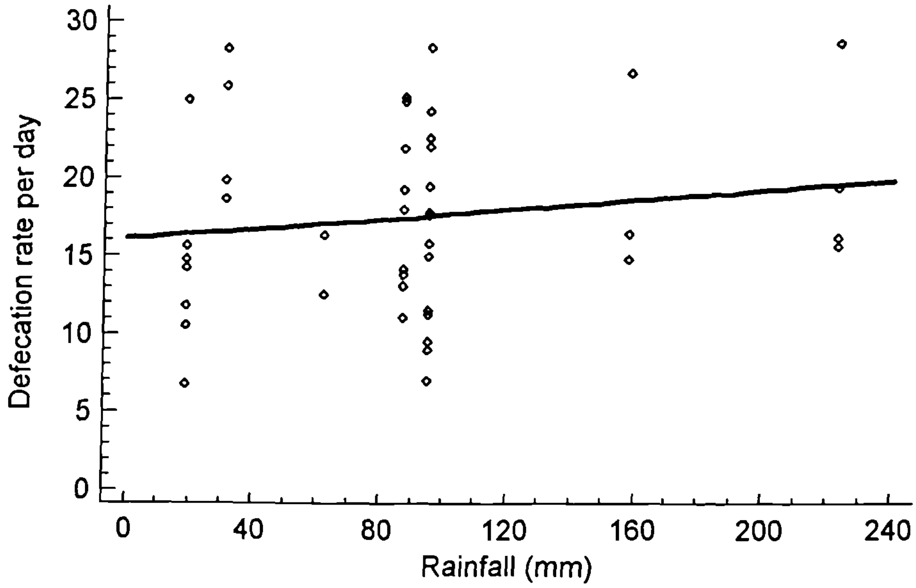


Figure 4-9: Fitted regression line of defecation rate and rainfall of the preceding month.

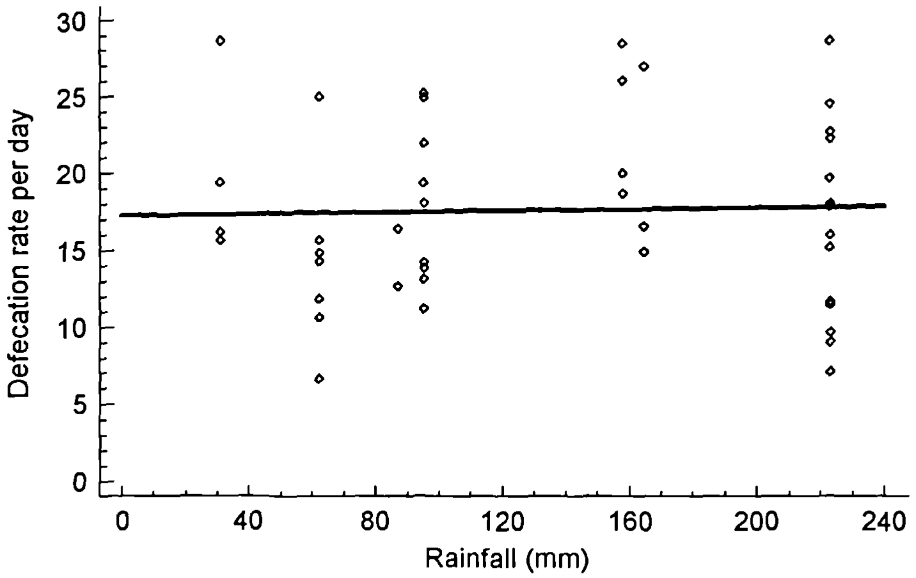


Figure 4-10: Fitted regression line of defecation rate and rainfall two months before data collection.

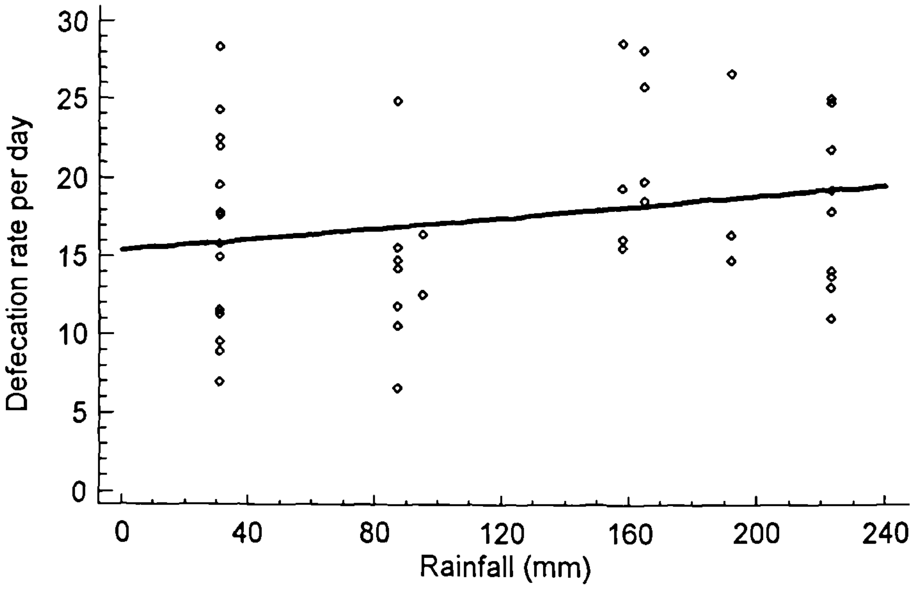


Figure 4-11: Fitted regression line of defecation rate and rainfall three months before data collection.

3) Dung-piles decay rate

The 39 dung-piles studied accounted for 4,320 dung-pile days of observations. Duration times in the sample varied from 16 to 182 days (about six months). Raw data are listed in the **Appendix 3**.

The "duration time" is the time that elapses from the moment a dung-pile is deposited until it is categorised as stage E (Barnes *et al.*, 1994). The Shapiro-Wilks test shows that the duration times are not normally distributed ($W = 0.927$, P-value = 0.0182). This confirms Barnes *et al.* (1994) and White (in press) observations.

The survival curve for the sample is presented in **Figure 4-12**. This curve shows that the decay rate does not remain constant. This confirms McClanahan (1986), Short (1983), Barnes & Jensen (1987) and Barnes *et al.* (1994) observations. The results of dung decay rate estimated by the programme MEDECAY3.BAS are presented **Table 4-7**.

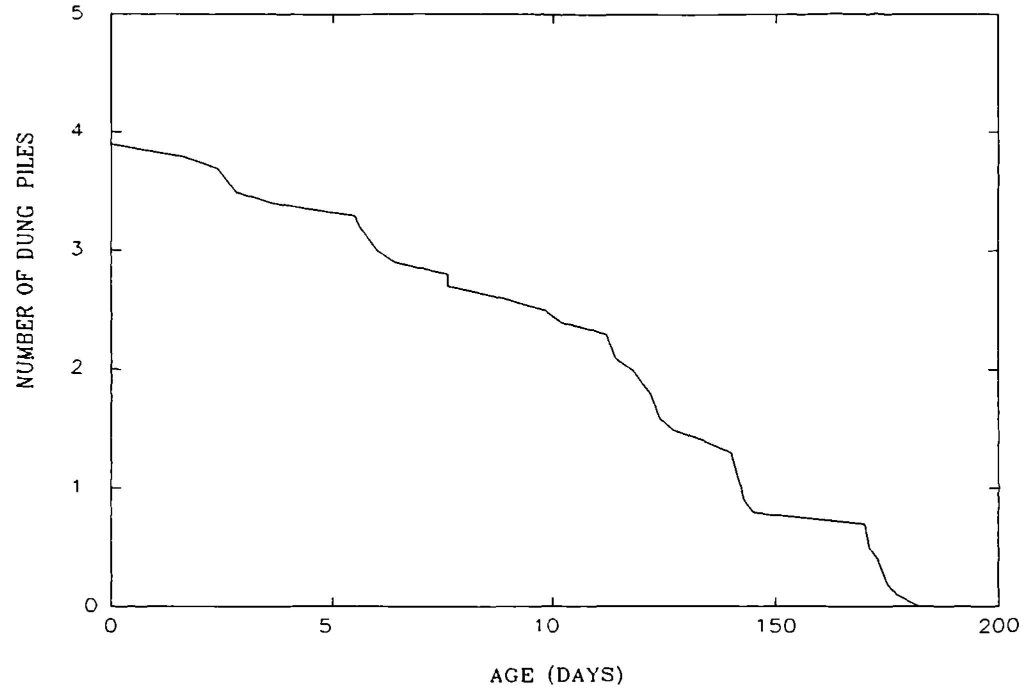


Figure 4-12: The survival fitted curve for the sample of dung-piles at Lobeke.

Table 4-7: Estimates of decay rate (per day) from the mean sample studied in the Lobeke forest.

DECAY RATE FROM ORIGINAL SAMPLE =	0.008333
BOOTSTRAP-ADJUSTED ESTIMATE =	0.007939
BOOTSTRAP ESTIMATE OF DECAY RATE =	0.008727
BOOTSTRAP VARIANCE =	0.00000089
BOOTSTRAP STANDARD ERROR =	0.000941
BOOTSTRAP 95% C.L. =	±0.001863
NUMBER OF ITERATIONS =	1000
NUMBER OF DUNG-PILES =	39

4) Elephant density

Elephant densities were calculated from the **Equation 3-5**. The results for each cell are given in **Appendix 4**. A mean elephant density with its 95% confidence limits was calculated for each survey using **Equation 3-5**, **Equation 3-6** and **Equation 3-7**. The results are presented in (**Table 4-8**).

Table 4-8. Mean elephant density estimate (km^{-2}) for each of the three surveys.

Period	Point estimate (km^{-2})	Standard error	95% C.L.
January-March 1993	3.1	0.39	± 0.77
May-August 1993	2.4	0.23	± 0.46
November 1993	1.0	0.16	± 0.32
Mean	2.17	0.16	± 0.32

Each of the mean estimate of elephant density was multiplied by the area of the proposed reserve to estimate the number of elephant supposed to be there during that specific period. The results are shown in **Table 4-9**.

Table 4-9: Estimates of the number of the Lobeke forest dwelling elephants for each of the three surveys.

Period	Estimated number of elephants
January-March 1993	6,588 ± 1,636
May-August 1993	5,249 ± 978
November 1993	2,125 ± 680
Mean	4,654 ± 680

The analysis of variance suggests that the density of elephants fluctuates significantly over these periods (F (2, 231) = 22.38, $p < .001$). However a post-hoc test shows that this is mainly between the second survey (May-August 1993) and the third survey (November 1993) (F (1, 154) = 49.83, $p < 0.001$). This means that elephant density was not significantly different between the period separating the first two surveys (F (1, 154) = 3.29, NS).

5) Distribution of elephants in the Lobeke forest over a seasonal cycle

The distribution of elephants for the period of January-March 1993 represents the long dry season's distribution (**Figure 4-13**), that the period of May-August 1993 represents the short rainy season and short dry seasons' distribution (**Figure 4-14**) and that of the November 1993 represents the long rainy season's distribution (**Figure 4-15**).

The following observations could be made when looking at the distribution of elephants over the seasonal cycle covered by the survey:

- For the long dry season, high densities appeared to be concentrated more in the Sangha drainage system. The central part of the forest seems less used.

- For the short rainy season and short dry season, the Sangha drainage system and the headwaters of the Boulou river appeared to be highly used.

- For the long rainy season, high densities appeared to be concentrated mainly along the Lobeke river and the head waters of the Boulou river.

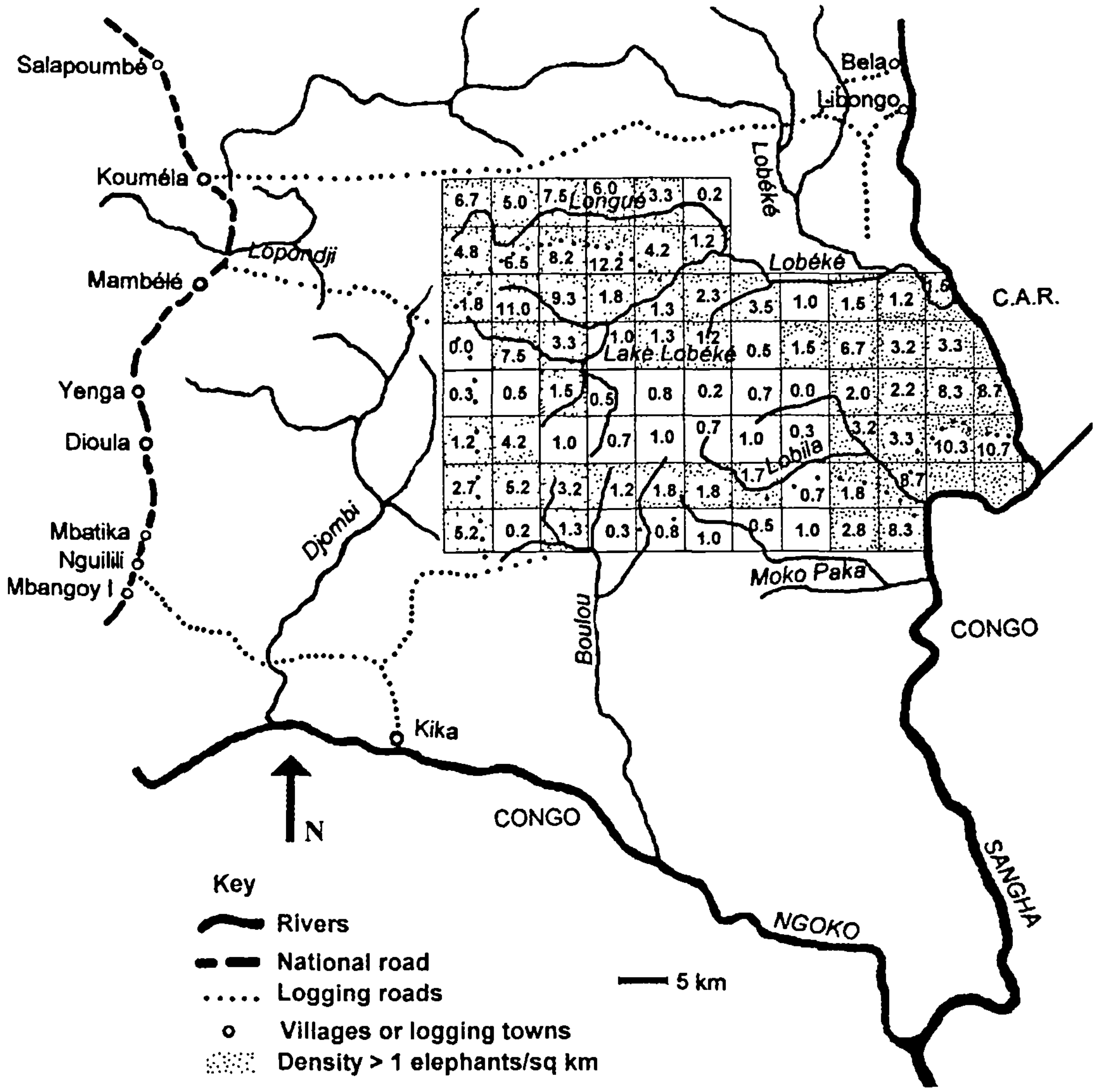


Figure 4-13: The distribution of elephant densities km^{-2} in the Lobeke forest during the long dry season.

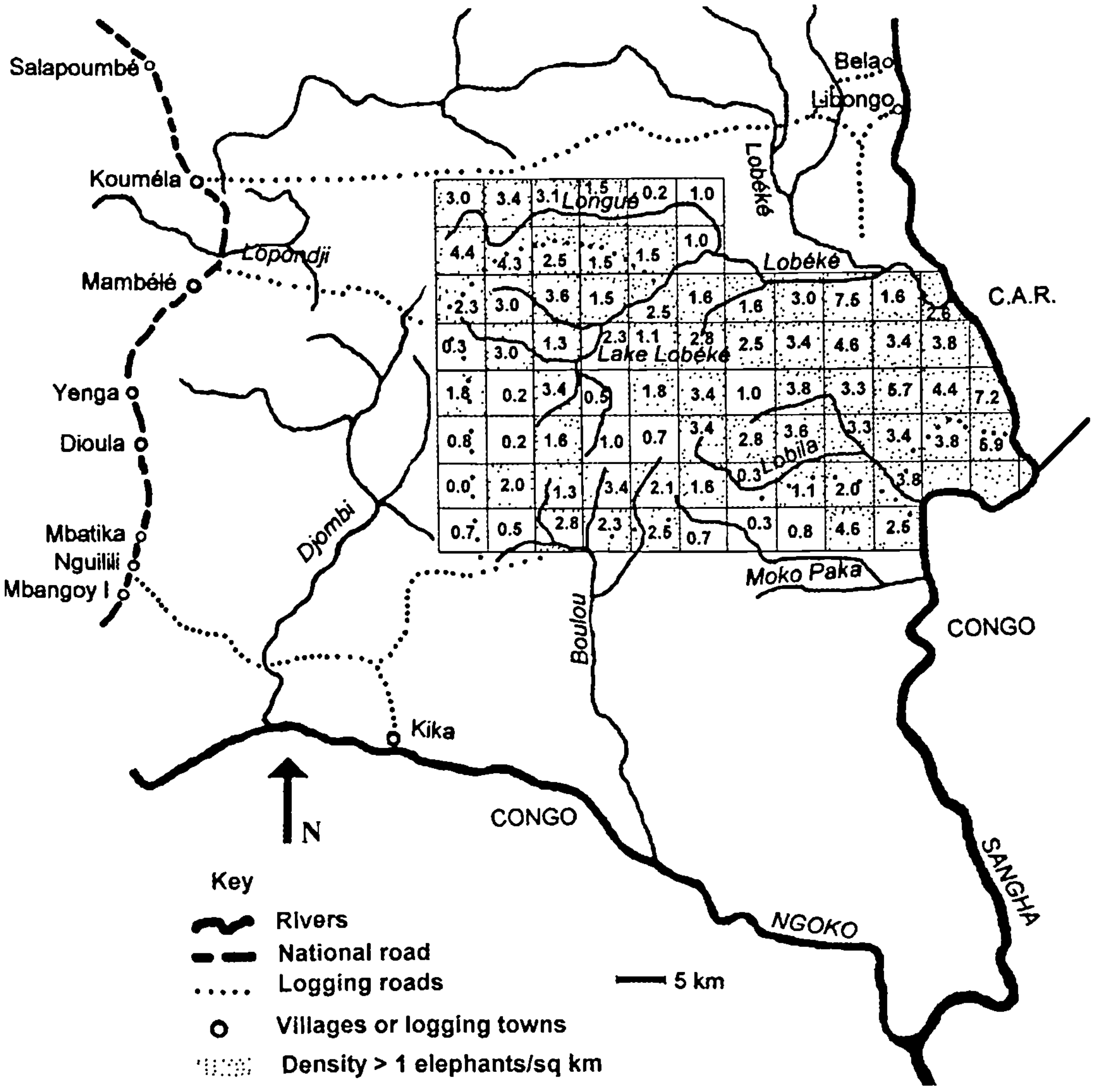


Figure 4-14: The distribution of elephant densities km^{-2} in the Lobeke forest during the short rainy season and the short dry season.

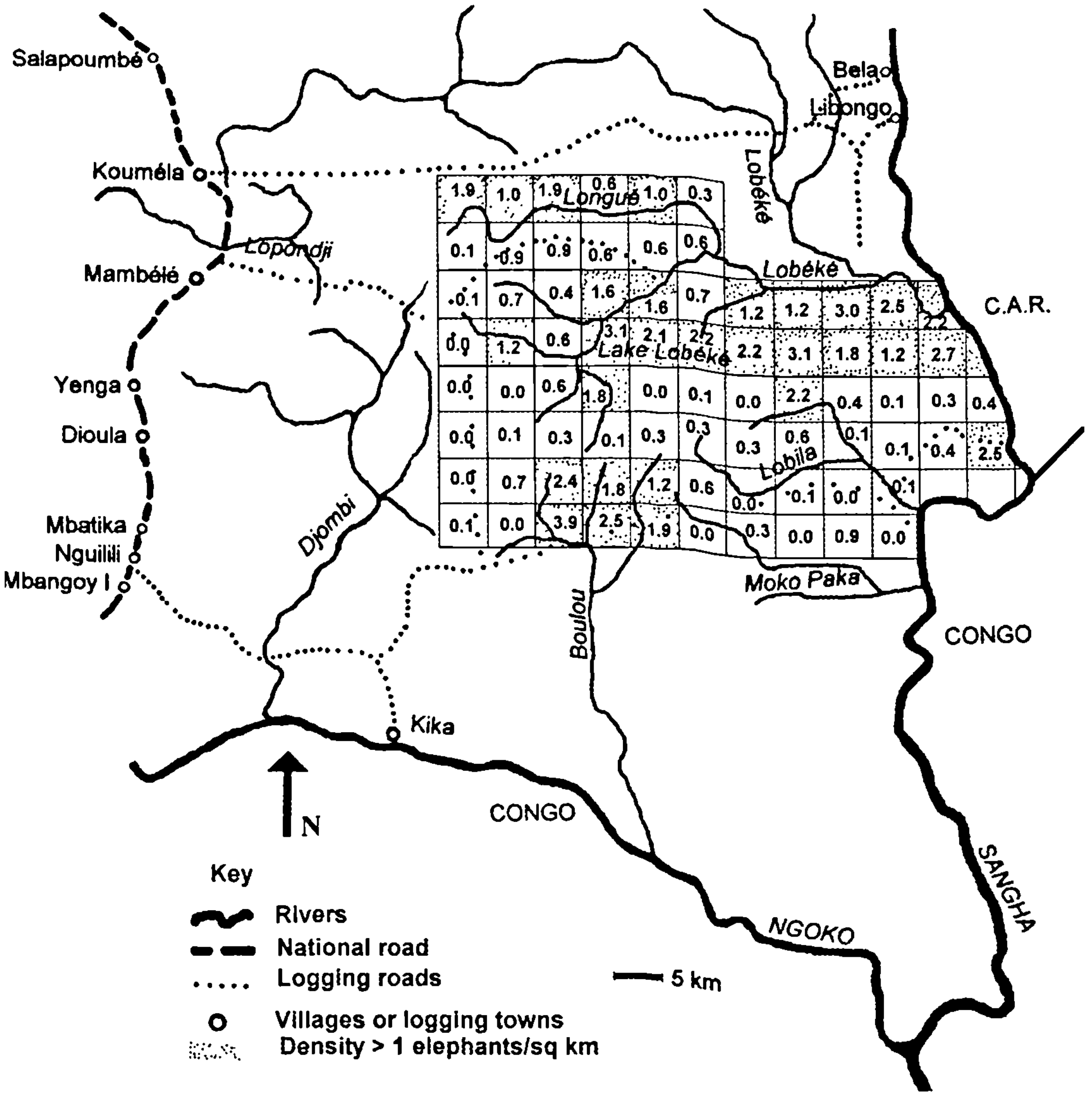


Figure 4-15: The distribution of elephant densities km^{-2} in the Lobeke forest during the long rainy season.

A) The distribution of elephants in relation to the distance from the main highway over a seasonal cycle.

The results of the regression analysis between elephant density and the distance to the main highway over the three surveys are presented in **Table 4-10** and the fitted regression lines are shown in **Figure 4-16, Figure 4-17** and **Figure 4-18**.

Table 4-10: Regression analysis between elephant densities and the distance from the main highway over the three surveys.

Period	*F*-value (d. f. = 1, 76)	*P*
January-March 1993	0.03	NS
May-August 1993	18.36	< 0.0001
November 1993	0.35	NS

The regression analysis suggests a significant positive correlation of elephant densities in relation to distance from the main highway only during the period of May-August 1993 that corresponds to the short rainy season and short dry season. The elephant density increased with the distance from the main highway (**Figure 4-17**).

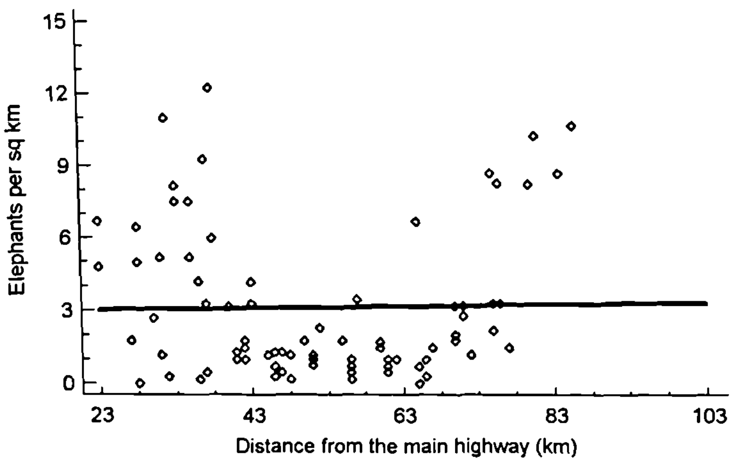


Figure 4-16: Fitted regression line of elephant density and distance from the main highway for January-March 1993 survey.

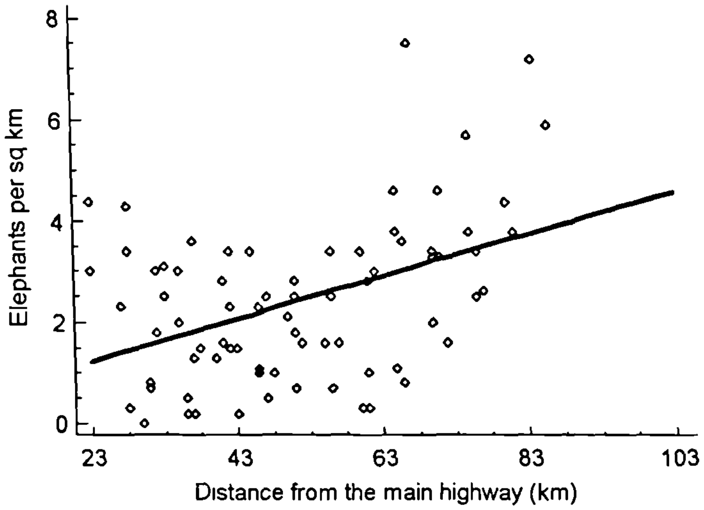


Figure 4-17: Fitted regression line of elephant density and distance from the main highway for May-August 1993 survey.

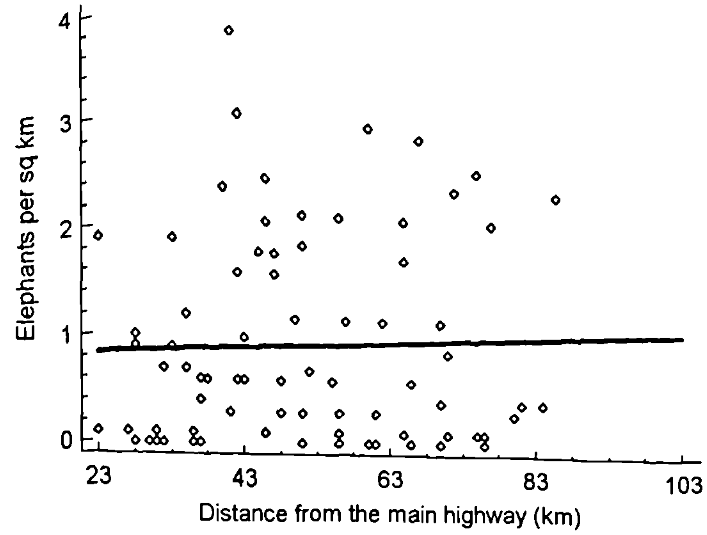


Figure 4-18: Fitted regression line of elephant density and distance from the main highway for November 1993 survey.

B) The distribution of elephants in relation to the distance from the Sangha river over a seasonal cycle.

The results of the regression analysis between elephant density and the distance to the Sangha river over the three surveys are presented in **Table 4-11** and the fitted regression lines are shown in **Figure 4-19, Figure 4-20** and **Figure 4-21**.

Table 4-11: Regression analysis between elephant densities and the distance from the Sangha river over the three surveys.

Period	*F*-value (d. f. = 1, 76)	*P*
January-March 1993	1.44	NS
May-August 1993	17.84	< 0.001
November 1993	1.68	NS

Human activities (fishing, transport of logs downstream) are concentrated along the Sangha river which is an important navigable river. The regression analysis showed a significant negative correlation of elephant densities in relation to distance from the Sangha river only during the short rainy season and short dry season (May-August

1993) (**Figure 4-20**). The density of elephants decreased with the increase of the distance from the Sangha river.

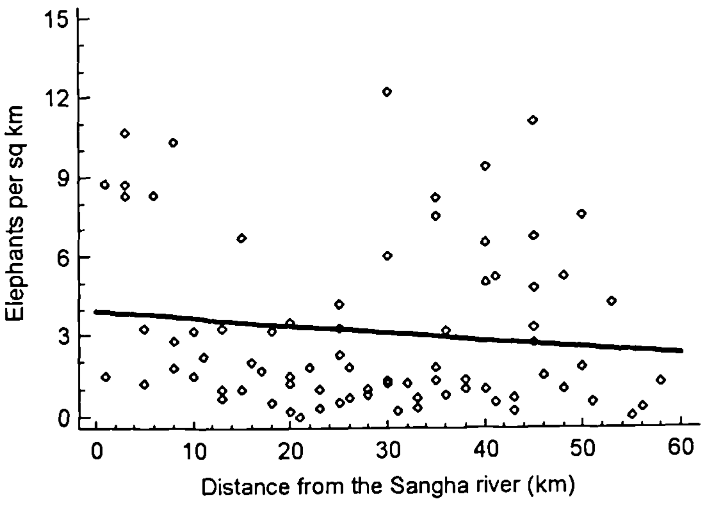


Figure 4-19: Fitted regression line of elephant density and distance from the Sangha river for January-March 1993 survey.

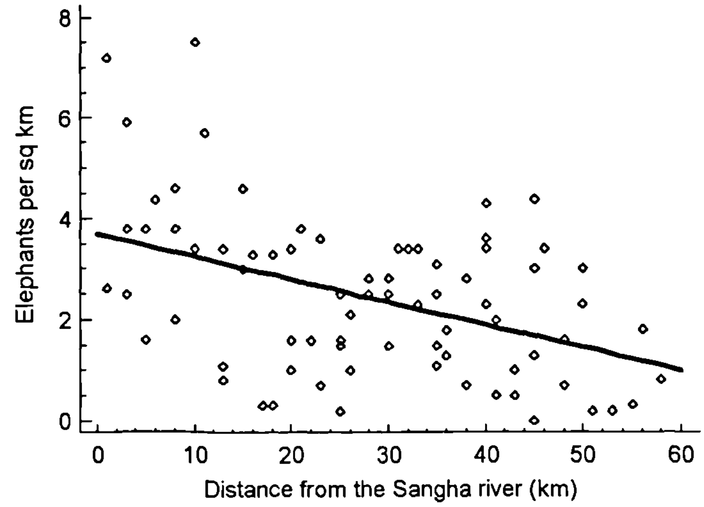


Figure 4-20: Fitted regression line of elephant density and distance from the Sangha river for May-August 1993 survey.

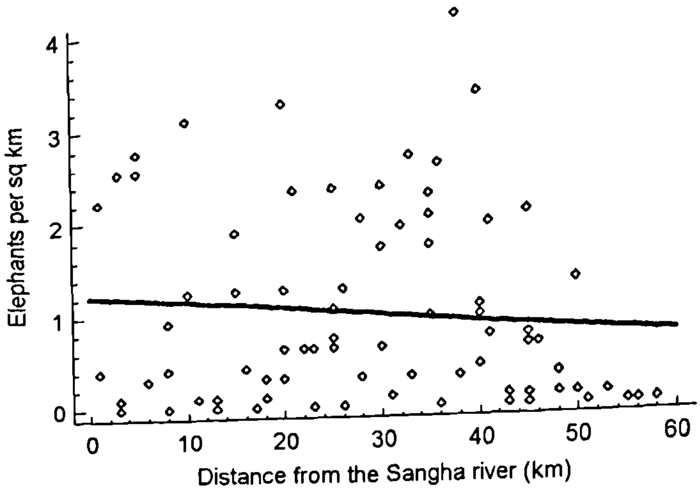


Figure 4-21: Fitted regression line of elephant density and distance from the Sangha river for November 1993 survey.

C) The distribution of elephants in relation to the distance from the nearest village over a seasonal cycle.

The results of the regression analysis between elephant density and the distance to the nearest village over the three surveys are presented in **Table 4-12** and the fitted regression lines are shown in **Figure 4-22**, **Figure 4-23** and **Figure 4-24**.

Table 4-12: Regression analysis between elephant densities and the distance from the nearest village over the three surveys.

Period	*F*-value (d. f. = 1, 76)	*P*
January-March 1993	3.82	NS
May-August 1993	19.62	< 0.0001
November 1993	0.05	NS

The regression analysis showed a significant negative correlation of elephant densities in relation to distance from the nearest village during the short rainy season and short dry season (May-August 1993) (**Figure 4-23**). The density of elephants decreased with the increase of the distance from the nearest village.

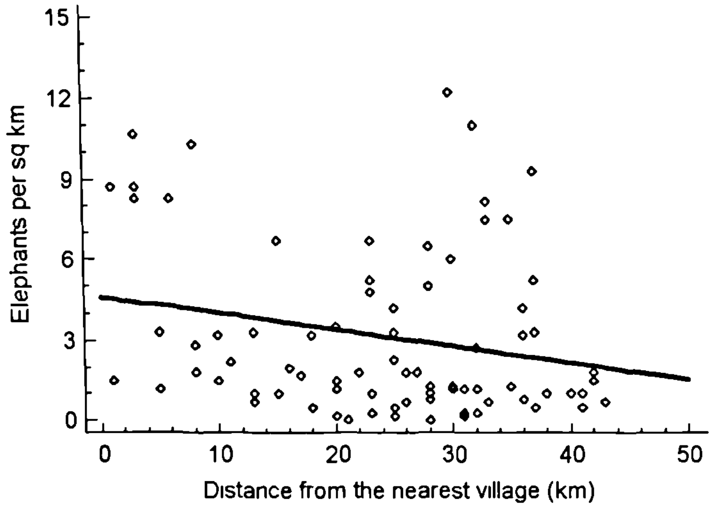


Figure 4-22: Fitted regression line of elephant density and distance from the nearest village for January-March 1993 survey.

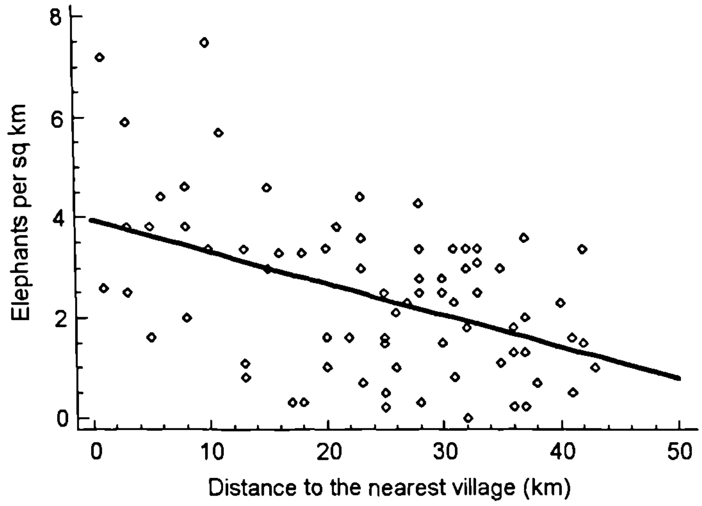


Figure 4-23: Fitted regression line of elephant density and distance from the nearest village for May-August 1993 survey.

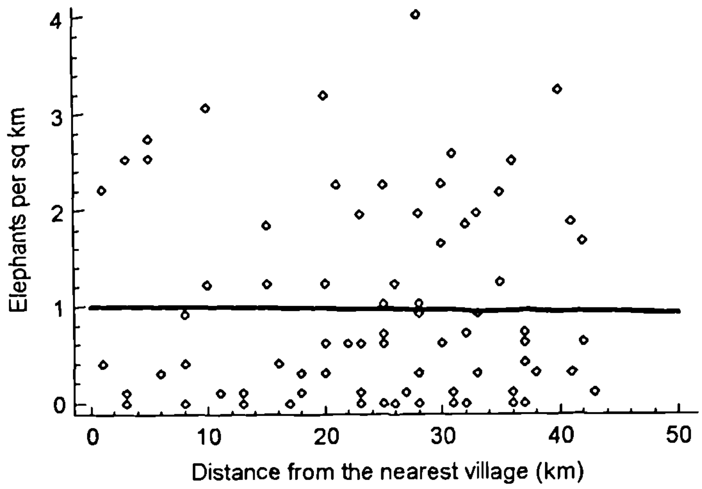


Figure 4-24: Fitted regression line of elephant density and distance from the nearest village for November 1993.

D) The distribution of elephants in relation to the distance from the nearest logging road in use over a seasonal cycle.

The results of the regression analysis between elephant density and the distance to the nearest logging road in use over the three surveys are presented in **Table 4-13** and the fitted regression lines are shown in **Figure 4-25**, **Figure 4-26** and **Figure 4-27**.

Table 4-13: Regression analysis between elephant densities and the distance from the nearest logging road in use over the three surveys.

Period	*F*-value (d. f. = 1, 76)	*P*
January-March 1993	0.10	NS
May-August 1993	5.09	< 0.05
November 1993	11.41	< 0.01

In the Lobeke forest, human activities are concentrated along logging roads in use. The regression analysis shows a significant positive correlation of elephant densities in relation to distance from the nearest logging road in use for the periods of May-

August 1993 and November 1993. The elephant density increased with the increase of the distance from logging roads in use (**Figure 4-26** and **Figure 4-27**)

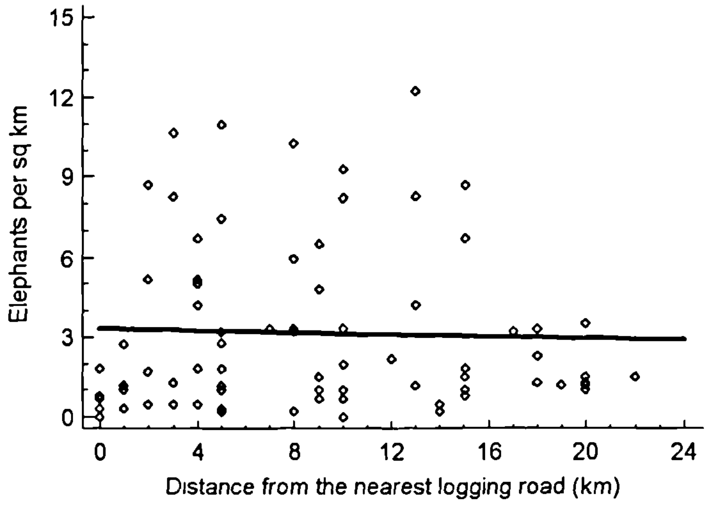


Figure 4-25: Fitted regression line of elephant density and distance from the nearest logging road for January-March 1993 survey.

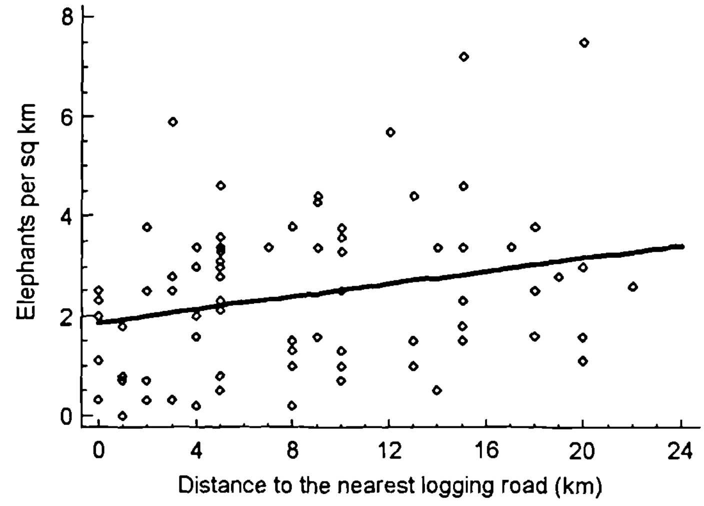


Figure 4-26: Fitted regression line of elephant density and distance from the nearest logging road for May-August 1993 survey.

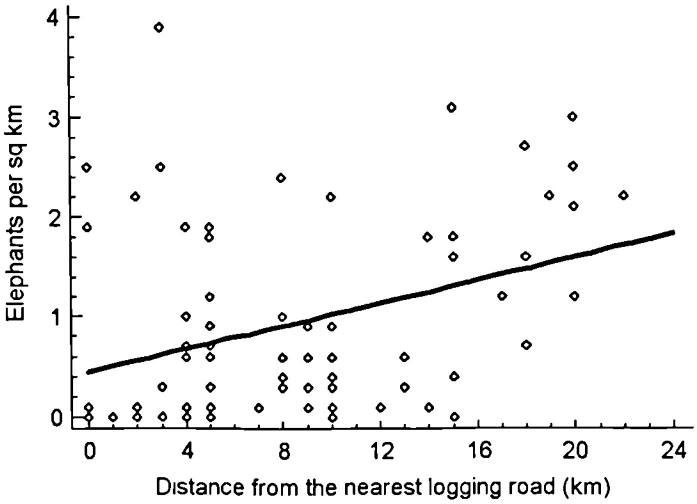


Figure 4-27: Fitted regression line of elephant density and distance from the nearest logging road for November 1993 survey.

E) The distribution of elephants in the study area in relation to the environment, human activities over the three surveys (seasonal cycle).

1) January-March 1993

The results of the analysis of variance of the mean elephant density between two groups of cells; one with an environmental factor and the second one without that specific environmental factor for January-March 1993 survey are given in **Table 4-14**.

Table 4-14: Results of the analysis of variance test between the two groups of cells over environmental factors for January-March 1993 survey.

Environmental factor or human activity	Mean elephant density			
	With	Without	F-value (d.f. = 1, 76)	P
Logged forest	3.8	1.9	6.55	< 0.05
Logging road in use	2.2	3.3	1.37	NS
Water	3.2	3.1	0.01	NS
Hills	1.6	3.4	3.06	NS
Swamp	2.6	3.5	1.65	NS
Hunting	3.3	3.1	0.01	NS

These results suggests that the mean elephant density was significantly higher in cells with logged forest than those with primary forest (without logged forest). The presence or absence of logging roads in use, water, hunting signs, hills and swamp in cells do not show a significant variation of elephant density.

2) May-August 1993

The analysis of variance of the mean elephant density between two groups of cells; one with an environmental factor and the second one without that specific environmental factor for May-August 1993 survey are given in **Table 4-15**. This analysis shows that the mean elephant density was significantly higher in cells with no logging road in use. The presence or absence of logged forest, water, hunting signs, hills and swamp in cells do not show a significant variation in elephant density.

Table 4-15: Results of the analysis of variance test between the two groups of cells over environmental factors for May-August 1993 survey.

Environmental factor or human activity	Mean elephant density With	 Without	*F*-value (d.f. = 1, 76)	P
Logged forest	2.41	2.44	0.01	NS
Logging road in use	1.6	2.6	4.09	<0.05
Water	2.5	2.3	0.21	NS
Hills	2.5	2.4	0.01	NS
Swamp	2.0	2.7	3.53	NS
Hunting	1.3	2.5	2.26	NS

3) November 1993

The analysis of variance of the mean elephant density between two groups of cells; one with an environmental factor and the second one without that specific environmental factor for November 1993 survey are given in **Table 4-16**. During this period, the results do not show a significant variation of elephant density in relation to environment factors including human activities.

Table 4-16: Analysis of variance test between the two groups of cells over environmental factors for November 1993 survey.

Environmental factor or human activity	Mean elephant density With	 Without	*F*-value (d.f. = 1, 76)	P
Logged forest	0.8	1.2	3.59	NS
Logging road in use	0.5	1.0	3.58	NS
Water	0.9	1.0	0.33	NS
Hills	1.3	0.9	1.86	NS
Swamp	1.0	0.9	0.46	NS
Hunting	0.3	1.0	1.99	NS

4.1.2 Crop raiding

Three hundred and ninety households (226 Baka households and 164 Bangando households) were interviewed. All farmers complained about crop-raiding. A total number of 972 "complaints" were recorded. Ten species were identified as crop-raiders. Three species were mentioned most often as the most destructive and/or persistently present in farms. These were monkey, gorilla and the brush-tailed porcupine. Primates appeared to be the most frequent raiders (about two-third of the complaints registered). **Table 4-17** presents the number of complaints (*C*) recorded for each species as well as the impact (*I*) on the agriculture. Banana (*Musa sp*), cassava (*Manihot esculenta*) and maize (*Zea mays*) appeared to be the crops most attractive to raiders. Compared to other species, crop raiding in cultivated fields and gardens by elephants in the Lobeke area (< 1% of the total number of complaints) are of negligible importance. Raids appeared restricted to two logging towns; Kika in the south-west and Libongo in the north-east (**Figure 4-28**), and occurred more often during the rainy season.

Table 4-17: Crop raiding species in the Lobeke forest (*C* = number of complaints recorded; *I* = impact on the agriculture).

Species	*C*	*I*
Monkey (*Cercocebus spp, Cercopithecus spp*)	374	38.5
Gorilla (*Gorilla gorilla*)	290	29.8
Porcupine (*Atherurus africanus*)	198	20.4
Cane rat (*Thryonomys spp*)	86	8.9
Francolin (*Francolinus spp*)	9	0.9
Elephant (*Loxodonta africana*)	6	0.6
Duiker (*Cephalophus spp*)	4	0.4
Rat (*Cricetornomys spp*)	3	0.3
Sitatunga (*Tragelaphus spekei*)	1	0.1
Chimpanzee (*Pan troglodytes*)	1	0.1

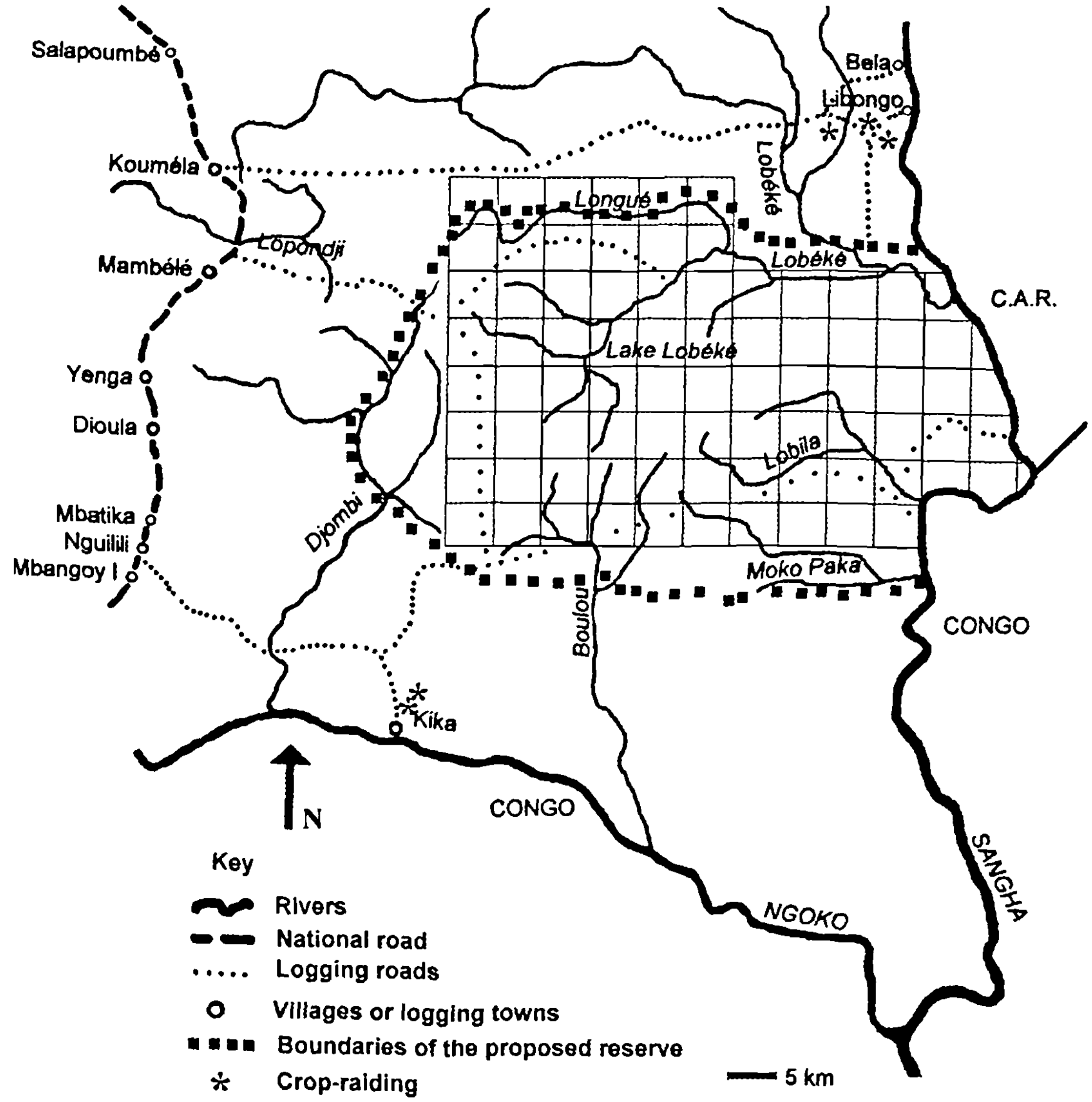


Figure 4-28: Map showing areas were crop-raiding by elephants were recorded.

4.1.3 Elephant movements

There were no reports of crop depredation by elephants in the eastern part the Lobeke proposed reserve. This observation suggests that elephant do not go far beyond the Djombi river (**Figure 4-28**) where indigenous peoples farm. The crop-depredation results suggest northern and southern movements. The estimates of the Lobeke forest dwelling elephant population (**Table 4-9**) suggest that about 68% (n = 6,588) of the long dry season's population (January-March 1993 survey) leave the area by the end of the rainy season (November 1993). **Figure 4-29** and **Figure 4-30** show the sign (positive or negative) of the variation of elephant density in each cell over the surveys. They also show a gradual move of positive signs (increase of elephant density) toward the centre of the forest.

Two types of movements could therefore be observed: The first one was directed toward the Centre of the Lobeke forest and the second out of the area. Movements towards neigbouring countries (Congo and Central African Republic) were also reported (M. Agnagna, personal communication).

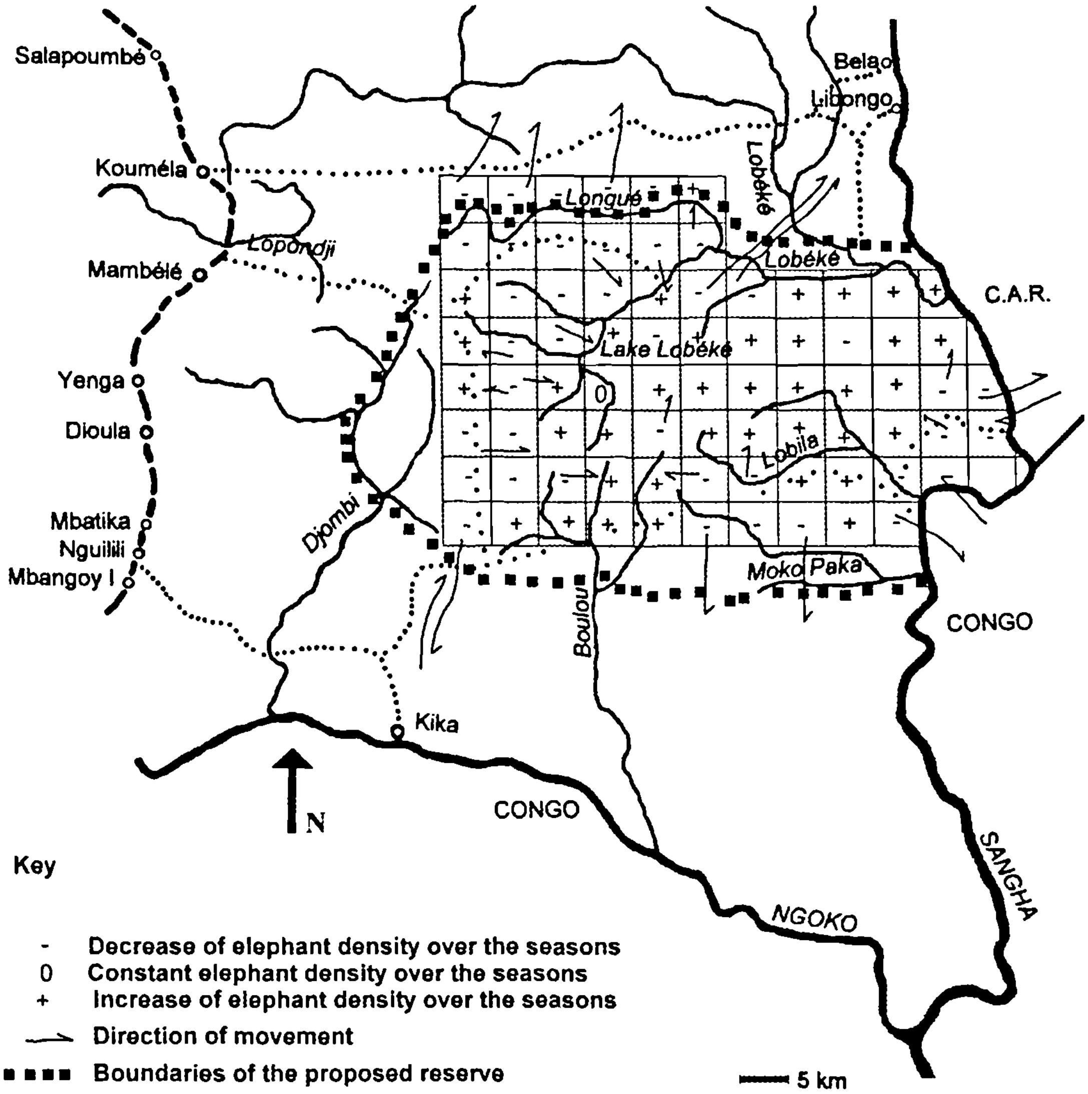


Figure 4-29: Movement of elephants from March to August 1993 in the Lobeke forest.

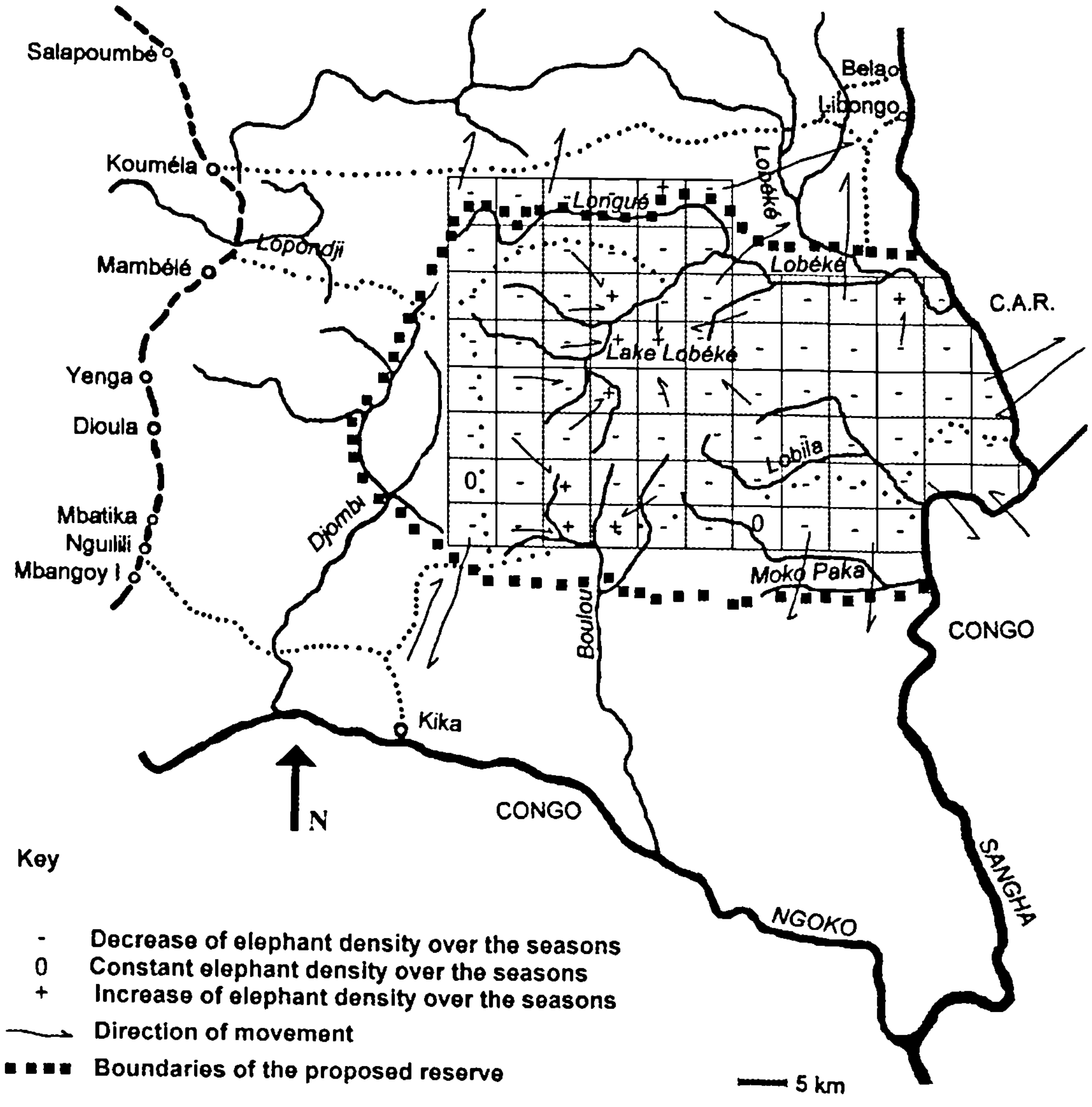


Figure 4-30: Elephant movements from September to November 1993 in the Lobeke forest.

4.1.4 Structure and population dynamics

1) Age structure

The percentage of each of the three classes in the sample of 178 individuals personally observed during all surveys in the Lobeke forest is given in **Table 4-18**.

Table 4-18: Age structure of elephants in the Lobeke forest

Age Class	Total number of individuals	Percentage
Adults	128	72
Immature	25	14
Calves of less than one year old	25	14
Total	178	100

2) Sex ratio

The total number of adult individuals observed and sexed was 128. Of these, 61 were males and 67 females, resulting in a ratio of one female to 0.9 male. The Chi-squared test suggests that the ratio 61 67 is not significantly different from the ratio 50:50 ($\chi^2 = 0.123$, d.f = 1, NS)

3) Females and calves of less than one year old

The were 25 individuals recorded as less than one year age old. The total number of adult females observed was 67 This produces a ratio of one female to 0.4 calf of less than one year old.

4) Calves of less than one year old

The percentage of individuals the less than one year old was 14% (n = 178).

4.1.5 Social structure

1) Size of social groups

Table 4-19 presents the results of 82 observations for a total number of 202 individuals. Groups of less than 5 individuals represent 91% of all the observations and groups of solitary elephants, 44%. The mean group size was 2.5 ± 0.55 individuals, increasing to 3.6 ± 0.84 if lone individuals were excluded. Small group sizes seemed to characterise the social structure of elephants in the Lobeke forest.

Table 4-19: Social group size of elephants observed in the Lobeke forest.

Number of individuals	Number of observations	Percentage
1	36	44
2	20	24
3	15	18
4	3	4
5	1	1
6	2	2
7	1	1
8	2	2
11	1	1
18	1	1

2) Characteristic of solitary individuals

The number of solitary individuals sexed was 35. Of these, 32 were males and 3 females These results suggest a high frequency of males (91%) among solitary individuals.

4.1.6 Daily activities

A total of 182 observations were recorded on the ethology of elephants during the morning period. The principal activity was feeding (67 %) followed by digging (22%) and walking (10%). Drinking represents only 1% of the observations during this period. For the noon period, 46 observations were recorded. Feeding was still the main activity (56%) followed by digging (28%) and standing (9%). For the evening period, 47 observations were recorded. Of these, 60% were feeding activities followed by walking (17°o) and digging (17%). Drinking, standing and lying down represent each 2% of the total number of observations. The results are shown in **Figure 4-31**.

For a total number of observations of 275 for the whole research period, feeding represent 64% followed by digging (23%) and walking (10%). Few standing (2%) and drinking (1%) observations were made. Elephants were scarcely seen laying down (< 1%) (**Figure 4-32**). No observations were made of breeding, birth, death or other behavioural activities.

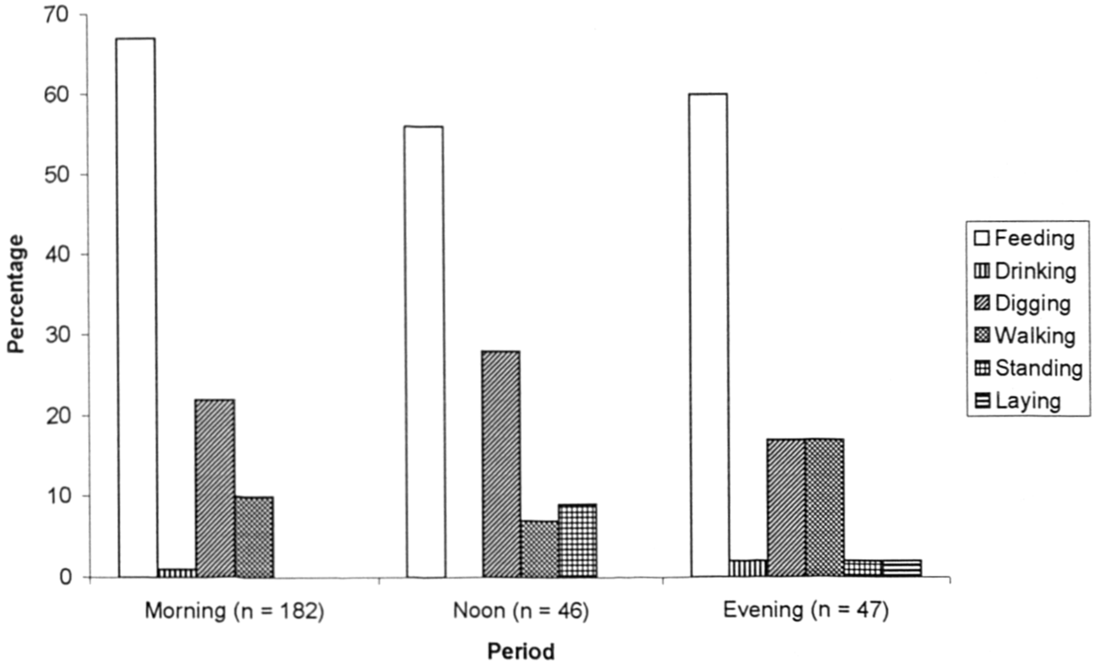


Figure 4-31: Elephant daily activities in the Lobeke forest broken down into periods of observations.

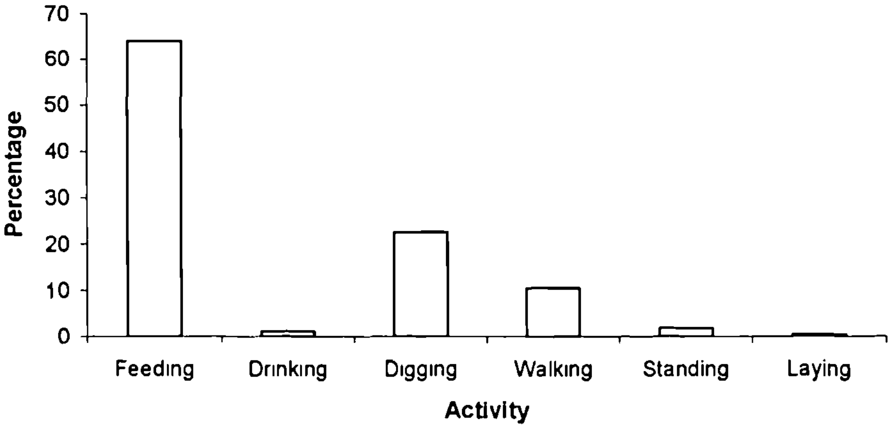


Figure 4-32: Total Elephant daily activities for the whole survey period.

4.1.7 Diet

For the study of the feeding behaviour of elephants in the Lobeke forest, 274 observations were recorded The results (**Table 4-20**) show that they feed on bark, leaves, tubers, roots and fruits. Thirty-three species belonging to 23 different families were identified as being eaten by elephants. *Triplochiton scleroxylon* is the most used species (26⁰ o) followed by *Ataenida conferta* (16%) and *Dioscora spp* (10%).

4.1.7.1 Seasonal variation of diet and preference index

1) Wet period (long and short rainy seasons)

For the wet period, 98 observations were recorded. An electivity index (Ei) was calculated for the 27 species eaten during that period by elephants (**Table 4-21**). The data suggest 16 of them as preferred food items; fruits of *Irvingia gabonensis* (Ei = 0.79), *Detarium macrocarpum* (Ei = 0.79) and *Picralima nitida* (Ei = 0.73) being the most preferred.

2) Dry period (long and short dry seasons)

Twenty-two species were identified for a total number of 176 observations during the dry period. The data (**Table 4-22**) suggest 7 preferred species with leaves of *Ataenida conferta* (Ei = 0.71), barks of *Triplochiton scleroxylon* (Ei = 0.50) and tubers of *Dioscorea spp* (Ei = 0.50) as the most preferred.

These data suggest a difference in one aspect: the evenness of the diet. That is in the dry period, three species made up a large proportion of the diet (leaves of *Ataenida conferta*, barks of *Triplochiton scleroxylon* and *Dioscorea spp.* make up 66% of the observations), while in the wet period, there was a more even spread across species during the dry period (the top three species make up only 41% of the observations).

Table 4-20: The diet of elephants in the Lobeke forest

Species	Family	N	r_i	Parts eaten
Triplochiton scleroxylon	Sterculiaceae	71	26	barks
Ataenida conferta	Marantaceae	43	16	leaves
Dioscorea spp	Dioscoreaceae	27	10	tubers
Combretodendron macrocarpum	Lecythidaceae	17	6	barks
Anonidium mannii	Annonaceae	16	6	barks
Desplatsia milbraedii	Tiliaceae	16	6	barks, fruits
Duboscia spp	Tiliaceae	13	5	fruits
Ceiba pentandra	Bombaceae	9	3	barks, roots
Panda oleosa	Pandaceae	6	2	barks, fruits
Picralima nitida	Apocynaceae	6	2	fruits
Campylosperma elongatus	Ochnaceae	5	2	leaves, barks
Entandrophragma cylindricum	Meliaceae	5	2	barks
Macaranga spp	Euphorbiaceae	4	1	leaves, barks
Ricinodendron heudelotii	Euphorbiaceae	3	1	barks, fruits
Sterculia tragacantha	Sterculiaceae	3	1	barks, fruits
Strombosiopsis tetrandra	Olacaceae	3	1	barks, fruits
Albizia glaberrina	Mimosaceae	2	1	fruits
Donella ubanguiensis	Sapotaceae	2	1	barks
Fagara spp	Rutaceae	2	1	leaves
Fernandoa spp	Bignoniaceae	2	1	barks, fruits
Gambeya lacourtiana	Sapotaceae	2	1	barks, fruits
Irvingia gabonensis	Irvingiaceae	2	1	fruits
Irvingia grandifolia	Irvingiaceae	2	1	fruits
Pausinystalia macroceras	Rubiaceae	2	1	barks
Xylopia spp	Annonaceae	2	1	barks, fruits
Afromomum spp	Zingiberaceae	1	< 1	leaves
Detarium macrocarpum	Cesalpiniaceae	1	< 1	fruits, barks
Breviea leptosperma	Sapotaceae	1	< 1	barks
Grossera macarantha	Euphorbiaceae	1	< 1	leaves, barks
Klainedoxa microphylla	Irvingiaceae	1	< 1	barks, fruits
Pterocarpus soyauxii	Fabaceae	1	< 1	barks
Rauvofolia macrophylla	Apocynaceae	1	< 1	leaves
Rinorea spp	Violaceae	1	< 1	leaves

N = Number of observations
r_i = Percentage in the diet

Table 4-21: Diet of elephants during the wet period (n = 98)

Species	r_i	n_i	Electivity index
Irvingia gabonensis	2.04	0.24	0.79
Detarium macrocarpum	2.04	0.24	0.79
Picralima nitida	6.12	0.95	0.73
Irvingia grandifolia	2.04	0.48	0.62
Rinorea spp	1.02	0.24	0.62
Pterocarpus soyauxii	1.02	0.24	0.62
Breviea leptosperma	1.02	0.24	0.62
Campylosperma elongatus	5.10	1.43	0.56
Xylopia spp	2.04	0.71	0.48
Dioscorea spp	8.16	3.57	0.39
Anonidium manii	16.33	7.86	0.35
Triplochiton scleroxylon	15.31	10.48	0.19
Desplatsia mildbraedii	6.12	5.00	0.10
Entandrophragma cylindricum	2.04	1.67	0.10
Duboscia spp	10.20	8.57	0.09
Donella ubanguiensis	1.02	0.95	0.04
Sterculia tragacantha	2.04	2.38	-0.08
Ataenida conferta	3.06	3.81	-0.11
Pausinystalia macroceras	1.02	1.43	-0.17
Klainedoxa microphylla	1.02	1.43	-0.17
Fagara spp	1.02	1.43	-0.17
Combretodendron macrocarpum	3.06	9.29	-0.50
Gambeya lacourtiana	2.04	6.43	-0.52
Strombosiopsis tetrandra	1.02	3.57	-0.56
Albizia glaberrina	1.02	3.81	-0.58
Ricinodendron heudelotii	2.04	15.95	-0.77
Macaranga spp	1.02	8.81	-0.79

r_i = Percentage in the diet
n_i = Percentage in the Lobeke forest

Table 4-22: Diet of elephants during the dry period (n = 176)

Species	r_i	n_i	Electivity index
Ataenida conferta	22.73	3.84	0.71
Triplochiton scleroxylon	31.82	10.55	0.50
Dioscorea spp	10.80	3.60	0.50
Afromomum spp	0.57	0.24	0.41
Sterculia tragacantha	0.57	0.24	0.41
Desplatsia mildbraedii	5.68	5.04	0.06
Entandrophragma cylindricum	1.70	1.68	0.01
Combretodendron macrocarpum	7.95	9.35	-0.08
Fernandoa spp	1.14	1.44	-0.12
Ceiba pentandra	5.11	7.19	-0.17
Donella ubanguiensis	0.57	0.96	-0.25
Panda oleosa	3.41	6.00	-0.28
Fagara spp	0.57	1.44	-0.43
Pausinystalia macroceras	0.57	1.44	-0.43
Rauvolfia macrophylla	0.57	1.68	-0.49
Strombosiopsis tetrandra	1.14	3.60	-0.52
Duboscia spp	1.70	8.63	-0.67
Macaranga spp	1.70	8.87	-0.68
Albizia glaberrina	0.57	3.84	-0.74
Grossera macarantha	0.57	4.32	-0.77
Ricinodendron heudolotii	0.57	16.07	-0.93

r_i = Percentage in the diet
n_i = Percentage in the Lobeke forest

4.2 Human Ecology

5.2.1 Social organisation

Baka and Bangando are divided into clans (group of people descended from the same ancestor) settled along the main road. These clans are more or less autonomous but they maintain relations (marriages, festivities, visits). A clan is generally headed by a Bangando chief appointed by the National Administration. The land belongs to the community (Baka and Bangando) and each member of the community has the right to exploit it for farming, hunting, fishing, gathering or building (pers. obs.). Baka and Bangando permanent houses are built along the main road. Houses are rectangular, frequently aligned on both sides of the road, generally in a single row. Indigenous peoples build most of their houses with mud and wattle. They use sapling-sized trees as standing poles and raphia (leaf petioles), making a lattice structure that is tied together using canes or other forest climbers. The most common roofing is raphia leaves. Few houses have metal sheets as roofing material and few other walls built with planks or barks of trees.

In the forest, the Baka pygmies always erect their traditional hemispherical (or ovoidal) huts made of a skeleton of flexible branches and covered with leaves of Marantaceae. These herbaceous forest plants are strong, durable, withstand heat and are impermeable, characteristics that contribute to their use. The huts are often arranged in a circular or elliptic ring. These traditional huts are sometimes found along the main road in Baka villages. Bangando hunting huts are rectangular but made with the same material. Baka pygmies and Bangando have dual type of settlements; nomadic and sedentary. During a seasonal cycle, they alternate between bush camps or bush huts dispersed in the forest (short stays) for hunting, gathering and fishing activities and their villages (long stays) along the main road. Bahuchet and Maret (1994) define this phenomenon as a "changing social morphology" during a seasonal cycle. The Bangando are much more affected because, unlike Baka, the whole village do not go hunting or gathering.

The Catholic mission has been active in the area for about half a century. There is a Catholic congregation in each village, although they receive only sporadic visits from church staff.

4.2.2 Demography

For the whole survey of local peoples, 390 persons were interviewed. **Table 4-23** shows the number into each category (men, women, single, married, widow), and tribe.

Table 4-23: The number of informants, their category and tribe.

Category	Baka	Bangando
Men	209	131
Women	17	33
Single	36	21
Married	182	136
Widows	8	7
Total	**226**	**164**

All the informants were above 14 years old. In the Lobeke area, adults of marriageable age are about 18 years for men and about 15 years for women (pers. obs.). This applies for both for Baka and Bangando.

The estimated number households was 452 for Baka and 328 for Bangando. The mean number of persons per household was significantly higher for Bangando (7.2 ± 0.79) than Baka (6 0 ± 0 46) ($t = 2.48$, d.f. = 269, $p < 0.05$). The population of the indigenous peoples in close proximity to the proposed reserve was estimated to be 5,074 ± 335 with 2,712 ± 208 Baka and 2,362 ± 259 Bangando.

The distribution of age groups varies significantly with the tribe ($\chi^2 = 18.392$, d.f. = 5, $p < 0.01$), with more Bangando above 59 years old (**Figure 4-33**).

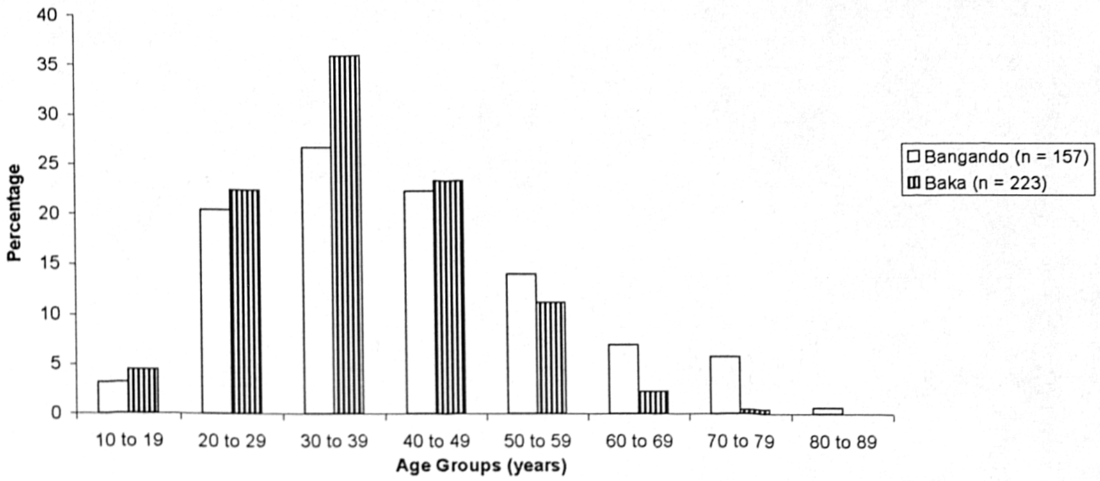


Figure 4-33: The distribution of age groups among Baka and Bangando.

The mean number of spouses per man among the Bangando (1.2 ± 0.14; 95% C.L.) is significantly higher than among the Baka (1.0 ± 0.08; 95% C.L.) (*F* (1, 338) = 5.36, *p* < .05) (**Figure 4-34**).

Figure 4-34: Number of spouses per man.

Monogamy appeared predominant in the area. The proportion of polygamists among married Baka males is 12% (n = 178) and the average number of wives per polygamist is 2.4 ± 0.13 (95% C.L.). The proportion of polygamists among Bangando is 22% (n = 116) and the average number of wives per polygamist is 2.5 ± 0.17 (95% C.L.). These results suggest no significant difference of the mean number of spouses per polygamists between the two tribes (F (1, 44) = 0.25, NS). However, Bangando are more polygamous than Baka ($\chi^2 = 6.131$, d.f. = 1, $p < .05$).

The Bangando have a mean number of 4.4 ± 0.67 (95% C.L.) children per family and the Baka 3.3 ± 0.39 (95% C.L) children per family. These results suggest that the Bangando mean number of children per family is significantly higher than the Baka's (F (1, 388) = 8.40, $p < .05$).

4.2.3 Logging experience

Bangando (40%, n = 131) have more job opportunities in logging companies than Baka (14%, n = 209) ($\chi^2 = 29 580$, d.f. = 1 $p < 0.001$). Both are mainly employed as labourers (unskilled workers) in these lumber companies (**Figure 4-35**) with low salaries varying from US $25 to US $110 per month, but there were more Bangando in the highest salary group (≥ US $80 per month) (**Figure 4-36**).

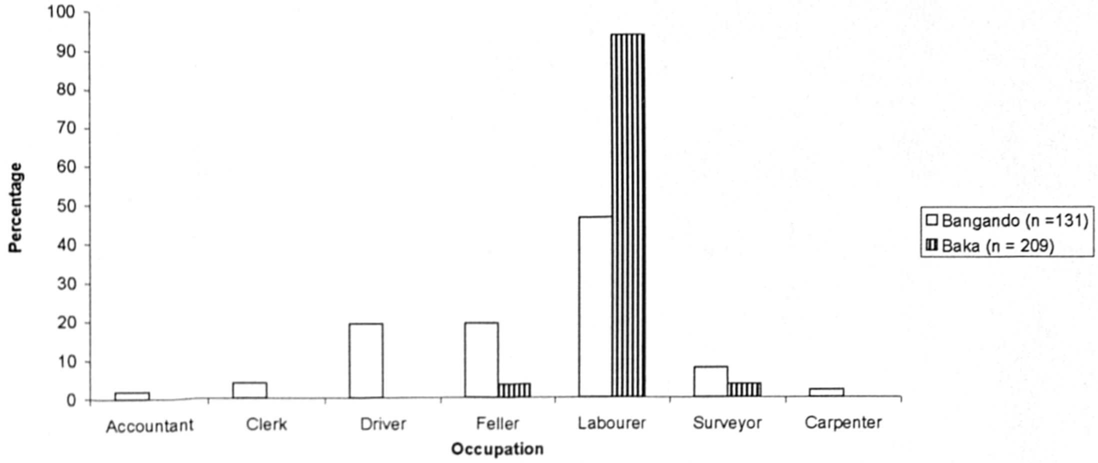


Figure 4-35: Occupations in logging companies.

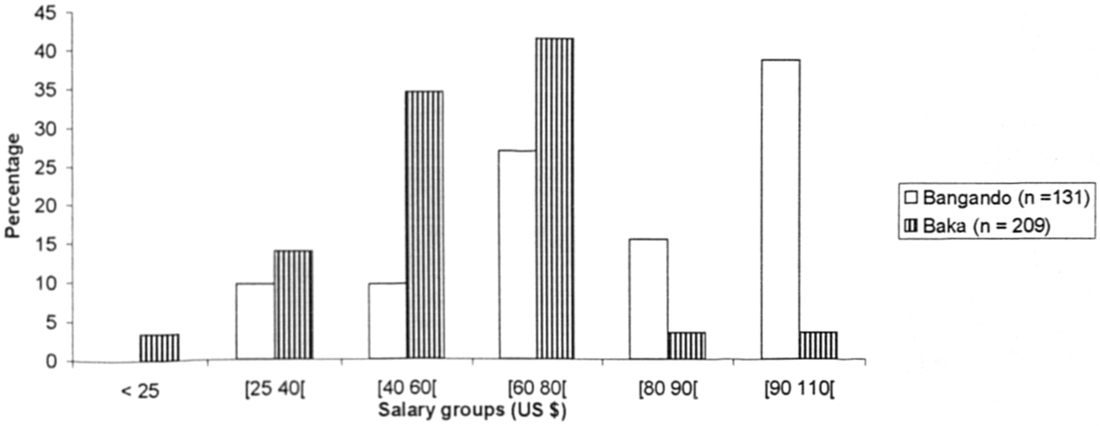


Figure 4-36: Distribution of salary groups (US $ per month).

4.2.4 Importance of the Lobeke forest for the indigenous peoples

There is no permanent settlement in the proposed reserve (**Figure 2-1**). However, the area is visited year round by 25 % (n = 390) people living locally. The highest number of visits is recorded during the long dry season (**Figure 4-37**).

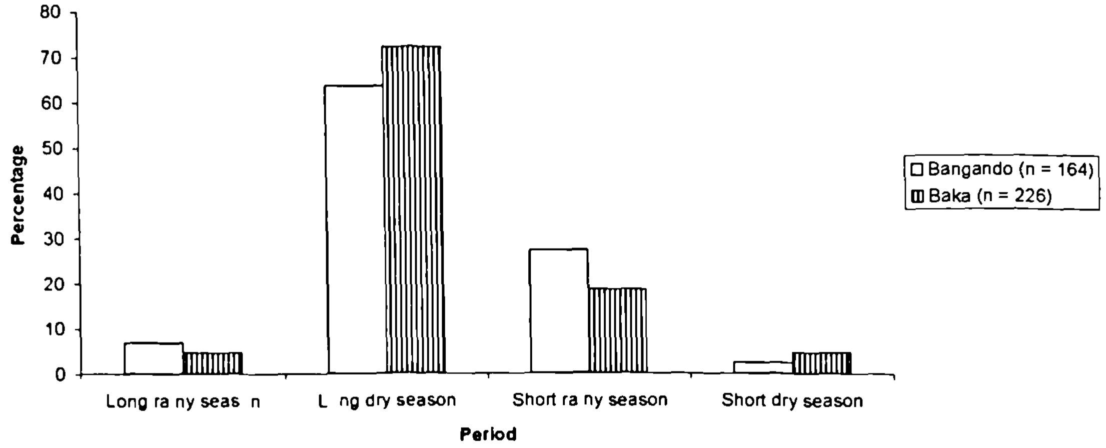


Figure 4-37· The Lobeke forest visiting periods.

There is no significant relationship between a particular tribe (Baka or Bangando) and the use of the area (χ^2 – 0 008, d.f. = 1, NS). Lake Lobeke is visited by 25% of Baka (n = 226) and 23% of Bangando (n = 164).

Although stated reasons for visiting the Lobeke forest are basically the same (hunting, fishing, gathering), their importance varies with the tribe (χ^2 = 15.980, d.f. = 2, $p <$ 0.001). Baka visit the Lobeke forest for gathering, fishing and hunting while the Bangando go there mainly for fishing and hunting (**Figure 4-38**).

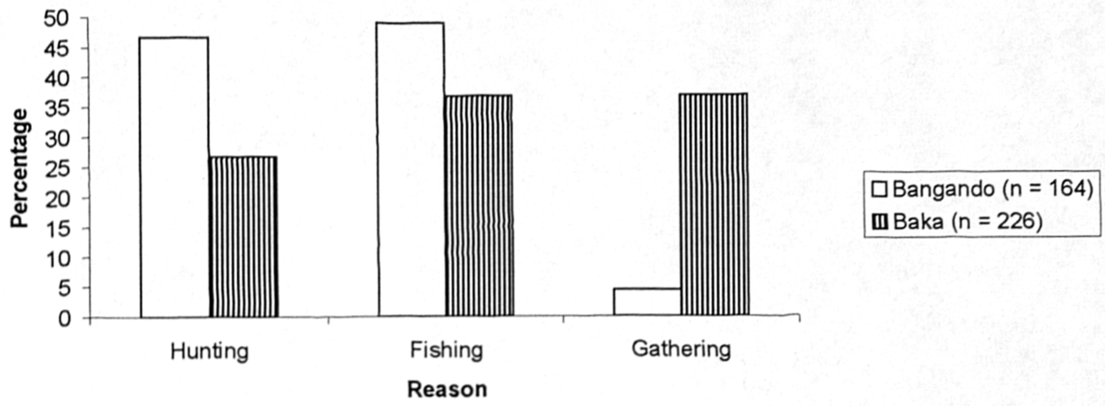


Figure 4-38: Reasons stated for going to the Lobeke forest.

4.2.5 Hunting

Baka (100%, n = 209) do more hunting than Bangando (79%, n = 131) ($\chi^2 = 46.792$, d.f. = 1, $p < 0.001$) but the reasons are the same: Both tribes hunt for food and for sale. The hunting activity that is carried out the year round reaches its peak (hunting season) during the short rainy season (**Figure 4-39**)

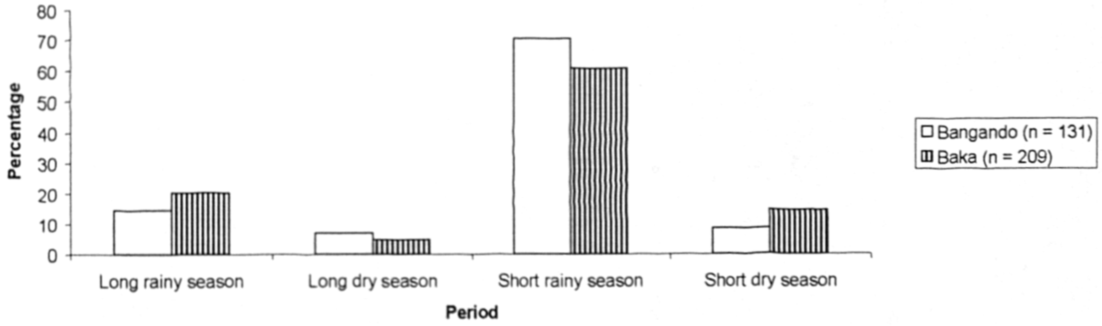


Figure 4-39: Hunting periods in the Lobeke forest.

The space utilisation of the two ethnic groups for hunting activities is not mutually exclusive. However, Baka go hunting deeper in the forest than Bangando (χ^2 = 47.527, d.f. = 4, p < 0.001). **Figure 4-40** shows the distance they walk before they start hunting.

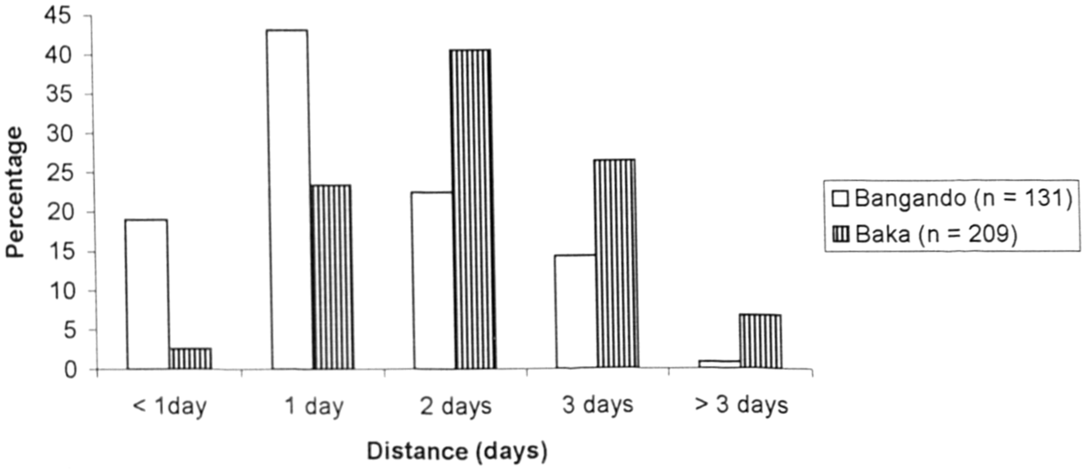


Figure 4-40: Distance walked before start of hunting.

There is no evidence of significant difference among the two tribes (Baka and Bangando) in terms of mean number of catches per hunter (*F* (1, 316) = .04, NS). In other words, they are equally skillful. However, hunting earnings are significantly different between the two tribes (χ^2 = 8.999, d.f. = 2, *p* < .05) (**Figure 4-41**), with 25% (n = 83) of Bangando earning more than US $30 per hunting season against 11% (n = 172) of Baka.

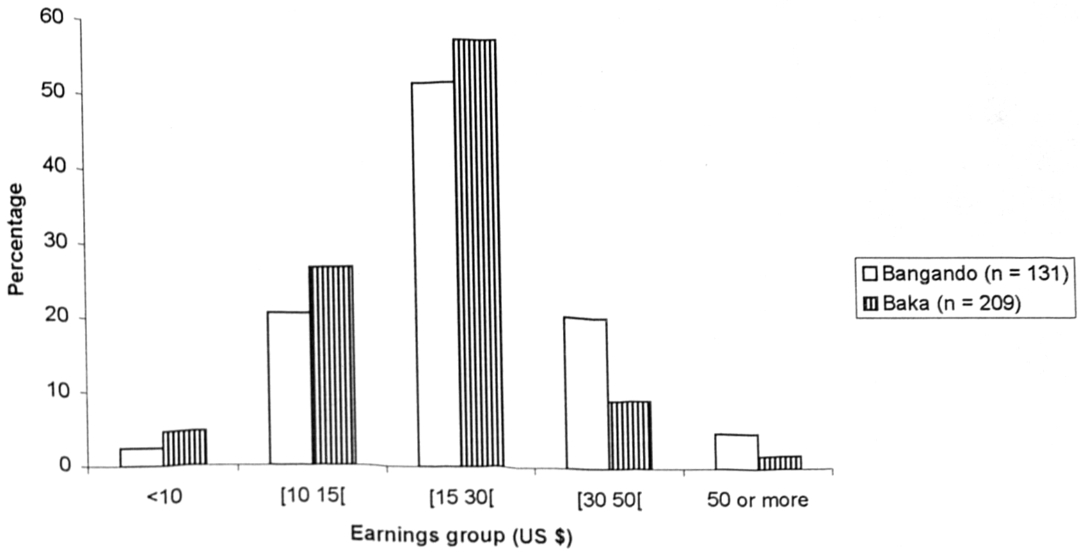


Figure 4-41: Hunting earnings (US $) per hunting season (short rainy season).

Hunting methods includes setting snares for duikers, porcupines, cane rats, bush pigs and giant forest hogs, killing monkeys with crossbow and poisoned arrows, and tracking animals (gorilla, chimpanzees) with spears (Baka) or guns (Bangando and Baka). Basically the same hunting methods are used by both groups. However, there is a significant relationship between the frequency of use of these methods and the tribe (χ^2 = 14.042, d.f. = 3, $p < 0.01$) (**Figure 4-42**). Baka use spears much more while Bangando use guns, cross bow and snares more, although spears are generally used in conjunction with snares Hunting methods are not associated with forest type. Snare , spear, crossbow or gun hunting can take place in primary forest as well as in fallow land (or secondary forest). Among the four methods used in the Lobeke forest, snare hunting appears to the most commonly used (**Figure 4-42**).

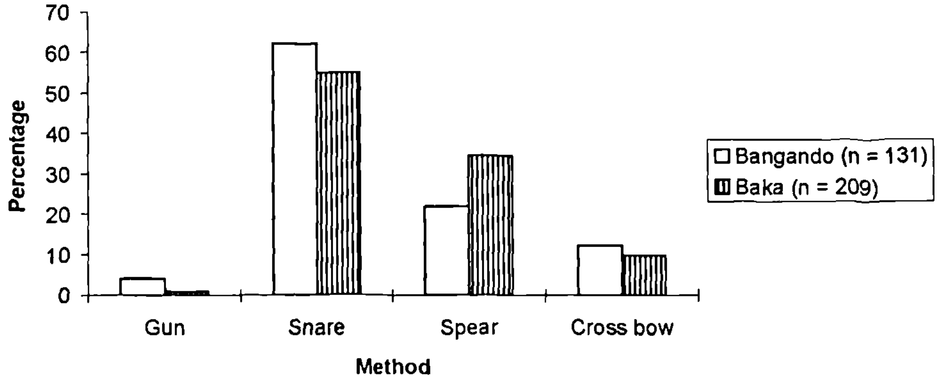


Figure 4-42: Hunting methods in the Lobeke forest.

For Bangando, hunting is generally individual but, 2 to 4 persons can share a hunting hut. Some go hunting with their wives, rarely with children. For the Baka, the whole village go hunting but, each man sets his own snares. Baka and sometimes Bangando women accompany their husband when they go visiting snares to help carrying the catches. Snares are visited in the morning. The biggest part of the catches is taken to the road (main road or logging road) for sale. It can also be smoked if the hunting camp is located deep in the forest. Catches can be sold entirely (if the hunting camp is close to a road) or cut into pieces

Table 4-24 lists the major species caught by Baka and Bangando. The relative number of catches appears very similar for both Baka and Bangando hunters. This table also shows that the species caught are the most common in the Lobeke forest (Stromayer & Ekobo, 1991). Large mammals such as buffalo, gorilla, chimpanzee, leopard are poorly represented in that table because they are scarcely killed in snare hunting that is the most used hunting technique. Cane rats are also poorly represented because they are more common in secondary forest (close to villages) than deep in forest where much hunting takes place.

Table 4-24: Major species caught and percentage for each ethnic group (n = 860).

	Ethnic group	
Species caught	Baka	Bangando
Duikers (*Cephalophus spp)*	38	35
Porcupine (*Atherurus africanus)*	23	21
Guinea Fowl (*Phasidus niger, Guttera edouardi)*	10	12
Suidae (*Potamochoerus porcus, Hylochoerus meinertzhageni*)	9	12
Francolin (*Francolinus lathami*)	5	9
Monkeys (*Cercopithecus spp, Colobus guereza*)	5	4
Bongo (*Tragelaphus scriptus*)	5	3
Cane rats (*Thryonomys spp)*	2	1
Gorilla (*Gorilla gorilla*)	2	1
Buffalo (*Syncerus caffer nanus*)	1	1
Leopard (*Panthera pardus*)	< 1	1
Chimpanzee (*Pan troglodytes)*	0	< 1

4.2.6 Food restriction

Each Bangando clan and some Baka groups have a specific animal which the members do not eat throughout their life (**Table 4-25**). They believe those animals were closely related to their ancestors but they do not perform any special ritual with them. The animals can sold or touched when caught in snares. These animals are totem (taboo) that identify each clan Some clans have only one species as totem; other extend it to any related species Those who have gorilla as totem will extend it to monkeys and chimpanzees. In the Lobeke forest, food restriction is a more significant socio-cultural factor for Bangando than Baka (χ^2 = 221.806, d.f. = 1, $p < 0.001$). Only 3% of Baka (n = 226) against 74°o of Bangando (n = 164) observe any food restriction. Among Bangando, themselves, this restriction is mainly observed by men than women (χ^2 = 6.867, d.f = 1, $p < .05$).

Both Baka and Bangando avoid eating only two species of animals in a certain period of their life. Adult men and women that are still able to procreate do not eat Bates's pygmy antelope (*Neotragus batesi*) and Bongo (*Tragelaphus euryceros*). They believe that those two species will cause an illness (epilepsy, fever) to the future child. Those two species are therefore dangerous only in a particular period of life cycle. For women, this period goes from the puberty to the menopause. It is not easy to set the upper limit of that period for men as it extends from the puberty to when the individual himself thinks that he is no more sexually active.

Table 4-25: List of Taboo species (or family) in both tribes (for Baka, the number of informants n= 226 and for Bangando, the number of informants n = 164) and percentage of the population that observe it.

	Ethnic group	
Taboo species or family	Baka (%)	Bangando (%)
Monkey (Papiinae and Galaginae)	20	28.79
Gorilla (*Gorilla gorilla*)	0	19.7
Monitor lizard (*Varanus spp*)	0	12.12
Leopard (*Panthera pardus*)	40	6.06
Tortoise (*Geochelone spp*)	20	5.3
Suidae	20	4.55
Buffalo (*Syncerus caffer nanus)*	0	4.55
Falconidae	0	3.79
Bates antelope (*Neotragus batesi*)	0	3.03
Yellow-backed duiker (*Cephalophus sylvicultor*)	0	3
Bongo (*Tragelaphus scriptus*)	0	2.27
Elephant	0	1.52
Sitatunga (*Tragelaphus spekei)*	0	1.52
Francolin (*Francolinus spp*)	0	0.76
Crocodile (*Crocodilus spp*)	0	0.76
Chimpanzee (*Pan troglodytes*)	0	0.76
African civet (*Viverra civetta*)	0	0.76
Genet (*Genetta spp*)	0	0.76

NOTE. Species that are taboo for both Baka and Bangando are shaded.

4.2.7 Gathering

Gathering takes place close to villages in fallow lands as well as deep into the forest (**Figure 4-43**).

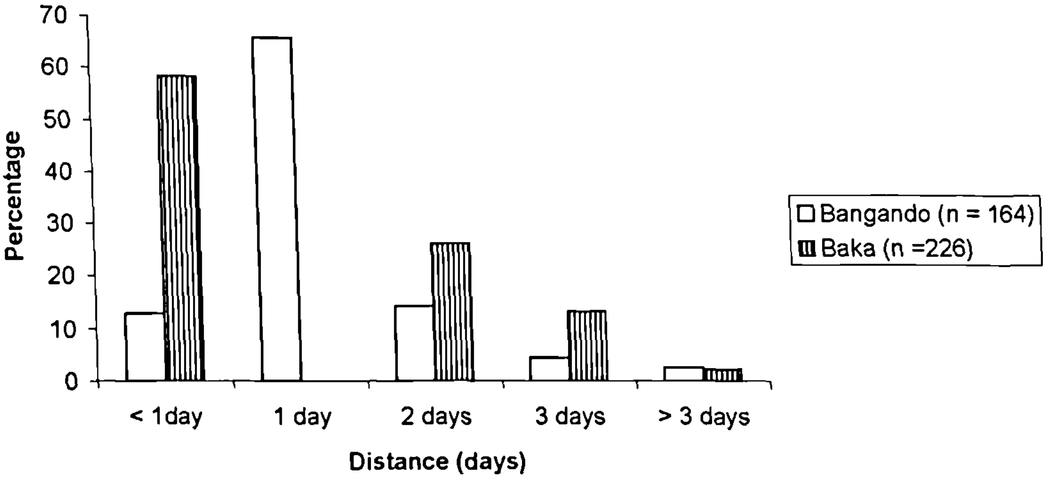


Figure 4-43 Distance walked before start of gathering.

Gathering activity is much more intense during the short dry season (**Figure 4-44**) which corresponds to the fruiting season of bush mangoes (*Irvingia gabonensis*).

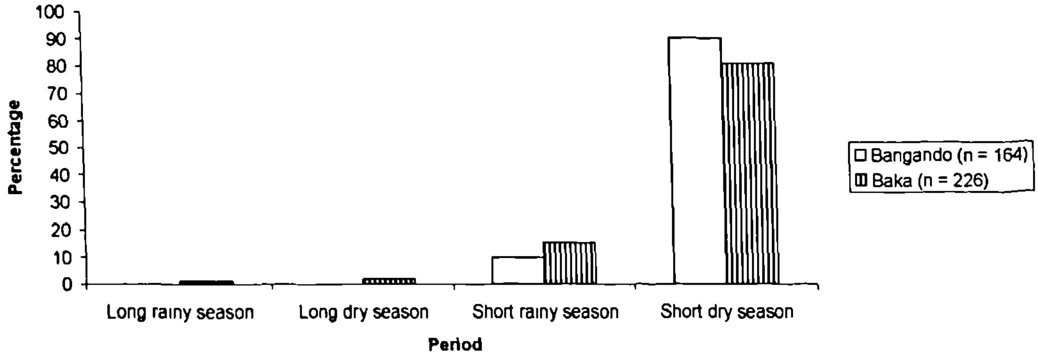


Figure 4-44: Gathering periods in the Lobeke forest.

Baka (99%, n = 226) gather more than Bangando (95%, n = 164) ($\chi^2 = 6.065$, d.f. = 1, $p < .05$). The gathering activity is not collective for the two ethnic groups and both males and females participate. They gather a wide range of products. Gathering products are: Honey, grubs of palm or raphia beetles, caterpillars, termites, mushrooms, bush yams (*Dioscorea burkilliana, D. minutiflora, D. semperflorens, D. Smilacifolia*), leaves (*Gnetum bucholzianum, G. africanum*), fruits (*Anonidium manii, Myrianthus arboreus, Antrocaryon klaineanum, Gambeya lacourtiana, Donella pruniformis, Gambeya perpulchra*) and seeds and nuts (*Ricinodendron heudelotii, Pentaclethra macrophylla, Antrocaryon micraster, Panda oleosa, Coula edulis, Treculia africana, Irvingia spp, Gilbertiodendron dewevrei*).

All these gathered products do not have the same importance for the indigenous peoples. Many are gathered and eaten when they are in the forest for other activities such as hunting, fishing or farming. The most important forest products for which Baka specially move to the forest to gather are honey (during the long dry season), caterpillars (during the long rainy season), and seeds of *Irvingia gabonensis* (during the short dry season). Caterpillars and seeds of *Irvingia gabonensis* are the most important forest products for the Bangando. The Bangando generally get honey from Baka. When a Bangando finds a bee hive, he calls Baka for help and they share the product. During the bush mangoes gathering period, entire families of Baka and Bangando settle in the forest. Stays vary from 1 to 4 weeks, and sometimes more. Gathering takes place in fallow land as well as in the primary forest.

The Lobeke indigenous people gather for food and sale (**Figure 4-45**). Baka (36%, n = 225) sell more gathered products than Bangando (21%, n = 155) ($\chi^2 = 9.816$, d.f. = 1, $p < 0.01$) but earnings are negligible generally less than US $3 per gathering season (**Figure 4-46**).

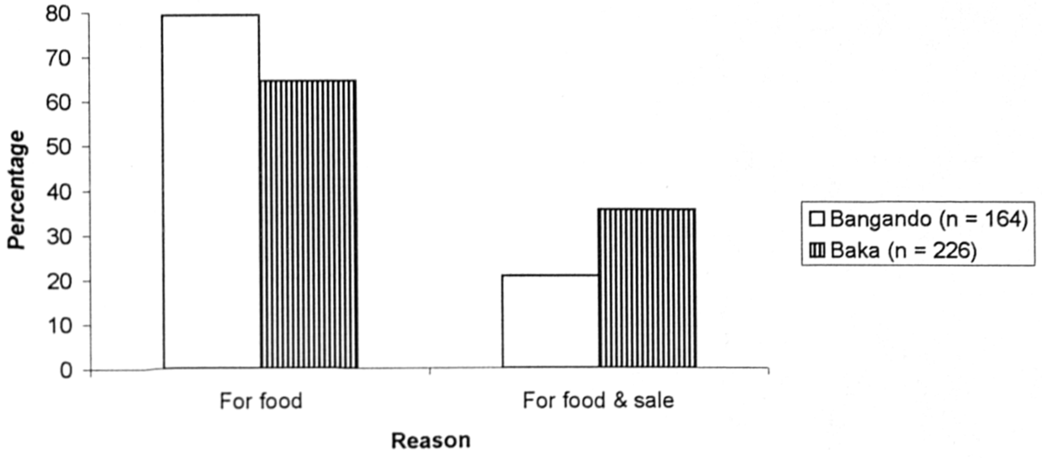


Figure 4-45: Stated reasons for gathering forest products.

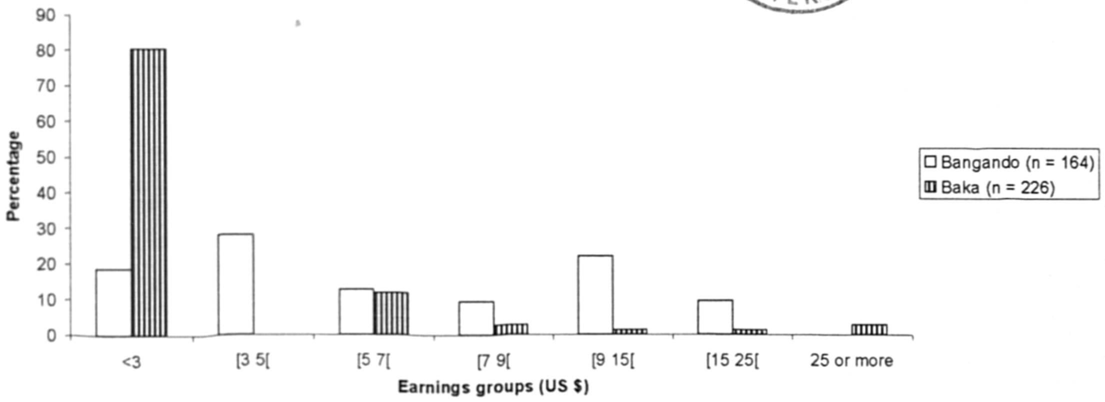


Figure 4-46: Gathering earning (US $) per gathering season.

4.2.8 Fishing

Fishing take place mainly towards the end of the long dry season (**Figure 4-47**).

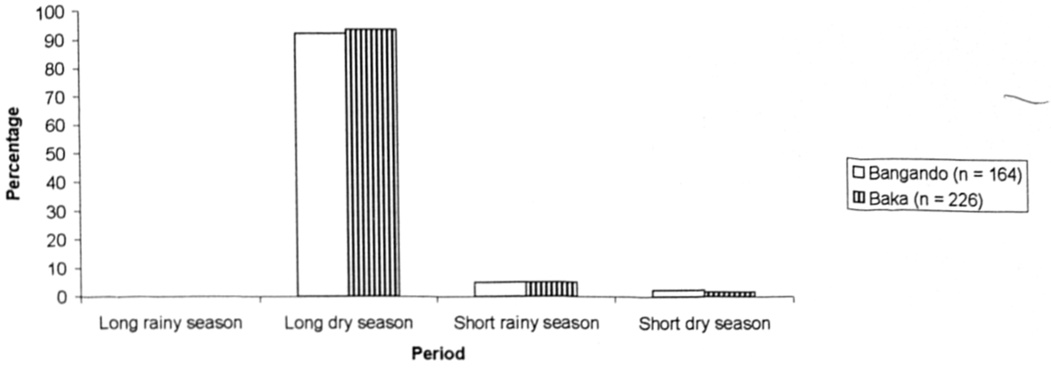


Figure 4-47: Fishing periods for both Baka and Bangando.

Bangando (37%, n = 164) go fishing more than Baka (26%, n = 226) ($\chi^2 = 5.960$, d.f. = 1, $p < .05$). Fishing is much more a female activity for both Baka ($\chi^2 = 4.411$, d.f. =1, $p < .05$) and Bangando ($\chi^2 = 7.127$, d.f. = 1, $p < 0.01$). Shellfish collection in shallow streams, generally located at less than one day walk from the villages (during the long dry season; December-February) is very important for both Baka and Bangando women. It is a source of highly valued food and income. Bow-nets and dam streams (with mud, dead leaves and branches) are used as fishing methods.

Much more important fishing activities take place in the headwaters of Lobeke river during the same period (long dry season). Bangando go fishing generally in groups of 2 to 4 men. Some go with their wives, rarely with children. They stay for three weeks maximum. For Baka, it is generelly the whole village that goes fishing. This activity is undertaken by only by 26° o (n = 226) of Baka and 37% (n = 164) of Bangando, even though the Lobeke river is abounding in fish. They use fishing lines and nets (set across the river) as methods. Baka undertake their fishing activities deeper in the forest than Bangando ($\chi^2 = 11.5, p < .05$) (**Figure 4-48**).

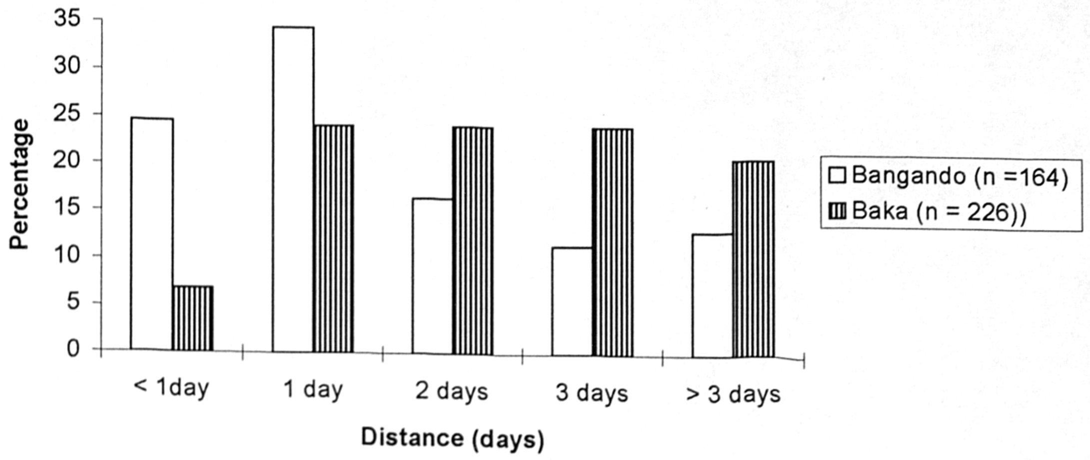


Figure 4-48: Distance walked before start of fishing.

Bangando earnings for fishing activities are significantly higher than Baka's (χ^2 = 13.464, d.f. = 2, $p < 0.01$) (**Figure 4-49**), although more Baka (83%, n = 53) go fishing for food and for sale than Bangando (61% n = 61) (χ^2 = 6.896, d.f = 1, $p < 0.01$) (**Figure 4-50**).

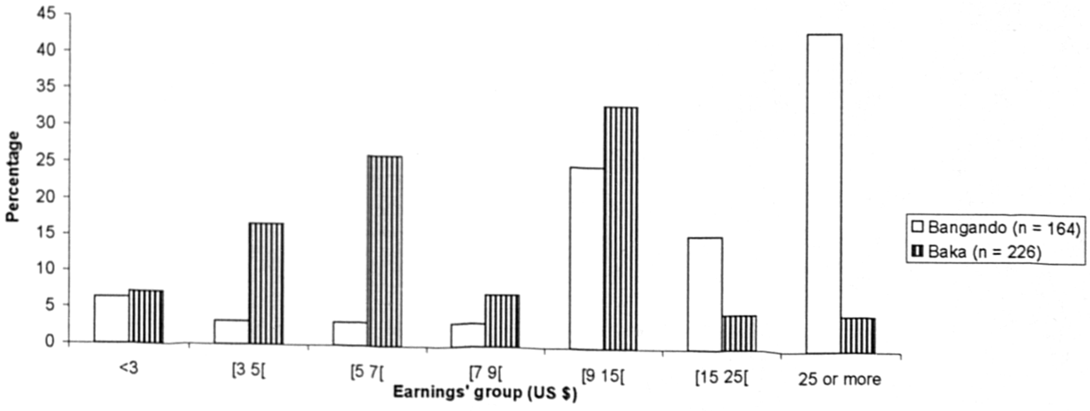


Figure 4-49: Fishing earnings (US $) per fishing season (long dry season)..

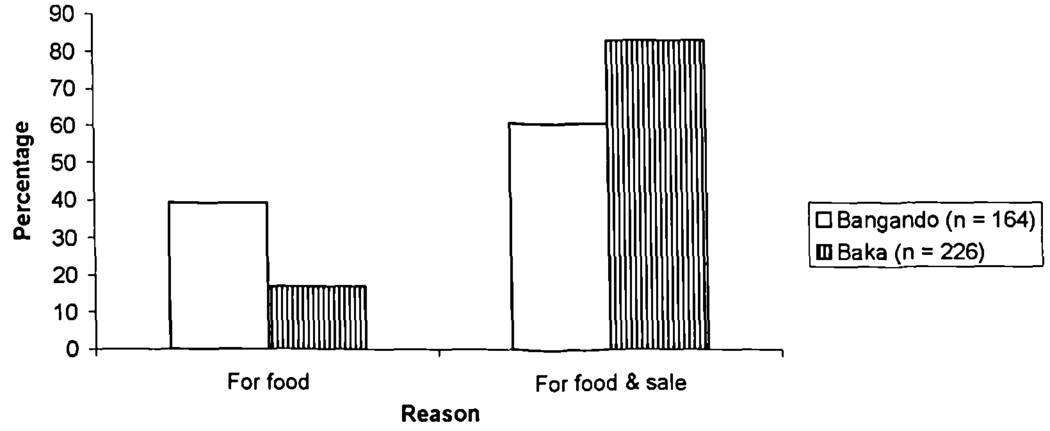


Figure 4-50: Reasons stated for fishing.

4.2.9 Plant cultivation.

Every year, one or two new farms (**Figure 4-51**) are created in old fallow lands or primary forest.

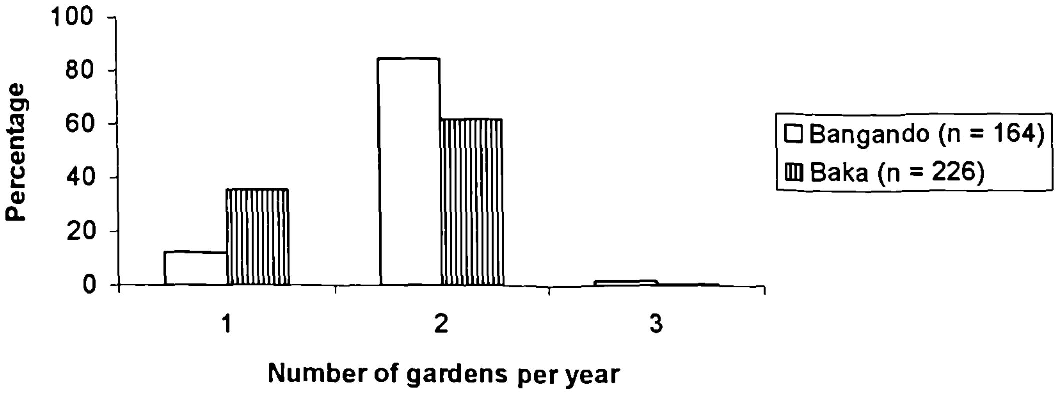


Figure 4-51: Number of gardens cultivated per year by both Baka and Bangando.

Baka and Bangando practice the slash and burn shifting cultivation. The main cultivated plants are maize (*Zea mays*), cassava (*Manihot esculenta*), plantain (*Musa paradisiaca*), banana (*Musa acuminata*), cocoyam (*Colocasia esculenta*), sweet potato (*Ipomea batatas*) and ground nuts (*Arachis hypogea*). Plantain is the staple starchy food. Almost all the Baka (99%, $n = 226$) and Bangando (99%, $n = 164$) do farming. Bangando (93%, n = 164) sell more food crop than Baka (75%, n = 226) ($\chi^2 = 20.129$, d.f. = 1 $p < 0.001$). Bangando (67%, n = 164) also have more cash crop farms than Baka (19%, n = 226) ($\chi^2 = 92.024$, d.f. = 1, $p < 0.001$).

Bangando (84%, n = 164) use more assistance for their farming activities than Baka (4%, n = 226) ($\chi^2 = 256.804$, d.f. = 1, $p < 0.001$). Baka clear land for themselves and Bangando. They also work in Bangando's cocoa and coffee plantations. Nowadays, Baka work mainly for money They rarely accept being paid in kind (starchy food as cassava or plantain). Their daily salary is less than US $1.

Farming provides both Baka and Bangando with the most stable and important source of income (**Figure 4-52** and **Figure 4-53**).

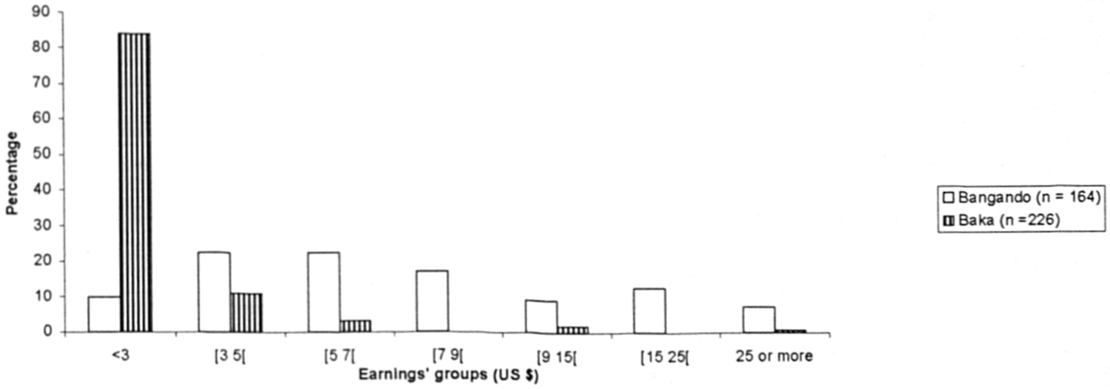


Figure 4-52: Food crop earnings (US $) per week in the Lobeke area.

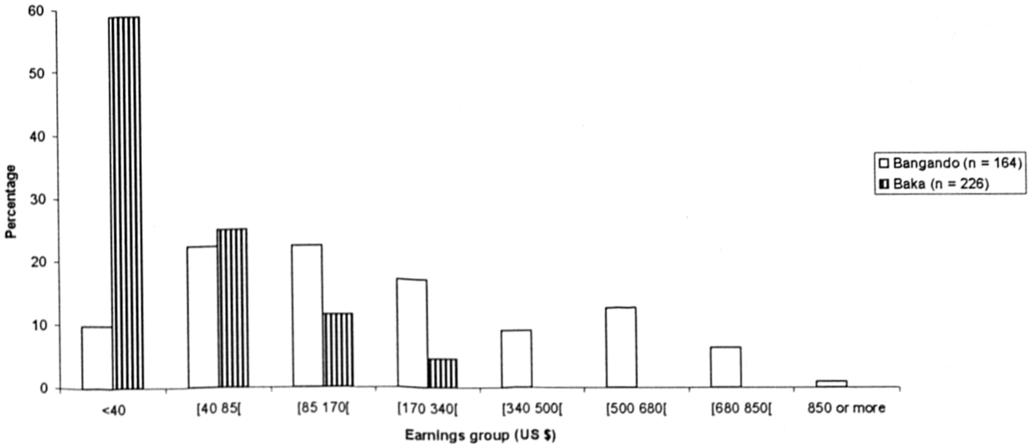


Figure 4-53: Cash crop earnings (US $) per year.

The farming implements of the Baka and Bangando are the same, few and simple. Major tools are: a hoe with a spade-shaped iron blade set into a short crooked wooden handle, an axe with a long narrow iron blade inserted in a heavy knobbed wood handle and a machete

The plant cultivation in the Lobeke area alternates with fallow periods. The mode for fallow duration is 5 years for Bangando and 4 years for Baka (**Figure 4-54**).

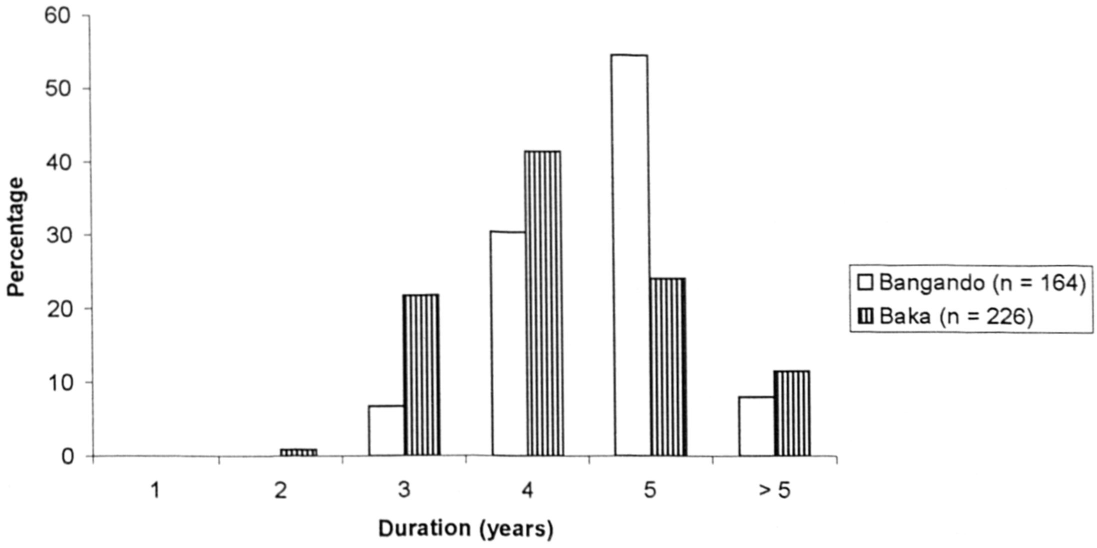


Figure 4-54: Fallow duration in the Lobeke area.

During that period, the owner keeps harvesting plantains, cassava, banana and cocoyams as well as wild products such as bush yams (*Dioscorea spp*) and edible leaves (*Ngnetum spp*) that grow mainly in secondary forests. Fallow lands are ideal places for snare hunting as they attract certain species of animals such as porcupine, cane rat, guinea fowl and francolin. They are also a source of fuel wood, some building materials and medicinal plants.

For their farming activities some Baka and Bangando build bush camps. These bush camps are used during the creation of new farms and the cash crop harvesting season. They are generally located less than half a day walk from the village. Bangando (23%, n = 164) use more bush camp than Baka (7%, n = 226) (χ^2 = 19.397, d.f. = 1, $p <$ 0.001)

4.2.10 Livestock farming.

Baka and Bangando own some free-ranging domesticated animals (chickens, goats, sheep). However, livestock production in the area is not a major farming activity. There is a significant relationship between the tribe and livestock farming (χ^2 = 8.999, d.f. = 1, $p < 0.01$). Bangando (84%, n = 164) are more involved in livestock farming than Baka (31%, n − 226). The same trend is observed on the species farmed. Baka are much more reduced to poultry farming while Bangando keep more sheep and goats (χ^2 28.052, d.f – 1, $p < 0.001$) (**Figure 4-55**).

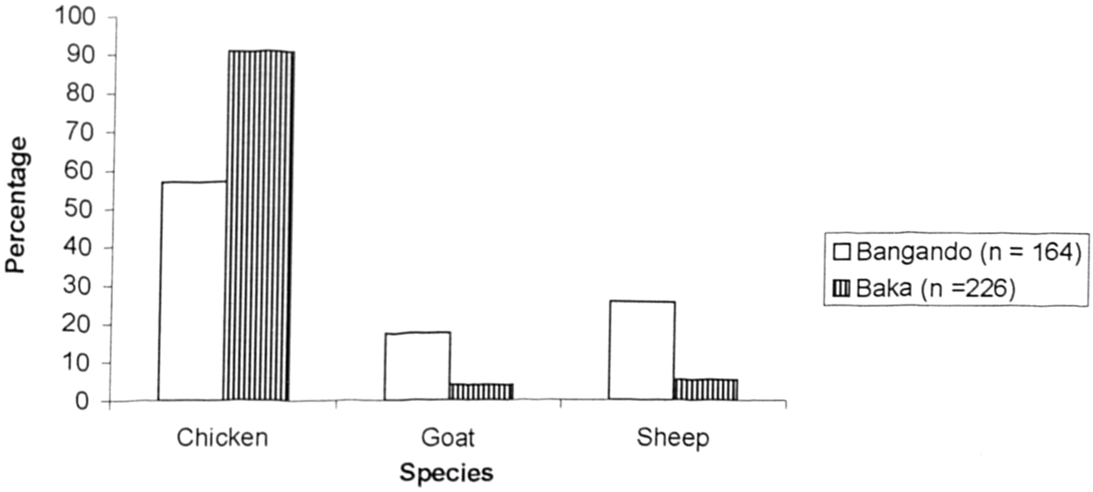


Figure 4-55: Livestock farming in the Lobeke area by Baka and Bangando.

Livestock farming does not have a significant input to their diet but does play an important economic and social relations role **(Figure 4-56)**.

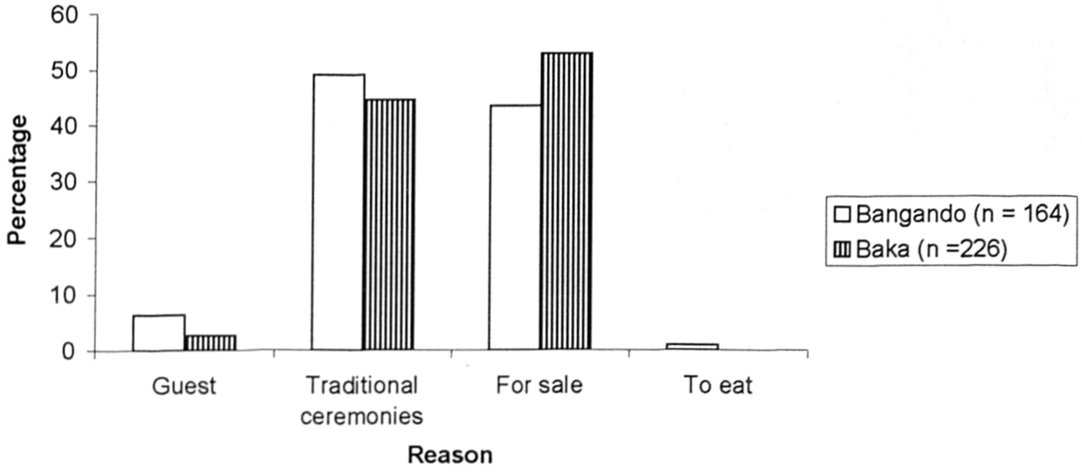


Figure 4-56: Reasons stated for livestock farming reasons in the Lobeke area.

Chapter 5

DISCUSSION

5.1 Elephant Ecology

5.1.1 Densities and numbers

a) The choice of the methods

1) Sampling technique.

The results of this study have shown that elephant dung counts in the forest are characterised by a high variation of dung densities (and therefore elephant densities) between transects surveyed in the same area during the same period (**Appendix 1 & 4**, see also Barnes & Jensen, 1987). That is why the study area was divided into 78 cells of 25 km^2 each, with one random transect cut in each cell to improve estimates of elephant numbers (Barnes 1995) and to determine their distribution and movements to the nearest 25 km^2. An advantage of using this method is that data on other aspects of elephant ecology (population structure, group size, diet) are collected in different cells, making samples more informative. This method was however time consuming and labour intensive. The total distance covered on foot for a single survey of all cells was estimated to be 860 km (390 km along transects and 470 km along base-lines). The total distance covered on foot for the three surveys was therefore estimated to be 2,580 km.

2) Direct or indirect counts?

Direct total counts and direct sample counts are methods in which objects (elephants) themselves are counted. The principal assumption underlying direct surveys is that no object (elephant) goes undetected. It has been shown by Barnes & Jensen in 1987 that direct counts of elephants are impractical in the tropical forest where it is difficult to see them in the dense vegetation. The solution is to use indirect counts, which require convertible indices. Convertible indices are defined as indices that can be translated into an estimate of animal numbers. The density of elephant dung-piles is such an index (Barnes 1993). However, two other values must be estimated for the conversion of dung-pile density into elephant density. These are the defecation rate and the dung decay rate. There are therefore four stages in the calculation of elephant density using dung-pile counts:

1) Estimating the density of dung-piles

2) Estimating the number of dung-piles produced per elephant per day

3) Estimating the rate of decay of dung-piles

4) Combining the above estimates (1-3) to obtain an estimate of elephant density.

These three variables (dung-piles density, defecation rate, dung-piles decay rate) were estimated in the Lobeke Forest.

3) Quadrats, strip transects or line transects?

Transects of fixed width (strip transects) and quadrats were the first methods used in forest elephant dung counts (Wing & Buss, 1970; Short, 1983; Merz, 1986a, 1986c). It is assumed in strip transects or quadrats that all objects (elephant or dung-piles) within the boundaries are seen (Barnes 1993). This assumption makes it impractical in an environment like the tropical rain forest where the visibility of dung-piles falls quickly with distance from the centre line of the transect (Barnes & Jensen, 1987). Barnes (1993) observed that even if the width of the transect is restricted to ensure that all objects within the boundaries of the transect are seen, fewer objects will be recorded. This will result in a larger standard error because the precision of the estimate is inversely related to the square root of the sampling size n (Eberhardt, 1978). Barnes & Jensen (1987) advised the avoidance of quadrat sampling in forest elephant surveys because of the clumped distribution of dung-piles that will result in a large sampling error. The only suitable method available for dung counts in forest is therefore the line transect survey or distance sampling (Barnes & Jensen, 1987; Barnes, 1993). This method provides estimates that are less biased and have a lower standard error than strip transects (Burnham *et al.*, 1980).

4) The line transect method

Line transects can be considered as a generalization of strip transects in that many, if not most of the dung-piles, remain undetected and sampling units are neither fixed nor of known size. Except near the centre line, there is no assumption that all the dung-piles are detected. The sample is the total number of dung-piles detected n and perpendicular distances $(x_1,.......,x_n)$ from the line to the centre of these dung-piles. The line transect or distance sampling is built around the concept of a detection function $g(x)$ which is the probability of detecting a dung-pile given that it is at a perpendicular distance x from the centre line of the random transect (Buckland *et al.*, 1993).

There are three assumptions underlying the line transect method. One of these is relevant to moving objects only. For the case of non moving objects like dung-piles, two assumptions are critical to achieving reliable estimates of their density.

1) Dung-piles on the line are detected with certainty, that is $g(0) = 1$.

2) Distances between dung-piles and the line are measured accurately.

To those two key assumptions, could be added two others (Buckland *et al.*, 1993:)

- Dung-piles are distributed in the area with a rate parameter Y (= expected number per unit area). Their distribution does not actually have to be Poisson (Buckland *et al.* 1993). What is important however, is that transects are placed randomly with respect to the distribution of dung-piles in the sampling area.

- The detection of dung-piles is certain on the line and stays certain or nearly certain for some distance away from the line. This means that the detection function of the analyzed data should possess a "shoulder" shape.

Many models are implemented in the programme DISTANCE. The choice of the best model is based on statistical tests. The limitations here are the necessity for a good background knowledge in "Distance sampling" in order to use the programme and interpret the results. The two main disadvantages of the line transect method are that it requires constant and strict supervision of the field workers to maintain accurate straight lines and measurements in order to avoid "heaped" or "spiked" data that are much more difficult to analyse and secondly, it requires access to computers (that are not always available to many field workers in Africa) for data analysis.

b) The Validity of dung counts

Wing & Buss (1970) used dung counts in the Kibale Forest, Uganda. They did not accept the reliability of the method because estimates of population size were large when compared to elephant densities in other areas of Uganda where damage to vegetation was higher than in the forest. In 1979, Jachmann & Bell tested dung counts in the Kasungu National Park, Malawi, and stated that the method overestimated the number of elephants when compared to a series of aerial surveys, due to such factors as double counting of dung-piles. They refined the method, obtaining similar estimates to an aerial survey in 1984. Jachmann (1991) compared different methods of counting elephants, including direct sample counts from air and ground, in the Nazinga National Park, Burkina Fasso, and concluded that dung count methods were the best and most cost-effective survey technique. Dawson (1990) used the line transect method to counting dung-piles in the Mudumalai wildlife sanctuary (India) and estimated an elephant density of 1.77 km^{-2}. Direct elephant counts from a vehicle using the line transect method gave estimates of 1.75 and 1.56 elephants km^{-2}. Total counts resulted in estimates of 1.39 and 1.25 elephants km^{-2} (Sukumar *et al.* 1991). Dung counts are therefore a valid method for estimating elephant numbers.

There are however some aspects of the dung counts methods that could be consider as sources of error.

c) Sources of error

Barnes (1993) described 7 main sources of error in dung count methods. Five are related to the dung density estimates and 2 to the "translation" of dung-density into elephant numbers.

1) Dung-pile visibility

Barnes & Jensen (1987) observed that in forest, a dung-pile is soon broken down into a "cow-pat" form which is difficult to see in the undergrowth. However, for the line transect method, only those dung-piles actually on the line or close to it must be detected for the estimates to be accurate (Buckland *et al.*, 1993).

2) Observer efficiency

This could be a problem in the case of dung counts in strip transects (Buckland *et al.* 1993). Models used in the DISTANCE programme yield reliable estimates of dung-pile density despite factors that affect the detection probability; such as observer efficiency (experience, eye sight, interest, training, fatigue). In other words, the line transect is robust to variations in detection probability (Burnham *et al.* 1980).

3) One or two dung-piles ?

The best definition of what is accepted as the unit in dung counts was given by Barnes & Jensen in 1987, who defined it as "a pile of boli produced at one time by one elephant". Often, an elephant defecates when walking. It is sometime difficult to decide whether two adjacent piles of boli represent a dropping. Jachmann & Bell (1984) tried to resolve the problem by estimating the mean number of boli per dropping. This was multiply by the defecation rate to calculate the mean number of boli produced per elephant per day. The technique is not reliable in the Lobeke forest because most dung-piles are laid into "cow-pat" form. The only criteria used in this case are the color, the content, the distance separating piles and the estimated age. If two apparent dung-piles occurred within 10 m, the surrounding area was searched for boluses which might indicate that they had been dropped by the same animal while on the move.

4) The cut-off point

The boundary between stage D (visible) and stage E (less visible) is not clearly defined. The time of decay is the time that elapses between deposition and grade E. Dung-piles of stage E are not recorded in line-transects as they are deemed to have "disappeared" (Barnes & Jensen, 1987). It is sometime difficult to decide whether a dung-pile is late D or early E. This problem could be minimised, as in the present survey, by the same investigator collecting data on line transect and decay rate. Thus the cut-point was set by the same person for both dung counts and decay rate.

5) What if an elephant has diarrhoea or constipation?

This question is commonly asked by those who do not accept that dung counts yield reliable estimates of elephant numbers. Defecation rates are physiological processes and as such will be normally distributed (page 54; see also Barnes, 1993). This implies that low values (constipation) or high values (diarrhoea) should be anticipated.

6) The steady-state assumption

The system is in a steady state (or in equilibrium) when the number of droppings disappearing each day through decay equals the number of droppings deposited each day (Barnes & Jensen, 1987). The steady state assumption allows the translation of dropping density into elephant numbers (McClanahan, 1986). It is closely related to the movement of elephants in and out of the study area (Barnes & Jensen, 1987). Small areas are much more sensitive and if the system is not steady, estimates of elephant density will be wrong (Barnes, 1993).

7) Biases in Y, r and D

Biases in estimating dung-piles density (Y), defecation rate (D) and decay rate (r) are additive (Barnes & Jensen, 1987). This means that any error in estimating these parameters will be reflected in the final estimate of elephant numbers.

d) Defecation rate

The defecation rate is the mean number of droppings produced per elephant per day. It is one of the two key parameters used in translating dung density into elephant density. The results of this study suggest a defecation rate of 17.45 ± 1.82 per day. This does not vary over the wet and dry periods and there was no correlation between the defecation rate and rainfall in the Lobeke forest.

The first defecation rate study on the African elephant was conducted by Wing & Buss in 1970. They calculated a figure of 17 defecations per day per elephant and found rates to be fairly stable for forest elephants. Coe (1972) showed that the defecation rate does not vary significantly with age. Merz (1986a) estimated the daily defecation rate to be 18 in the Tai National Park, Ivory Coast. In 1992, Tchamba obtained a defecation rate of 20 droppings per day in the Santchou forest, Cameroon, and moreover found no significant difference between the defecation rate in the forest of Santchou, Kibale and Tai. Analysis of variance suggests that the mean defecation rate estimated in the Lobeke forest is not significantly different from that of the Santchou forest (Tchamba, 1992) and the Kibale forest (Wing & Buss, 1970); $F(2,62)$

= 1.34, NS. Barnes (1982) found defecation rates for elephants in the savanna ecosystem to vary with the seasons and also between sites (woodland/bushland versus grassland). Mclanahan (1986) suggested that defecation rates are likely to vary in proportion to variations in the food intake which is determined by environmental conditions.

The results of this study (page 54) confirm the observations of Tchamba (1992) that the defecation rate does not vary significantly over the seasons. A "non significant fluctuation" over the seasons, similarities in defecation rates in forest, and a non significant relationship between rainfall and defecation rate may suggest a much greater stability of food availability in forest ecosystems than in others examined.

e) Dung decay rate

The estimated dung decay rate in this study (page 58) is lower than the estimates of decay rates in forests calculated (Barnes *et al.* 1994). The main potential source of error in these results is in misclassifying dung-piles at the transition between stage D and stage E (Barnes 1993). As stated previously (page 38), when a dung-pile reaches stage E, it is deemed to have "disappeared". There is no clear cut between stage D and stage E. However, Barnes *et al.* (1994) showed that even if large numbers of dung-piles are misclassified, it will have little effect upon the estimate of the decay rate. The sequences of the decay process involve a wide range of organisms. In the Lobeke forest, 46 % (n = 39) of the dung-piles were scattered by duikers (*Cephalophus spp*), bushpigs (*Potamochoerus porcus*) and francolins (*Francolinus lathani*) in search of seeds. Dung beetles (Scarabeidae) and termites (Termitidae) were observed in activity in 18% (n = 39) of the dung-piles. However, the activity of the "decomposer community" as agents of decay is not as important as in savanna (Coe, 1977; Barnes *et al.*, 1994).

f) Elephant densities and numbers

Elephant estimates from the line transect method have large confidence intervals (page 59; See also Barnes, 1993) because the estimates of dung-pile densities, defecation rate and dung decay rate have their own standard errors which contribute to the standard error of the elephant numbers (page 40).

The results of the present study (**Table 4-8**, page 58) are much higher than those computed for other regions in Central Africa (**Table 5-1**). It is however important to mention that the survey methods, although based on dung counts were different.

Table 5-1: Forest elephant densities reported for different parts of the Central African rain forest

Location	Density (km-2)	Reference
Lobeke forest	2.17	This study
SW, Central African Republic	0.6	Carroll, 1988
North Congo	0.6	Fay & Agnagna, 1991
NE Gabon	0.4	WCI, 1989
SE Central African Republic	0.3	Fay, 1991
Salonga Park, Zaire	0.2	Barnes, 1989
South, Equatorial Guinea	0.1	Alers & Blom, 1988
Gabon	0.3	Barnes et al., 1995b
Korup	0.9	Powell *et al.*, 1994

Stromayer & Ekobo (1991) estimated a density of 4.64 elephants km^{-2} for the Lobeke forest. The highest mean density estimated for the present survey was during the dry season (3.1 elephants km^{-2}). The difference between these estimated densities may be due to the high mean decay rate (0.0233 day^{-1}) used. This confirms the necessity of undertaking the decay rate experiment to provide more accurate density estimates. The second reason may also be the survey method used by Stromayer & Ekobo (strip transect).

Elephant densities in the Lobeke forest showed seasonal fluctuations. This suggest major movements of elephants in and out of the Lobeke forest over a seasonal cycle. In 1983, Short described similar results in Bai National Park, Ghana. In the Lobeke forest, the mean elephant density was at its maximum (3.1 km^{-2}) in the dry season, about three times the estimated mean density of the end of the rainy season (1.0 km^{-2}). Lobeke therefore appears to be a refuge for elephants during the dry season. Laws (1970) described the optimum habitat of elephants to include roughly equal proportions of grass and browse available as food. About 85% of the Lobeke forest is logged (Stromayer & Ekobo 1991). There is also an important number of clearings (see description of the study area, page 27) within primary and logged forests. Hence high elephant densities may be expected.

The critical threshold above which the habitat is likely to be damaged in the savanna ecosystem was estimated to be 0.5 elephants km^{-2} (Fowler & Smith, 1973). Laws *et al.* (1970) suggested that Bunyoro forest, Uganda could easily support 3.9 elephants km^{-2}. Forest can support a higher density of elephants than savanna (Merz, 1986a). No important tree destruction was observed in the Lobeke forest even during the dry season. This suggests that the critical threshold may have not yet been reached in the Lobeke forest in spite of the high elephant density during the dry season.

This study supports Merz's (1986a) hypothesis that there are significant changes in density of elephants with seasons in the rainforest.

5.1.2 Distribution and movements

The results presented in **Section 4.2.1** (page 59 to 73) show that the density of elephants varied significantly with the distance to the main highway, to the Sangha river and to the nearest village during the period of May-August 1993. The elephant density also varied significantly with the distance to the nearest logging road during the periods of May-August 1993 and November 1993. It increased with increasing distance from logging road and the main highway but decreased with the distance from the Sangha river and the nearest village. Barnes *et al.* (1991) observed in Gabon that the density of elephants increased with distance from roads and villages. They also pointed out that human activity is the most important factor determining elephant abundance. However, Agnagna, Barnes & Ipanda (1991) found elephant dung in Ngongo village and fresh elephant signs in Sialikou village (Congo).

The important point to consider is that, the hypothesis that elephant density increases with the distance from roads and villages (Barnes *et al.*, 1991) does not always hold in the case of the Lobeke forest. The results of the current work also suggest that the estimates of elephant numbers provided by Michelmore *et al.* (1994) using the GIS (Geographical Information System) may be wrong for the case of the Lobeke forest. Their working hypothesis was that the elephant density rises with the increasing distance from roads and major rivers thought to be navigable. That hypothesis was not substantiated during the present study.

Line transect surveys indicated the highest concentration of elephants in the Lobeke forest during the dry season (January-March 1993). By the end of the seasonal cycle (November 1993), about 68% of the dry season's population had left the Lobeke forest. Where they go has not been determined. They move mainly northward. Some cross the border to Congo and Central African republic (M. Agnagna, personal communication). A nucleus of elephants stay in the Lobeke forest.

Forest elephants usually expand their range during the rainy season and their movements are likely to be governed by the availability of food more than any other factor (Merz, 1986b). Short (1983) observed that forest elephant densities fluctuate locally, and even regionally, in response to fruit availability. White (1994) showed that the seasonal movement of elephants in the Lopé reserve, Gabon is highly influenced by *Sacoglottis gobonensis* fruiting.

In the surveyed area, the maximum number of cells with high elephant density (> 1 elephants km^{-2}) was found during the period of May-August 1993 (82% of the cells, n = 78). Elephant densities were also significantly higher in cells with no logging roads during the same period (maybe because of the scarcity of fruit bearing trees along logging roads as most woody plant species produce fruits during this period in the Lobeke forest).

The results of this study show that the mean elephant density is significantly higher in logged forest during the dry season. Barnes *et al.* (1991) linked the greater attraction to secondary forest to the greater diversity of food plant, more of which are within reach than in primary forest.

These observations confirm the suggestion that the availability of food may be the main factor influencing elephant distribution and movements in the Lobeke forest.

5.1.3 Crop-raiding

This study shows that elephants are of negligible importance compared to other species as crop-raiders in the Lobeke forest. This appears not to be the case in other parts of the of the Central African rainforest (Agnagna *et al.*, 1991; Lahm, 1994;

Korup, pers. obs). Barnes *et al.*(1995a) stated that crop-raiding occurs whenever cultivators live in close proximity to elephants. It could be added that crop-raiding also occurs whenever people farm on elephant migration routes (as in Lobeke and Korup National Park, pers. obs). Elephant crop-raiding appear to occur in the Lobeke forest only during the migration period (long rainy season) and in two logging towns created deep in the forest (**Figure 4-28**, page 75).

The negligible impact of elephants on agriculture in the Lobeke forest is one of the principal factors governing human-elephant relationship in the area. No elephant killing by the local people was recorded during this study (approximately two years). Lobeke therefore appears to be one of the few places in Central African rainforest where the human-elephant conflict is negligible.

5.1.4 Structure and population dynamics

It was difficult to count large groups of elephants in the Lobeke forest. Thus estimates of the mean group size (**Section 4.1.5**, page 80) might be biased towards smaller groups since it was impossible to be certain that all individuals were counted in the census of large groups The term "group" was defined by Leuthold (1976b) as "any number of elephants that are closely associated in space and appear to be fairly co-ordinated in their activity at the time of observation".

The mean group size of savanna elephants varies between seasons and areas due to food availability (e g. Barnes, 1983b; Moss, 1988). In Amboseli National Park, the mean group size was 15.1 in a year during which there was a serious drought and food was scarce, but was 45.9 in a year with good rains and abundant food (Moss, 1988).

White *et al.* (1993) estimated a mean group size of 2.8 individuals in the Lopé forest, Gabon. Merz (1986b) calculated a mean group size of 2.44 ± 1.7 (or 3.4 ± 1.6 excluding solitary), for the Tai forest, Ivory Coast.

The important conclusion therefore is that group sizes appear to be much smaller in forest compared to savanna.

In the Lobeke forest, the results (**Section 4.1.5**, page 80) show a high frequency of males among solitary individuals. The same trend was observed by (Merz, 1986b) In

Tai National Park. These observations suggest that solitary elephants in forest are likely to be males.

The sex ratio resulted during the present survey (**Section 4.1.4**, page 79) is not significantly different from unity. This suggests that sport hunting and poaching currently taking place in the Lobeke forest might not have a deleterious effect on the sex ratio of the population. Another explanation might be that poachers kill elephants randomly, irrespective of age and sex (therefore basically for meat). The mean weight of the 9 tusks seized from poachers in the area is 1.9 kg (Ekobo, 1994) but the mean weight of the 230 tusks acquired legally through sport hunting (over 8 years) is 14 kg (Bidja, pers. comm.). The sample size of confiscated ivory is small but shows the tendency poachers have to kill any elephant regardless of size. The impact of poaching on elephants in Central African rain forest (which Lobeke is part) has been described by Alers *et al.* (1992), Barnes (1989), Barnes *et al.*(1991, 1993, 1995b), Fay (1991), Fay & Agnagna (1991). They pointed out that large-scale commercial poaching has been especially severe in Zaire, Congo and Cameroon. However, there are no reliable data on poaching in Lobeke.

5.1.5 Daily activities

This study shows that feeding comprises 64% of elephant total observed activities in the Lobeke Forest. This supports the results of Wyatt & Eltringham (1974), Guy (1976), Barnes (1982) and Kalemera (1987) although the method used are different. All studies showed that elephant spend most time (56-85%) feeding. No attempt was made during this study to differentiate activity patterns between males and females but Guy (1976) showed that there were no sex differences in activity patterns. Drinking was only 1% of the total number of observations, which may be an underestimate. However, Wyatt & Eltringham (1974) results show less than 1% of the time spent in drinking activity per 24 hours for elephants studied over 24 hours.

5.1.6 Diet

The method used for this study did not allow exhaustive analysis of elephant feeding behaviour in the Lobeke forest. It was based on conspicuous feeding signs. However, the results compare favourably (in terms of number of species and items eaten) with the results obtained in other forests (Merz, 1981; Short, 1981; White, 1994).

Barks and leaves constituted 81% of all elephant food items (**Section 4.1.7**, page 84) in the Lobeke forest. In the Lopé forest, Gabon, 70% of all elephant food items recorded were leaves and barks (White, 1994). This suggest a strong preference for barks and leaves. McCullagh (1969) pointed out that elephants eat barks because they are prone to deficiency in certain fatty acids that barks could satisfy. Short (1981) noted that bark feeding in Bai National Park, Ghana, was highly selective, with only 20 species of tree affected, and only seven regularly fed upon. In Tai National Park, Ivory Coast, Merz (1981) identified 22 species of trees whose barks were eaten. Wing & Buss (1970) recorded 8 species that were heavily utilized in the Kibale forest, Uganda.

There is no widespread habitat modification by elephants in the Lobeke forest such as that suggested in savanna ecosystems (Buechner & Dawkins, 1961; Laws, 1970; Field, 1971; Caughley, 1976) although elephants feed almost entirely on trees. Short (1981) however concluded that elephants contribute to the complexity of the forest by dispersing seeds and maintaining open areas.

5.2 Human Ecology

5.2.1 Demography

The present work (**Section 4.2.2**, page 88) suggests that the population of the indigenous peoples that live in close proximity of the Lobeke forest is 47% Bangando and 53% Baka. Chi-squared test shows that the ratio 47:53 is not significantly different from the ratio 50:50 (χ^2 = 0.18, d.f. = 1, NS). Therefore the difference between the population of Baka and that of Bangando that may have a direct impact in the Lobeke forest is not significantly different.

This study also suggest that they are more Bangando above fifty years than Baka. Turnbull (1986) pointed out that in the Ituri forest cool damp climate with little direct sunlight, the Mbuti pygmies retain remarkably good health and pygmies living in the forest in nomadic camps do not encounter pollution found in a sedentary village. After an age of 7 or 8 years, a child has good chance of living well into his sixties. These observations suggest that the low life expectancy of Baka pygmies may be due to their new sedentary life style.

5.2.2 Logging

The logging industry did not appear to be beneficial to the local communities and elephants for the following reasons:

1) Many species of trees exploited by logging companies (**Section 2.6.1**, page 29) are elephant food (**Section 4.1.7**, page 84) and are used by the local communities. For example *Pericopsis elata*, *Entandrophragma cylindricum* and *Triplochiton scleoxylon* are medicinal plants and they also provide caterpillars; *Triplochiton scleroxylon* is used as building material.

2) The local communities become more and more part of the new economic system introduced by logging companies. They have new needs that only money will satisfy. They therefore start an over-exploitation of their natural resources crossing the boundary between subsistence and professional hunting.

3) Logging companies import non-indigenous people and build camps deep in the forest. Those camps increase local food demands and disrupt the fragile local trade by increasing demand for bush meat (wild game meat) and food crops. Logging

companies also open roads for extraction purposes, encouraging non-native population settlements and movement for hunting, trade or farming.

The direct implication for elephants is an increased poaching to supply the high demand for bush meat (Ekobo, 1994; Stromayer & Ekobo, 1991).

5.2.3 Relations between the local people and the natural environment

5.2.3.1 Hunting

The characteristic that defines both Baka pygmies and Bangando Bantu is their dependence on bush meat as a food and income source. This consumption is considerably increased by residents of the five active logging company towns in the area and traders who supply large population centres elsewhere in the country.

Baka hunt more than Bangando. Their former hunter-gather life style made them skilled hunters. This relates to their selling bush meat more than Bangando.

This study has shown that hunting methods are not associated with forest type. Snare, spear, crossbow or gun hunting can occur in primary forest as well as in fallow land (or secondary forest). Among the four methods used in the Lobeke forest, snare hunting appeared to the most commonly used since it is difficult to locate an animal in the thick undergrowth of the tropical rain forest. The Mbuti pygmies solve the problem by net hunting although Mbuti archers employ beating to locate animals (Ichikawa, 1983). The Baka and Bangando use the most adapted and cost effective method consisting of snares set on animals tracks and visited every second or third day. Catching probability is increased by setting many snares, generally more than fifty, sometimes more than a hundred.

Elephants did not appear to be a major species killed by the indigenous peoples (**Table 4-24**, page 98). It is therefore concluded that "traditional" hunting does not have a negative impact on elephant population in the Lobeke forest.

5.2.3.2 Food restriction

The results of this study (**Section 4.2.6**, page 97) suggest that very few Baka observe food restriction. The situation of Lobeke forest is quite different from the one in Eastern Zaire where both Mbuti Pygmies and Bira agriculturists have totems

Plate 5: A Baka hunting camp. Notice the traditional hemispherical hut.

Plate 6: A Bangando hunting camp. Notice the rectangular hut.

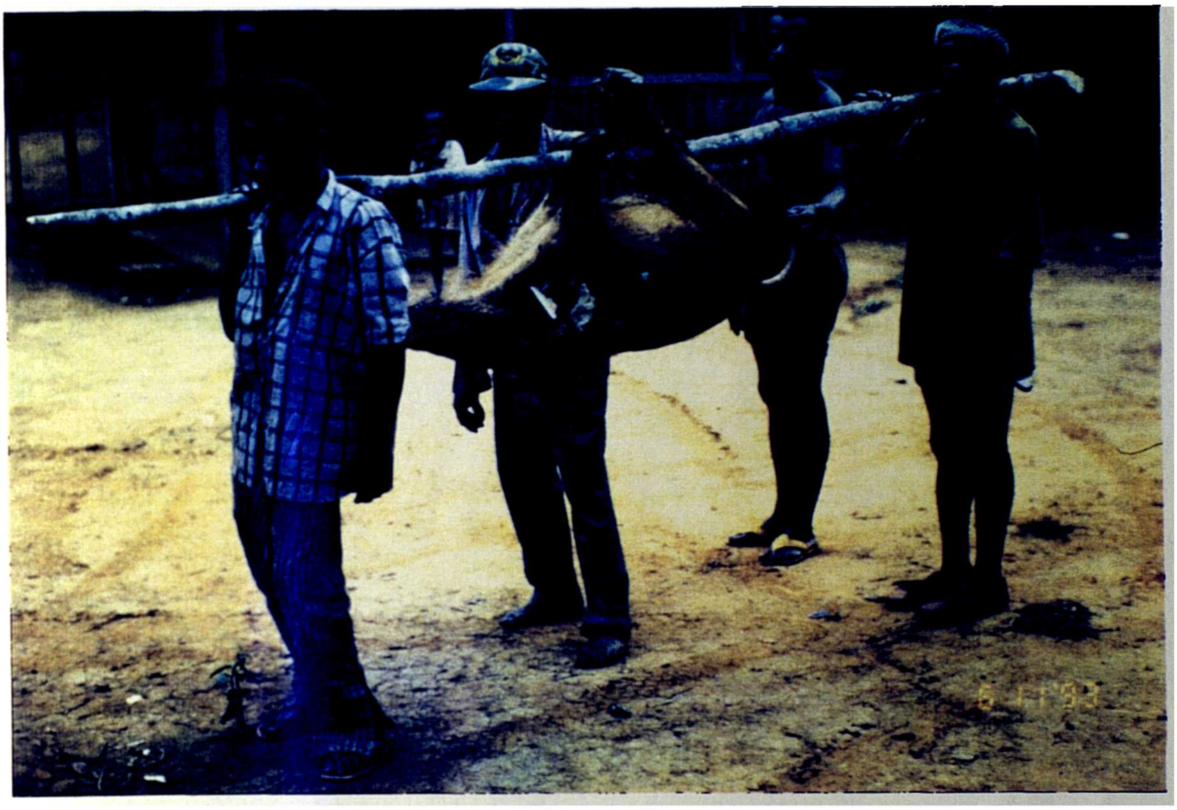


Plate 7: A bush-pig (*Potamochoerus porcus*) killed in snare hunting.

(Ichikawa, 1987). Totems did not actually exist in the Baka pygmies' world. The Baka were linked to a Bangando master, chief in a Bangando community, through a contract that enabled the Baka to obtain metal works and farm food in exchange for total submission (Althabe, 1965). This relationship bound the Baka to observe their master's food restrictions.

Food restriction is explained from a conservation point of view. Each clan of the ethnic group does not eat a given species to reduce hunting pressure on that specific species. This restriction appears also to be "weighted". Most of the species that are on the top of the list (high percentage of restriction) like monkeys, gorilla, leopard, bush pig or forest hog are highly valued in the area for their meat or the returns they can provide. This explanation would hold only for the early society. Nowadays, bush meat trade in the present changing society seems to put at stake this type of restriction.

The elephant figures in the list of taboo species (**Table 4-25**, page 98). This may mean that indigenous peoples in the early society were not over exploiting the species because not all of them were eating elephant meat.

5.2.3.3 Gathering

There are five main problems with gathering foods:

The first is the marked seasonality that limits dietary importance to a few months of the year. Bush yams are abundant and tasty only during the dry season. Honey and termites, although high in available calories (Wu Lueng, 1968), are not available the year round Termites emerge at the peak of the rainy season. Honey, including that of the stingless honey bees may be found sporadically at other time of the year but is abundant only during the dry season. Fruits are rare during the long dry season.

The second problem is their irregularity from year to year. An important product like *Irvingia gabonensis* is abundant only every second year.

The third problem is the short availability in time. The entire fruiting season last about 2 to 3 months and ungerminated fruits rot. Indigenous people in the Lobeke forest have not developed preservation techniques for gathered products, except for the *Irvingia gabonensis* almonds. They are smoked, ground and added to sauces which

Plate 8: Baka males harvesting honey in the Lobeke forest.

accompany the starch staples. Smoked almonds of *Irvingia gabonensis* can last for a year and they have a high nutritional value (Wu Lueng, 1968).

The fourth problem is their dispersion in space. Baka families sometimes have to trek for 3 to 5 days in the forest looking for bee hives, indicating how dispersed and rare a highly valued wild food is.

The final problem is that gathering is labour intensive. Bush yams are deep rooted and excavation take many hours. Cracking seeds of *Irvingia gabonensis* takes hours and the smoking process days. These problems explain why many hunter-gatherers (Baka & Bangando) are now farming in the area.

Gathered products like bush yams (*Dioscorea spp*) and *Irvingia gabonensis* for example are elephants' favoured food when available (**Table 4-21**, page 85). However, the problems cited above lessen human-elephant competition for natural resources.

5.2.3.4 Fishing

Baka and Bangando eat all the fish species available in the study area. However, Baka males seldom fish. Women and children mostly do collective fish poisoning and fish bailing (they build a dam with mud, dead leaves and wood and bail water with buckets) in the dry season. Fishing with nets and hooks is carried out mainly by Bangando. This shows an example of specialisation in the subsistence activity, or role differentiation between Baka and Bangando; the Baka specialised in hunting and Bangando in fishing. Ichikawa (1987) presents this as "symbolic opposition" between hunting and fishing or between land and water.

Fishing activity is advantageous for elephant conservation in the area because it reduces bush meat demand and therefore elephant poaching.

5.2.3.5 Plant cultivation

Bahuchet and Maret (1994) define the farming system in the Central African rainforest as "simultaneous polycultures" since any cultivated area has many different species of plants (sometime more than 15 different species). Cassava and plantain do not have a harvesting season. They can be harvested for the next three to five years when needed. This maintains a constant supply of starchy food.

It is now rare for Baka to live only on hunting and gathering (less than 1% of total studied). They are hunter-gatherers in transition (Bahuchet and Grenaud, 1994). Farmers set snares for crop raiders around their gardens. This "agricultural hunting" provides them with an important part of their protein and alternates with trapping in the forest and fallow lands. Farming provide both Baka and Bangando with the most stable and important source of income (**Figure 4-52** & **Figure 4-53**, pages 105 & 106), and helps them overcome hunting uncertainty.

Plant cultivation, unlike subsistence activities requires less space. This lessens human-elephant competition for natural resources.

5.2.4 Importance of the forest for the indigenous peoples

Forest food contributes significantly to the diet of the Lobeke dwelling people. All households in the study area consume forest products on a daily basis. Many different fruits are eaten as snacks on the farm or in the forest. Gathered foods are added to sauces that accompany the starch staple for flavouring. They are also use as substitutes for staple food. For all the households in the Lobeke forest, bush meat (wild animal meat) is one of the most valued products of the forest. The forest is also a common source of freshwater fish, crabs and shellfish which provide source of calories and protein in absence of bush meat.

The forest is highly valued as source of medicine. The indigenous people use plant medicines throughout the area. Knowledge and use of plants medicines is not confined to specialist healers. By far the most common and important use of medicinal plants is as self-administered first aid. Women play a key role in first aid treatments as they are usually the first to diagnose and treat their children's illness. The indigenous people pass on their knowledge of plant medicine treatments in the family. Even young children know many medicine plants. All people interviewed in the Lobeke area use medicine plants and rely on them as their main medicine source, turning to western-type medicine only when the traditional ones fail. The most common medicine plants are obtained in fallow lands. However, the primary forest is also valued as a source of medicine. For a particular ailment, people will travel great distances in the forest to find a specific plant. Many of these plants are not cut down during farm clearance because of their medicinal value.

The indigenous people of the Lobeke forest rely on the forest for building material. In all villages, Baka and Bangando highlighted the importance of the forest for building materials such as tree saplings, raphia leaves and canes. The type of material used depends on the household's disposable income and the intended use of the building. The most important qualities of building materials are the durability and insect resistance. The Baka and Bangando build their houses with mud and wattle. They use sapling-sized trees as standing poles and raffia (leaf petioles) making lattice structure which is tied together using canes or other forest climbers. They use raffia leaves as roofing material.

Every household uses items such as pestles, mortars and basket to carry food made from forest products. Forest resources are also used for furniture, brooms, sleeping mats, pit latrines, bath huts and ladders. Each household make its own items, however, they buy carved articles as mortars or pestles from local producers. The forest also supplies materials for most agricultural equipment: wood for hoe and other tool handles, and canes for baskets and crop drying mats. Cane baskets are used to carry bush meat, food or fuel wood from the forest to the village. Fishing equipment is also made with canes.

All people rely on fuel wood to meet major energy needs. Most fuel wood is collected from farm and fallow lands. The supply of fuel wood is not a problem in the Lobeke forest, even when large quantities are needed for wild meat smoking.

Both Baka and Bangando can be described as farmers-hunters-gatherers. Hunting and gathering activities supplement their diet with natural products while the agriculture supplies the staple starchy food.

5.2.5 Interrelations between Baka Pygmies and Bangando Bantu

Half a century ago, Baka pygmies' economy was based on hunting and gathering. This means that they were exploiting natural resources without modifying the ecosystem (i.e. no agriculture). They were living in traditional temporary huts, exploiting an area of the forest with defined boundaries. Some aspects of that life style remain unchanged; for example they do not have craftsmen and the only pet they have is the dog. The simplicity of their technology makes it possible for everyone to make rudimentary tools with a wide range of utilisation.

The past socioeconomic relationship between these two ethnic groups (Baka and Bangando) involved the exchange of forest products (game, honey, mushrooms, caterpillars), plantation work and other services provided by Baka Pygmies hunter-gatherers with iron, pottery artifacts and village products (plantain, cassava, local gin, tobacco, Indian hemp) provided by Bangando Bantu farmers. Bahuchet (1992) illustrated this interdependence (or symbiosis) by presenting their economic association as "a way to exploit two different ecosystems, with specialisation": the Pygmies using farms through Bantu and at the reverse, Bantu using the inner part of the forest through exchange with Pygmies. Nowadays, Baka scarcely accept being paid in kind.

The origins of these dramatic changes in Baka-Bangando relationships were triggered with the introduction of cash crop farming (coffee and cocoa) which had as a consequence the increase circulation of banknotes in the region (Althabe, 1965). In the new situation with a cash-based economy, the original symbiotic relationship withered.

A different phenomenon, but having the same origin, lead to the same result. Baka Pygmies belonged to their masters as children to their parents. For the other villagers, they were not responsible for their acts. Masters had therefore to pay for thefts committed by Baka in other peoples' farms. As remedy to this problem, they compelled Baka to create their own cassava and plantain farms.

Thus two different phenomena, with the same origin, contributed to a total change of Baka's life style from specialised hunter-gatherers to farmers.

In summary, the introduction of farming, a new economic technology in the Baka's society triggered an economic upheaval, a sociological upheaval and an ecological upheaval all of which have implications for the Lobeke forest.

1) Economic upheaval

Farming requires that people become sedentary. However, the introduction of farms in the Baka's society did not lead to the elimination of hunting and gathering. In the rainy seasons, they continue hunting but long hunting expeditions aimed at killing big game such as elephants are replaced by short snare hunting expeditions for medium-sized mammals such as bush pig, duikers and porcupines (Althabe, 1965). All survival activities were now converging toward the village along communication routes as farming activities grow.

The introduction of money in Baka's life is a fundamental event. Its psychological importance was by far bigger than its real value (they were receiving a salary of about $0.01 per working day) (Althabet, 1965). They could not read or write but they knew the value of each banknote and therefore were able to add them qualitatively and provide or receive the right amount of money (Althabe, 1965). Money for the Baka gave them access to european objects. However, they were not able and are still not able to fix a fair price to items like bush meat, crossbow, axe and drum. This explains why earnings are always lower than Bangando's, even when more products are sold.

2) Sociological upheaval

Although polygamy was accepted (Althabe, 1965), the Baka's nomadic live made it rare and exceptional. With the sedentary life style, the number of polygamists increased. This was due to the introduction of a dowry in the Baka society. A dowry was generally paid with money and european objects (watch, loincloth, bucket, etc.). Banknotes given in a dowry were only used for it. Money had therefore two ways of circulating among Baka: The first was economic and the second and the most important one was matrimonial. The dowry favoured polygamy in the Baka society in which the monogamy was linked to the exchange system (Althabe, 1965).

3) Ecological upheaval

Although Baka pygmies remain professional hunter-gatherers and Bangando Bantu professional farmers, there is presently a dramatic change in their economic association. The barter economy is disappearing. Most items are paid for in cash. They no longer exploit two different ecosystems (Bahuchet, 1992) although the Baka exploit the farthest parts of the forest for hunting and fishing activities. All survival activities tend to overlap in space. Both Baka and Bangando exploit the same ecosystem for hunting, fishing, farming and gathering during the same seasons.

5.2.6 Regional and International relation

The Baka and Bangando are influenced by two external economic forces: an increased regional demand for bush meat in logging towns and main cities and an international demand for cash crops (cocoa and coffee). For the Baka Pygmies these economic changes create a continuum (Bahuchet, 1992), from hunter-gatherers with their symbiotic relationships with Bangando, to farmers (food crop and cash crop) and professional game producers. Farming and hunting allow both Baka and Bangando to supply regional markets (with food and meat) as well as the international market (with cash crops) therefore provide returns. Bahuchet (1992) pointed out the advanced evolution of the Baka pygmies compared to their neighbours the Aka. Almost all the Baka in the eastern Cameroon are farmers and some even have cocoa plantations. Nowadays, Baka employ other Baka in their farms and pay them as do the Bangando.

5.3 Conservation of elephants in the proposed Lobeke forest reserve

Large mammals like elephants require a large amount of food and water and must travel far to satisfy the requirement. Seasonal movements often encompass an area far bigger than that of reserves and National Parks set aside for their protection (Wilcove & May, 1986). These aspects of ecology illustrate the particular difficulty posed in the conservation of migratory species like elephants. According to Shaffer (1981), a reserve is intended to maintain a stable and self-sufficient population of biota in the interior, by means of protection and management.

The ideal solution is to make reserve boundaries more compatible with ecological realities (Wilcove & May, 1986). To make the Lobeke reserve big enough to encompass the elephant range is impossible for three reasons:

1) Elephant range goes far beyond the international boundaries of Cameroon-Central African Republic and Cameroon-Congo.

2) The northern extent of elephant range remains unknown.

3) The needs of the local people have not been taken into account.

Schonewald-Cox & Bayless (1986) proposed that the administrative boundary of a reserve should be "a filter that is activated by the mandated regulations stating how people should behave with respect to the reserve". Ecological change will be induced by human response to the filter. Machlis & Tichnell (1985) observed that sociological properties associated with surrounding land use and human communities in a reserve's vicinity both influence and are influenced by the boundary. Indigenous peoples generally perceive reserves as government-imposed restrictions on their rights (Oldfield, 1988). To be enforced in the long term, laws should have popular support (Oldfield, 1988). If the survival or welfare of the indigenous peoples is threatened, they would probably ignore regulations on resource exploitation (Schonewald-Cox & Bayless, 1986). These observations imply that variables concerned not only with the ecology of elephants, but also with the culture and economy of the indigenous peoples, must be brought together in the analysis.

This work has shown that the indigenous peoples of the Lobeke forest rely on its natural resource base for food, shelter, medicine and commerce. Makombe (1994) observed that the use of high profile species such as elephant, gorilla, and rhino are in a centre of a new conflict in Africa, between those who believe that preservationist strategies are the only option for the survival of Africa's wildlife and those who believe that conservation must include the economic utilisation of wildlife. Neither side would hardly deny that success depends on providing benefits to the local people.

The definition of conservation by Passmore (1974) does not prevent the use of natural resources or other types of land use. If indigenous peoples are prevented from using wildlife legally, they will tend to eliminate it by illegal use. Conservation emphasizes the need for the indigenous peoples to manage biological diversity as an essential foundation for the future, to maintain wildlife populations for their benefit and use species sustainably to enhance their quality of life. As such, natural resources management will profit immensely from the genuine involvement of the indigenous peoples. The Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) project in Zimbabwe shows that indigenous peoples can effectively organise and take action when they recognise clear benefits from their conservation efforts.

Preservation implying that natural resources currently in short supply must be saved from use so as to be in plentiful supply later emphasizes the role of guarding natural resources from inappropriate uses. The positive aspect of this concept is that it secures the future, but natural resources may remain forever untouched and therefore valueless for the indigenous peoples.

It is obvious in the case of the Lobeke forest that the indigenous peoples will continue to use natural resources. The indigenous peoples should take part in planning the area, understand and agree with its purpose. Hunters are always referred to as poachers. Less attention is given to the fact that they have few, if any, alternative options to using available wildlife resources. Much of the game meat eaten in the Lobeke area is derived from small animals (**Table 4-24**, page 97). The results of this work have shown that indigenous peoples of the Lobeke forest have long entered the market economy. Economic activities are based on game hunting and harvesting from the wild. Cash income derived from the collection and sale of wild products is of great value to the indigenous peoples of the Lobeke forest and represents a large proportion of total household income. Wild resources supply most of the basic requirements.

It is clear from this study that there is a strong dependence on natural resources by the indigenous peoples. It is also clear that the rate at which natural resources such as wild game and lumbers are harvested to supply the internal and international market is most probably not sustainable in the long term (Stromayer & Ekobo, 1991). Use at present levels may lead, not only to loss of habitats, species and biodiversity but also to the loss of productive assets and resources vital to the indigenous peoples.

The conservation methods used in Cameroon to date separate people from wildlife. These methods have failed completely to stop people from using protected resources (pers. obs.) and have not ensured the survival of wildlife. In the case of the Lobeke forest, the indigenous peoples have been using natural resources and will continue to do so. The challenge of ensuring the survival of wildlife while meeting the needs of local communities will be met only when economic and institutional structures are put in place, allowing people to use and manage the resources sustainably.

5.3.1 New strategies

The aim of the new strategies should be to link the needs of the indigenous peoples of the Lobeke forest to the renewability of natural resources. The use of natural resources, whether sustainable or unsustainable, is a fact of life in the Lobeke forest. Irrespective of whether use is for subsistence or commercial purposes, the forces that drive demand and consumption have proven to be so resilient as to render most protection strategies futile in the long term (e.g. Korup National Park, pers. obs.).

5.3.1.1 Sustainable use of natural resources in the reserve

Low impact sustainable use such as fishing in the Lobeke river, harvesting bush yams, caterpillar, honey, medicine, fruits and traditional hunting for subsistence should be allowed in the reserve. Animals such as elephant and Bongo can be sustainably harvested. For instance, licences can be sold to safari hunters and the revenues shared between the government and the local communities. Such an approach offers the indigenous peoples real incentive for accepting the reserve as more than just an inconvenience or an economic cost. The Department of National Parks and Wildlife in Malawi promotes natural resources use as a complement to agriculture in the form of bee keeping and caterpillar use in Kasungu National Park, Malawi (Makombe, 1994).

5.3.1.2 The buffer zone strategy

Mackinnon (1981) defined buffer zones as "Areas peripheral to National Parks or reserves which have restrictions placed on their use to give an added layer of protection to the nature reserve itself and to compensate villagers for the loss of access to strict reserve areas". In Cameroon, a buffer zone is defined as "A protection zone situated at the periphery of each National Park, nature reserve or wildlife reserve, intended to mark a transition between these areas and the areas where hunting and agriculture can be freely practiced". It is subject to the same protection as Parks and Reserves except that the Director of the protected areas may authorise agriculture and habitation (Oldfield, 1988).

The eastern boundary of the Lobeke reserve is at about 31 km from the nearest village and only about 25% of the indigenous peoples venture that far (they are generally helped by logging company's trucks to get there). A buffer zone of 10 km wide (**Figure 5-1**) surrounding the reserve is a minimal recommended. The forest is surrounded by people engaged in subsistence or commercial activities. The buffer zone would seek to enlist the indigenous peoples as co-managers and beneficiaries of resources on the edge of the reserve, instead of their being treated currently as enemies.

- The ecological benefit will be extra protection to the protected core zone and a larger forest unit for elephants.

- The socio-economic benefit will be that indigenous peoples will have full access to natural resources in the buffer zone.

The essence of a buffer zone management would be to generate local interest and support for the reserve, through the provision of economic and development benefits. Local support is essential to maintain the reserve and it could also be invaluable to help monitor illegal use by outsiders.

Diamond (1976) and Diamond & May (1976) suggested that two dimensions: the area and the perimeter are needed to determine "an area-to-perimeter" (a/p) ratio. This is used as a measure of the exposure of a reserve's interior to the exterior. For "bar-shaped" reserves, the a/p ratio is low and the average distance from any interior point to the nearest boundary point is small. External processes in such cases would have a stronger influence on internal processes. The a/p ratio is high for a "circular" reserve of the same area. The average distance from any interior point to the boundary is increased and the exposure is decreased (Schonewald-Cox & Bayless, 1986). In the case of the proposed Lobeke reserve which is 2,125 km^2, the upper limit of the a/p ratio (circular shape) at which the system would approach self sustainment is 46.1. The perimeter of the proposed reserve is about 184 km, giving an a/p ratio of 11.5. This suggests that strong protection and management actions will be necessary for the conservation of the Lobeke forest. However, the proposed buffer zone will increase available habitat and decrease potential exposure to adverse impact.

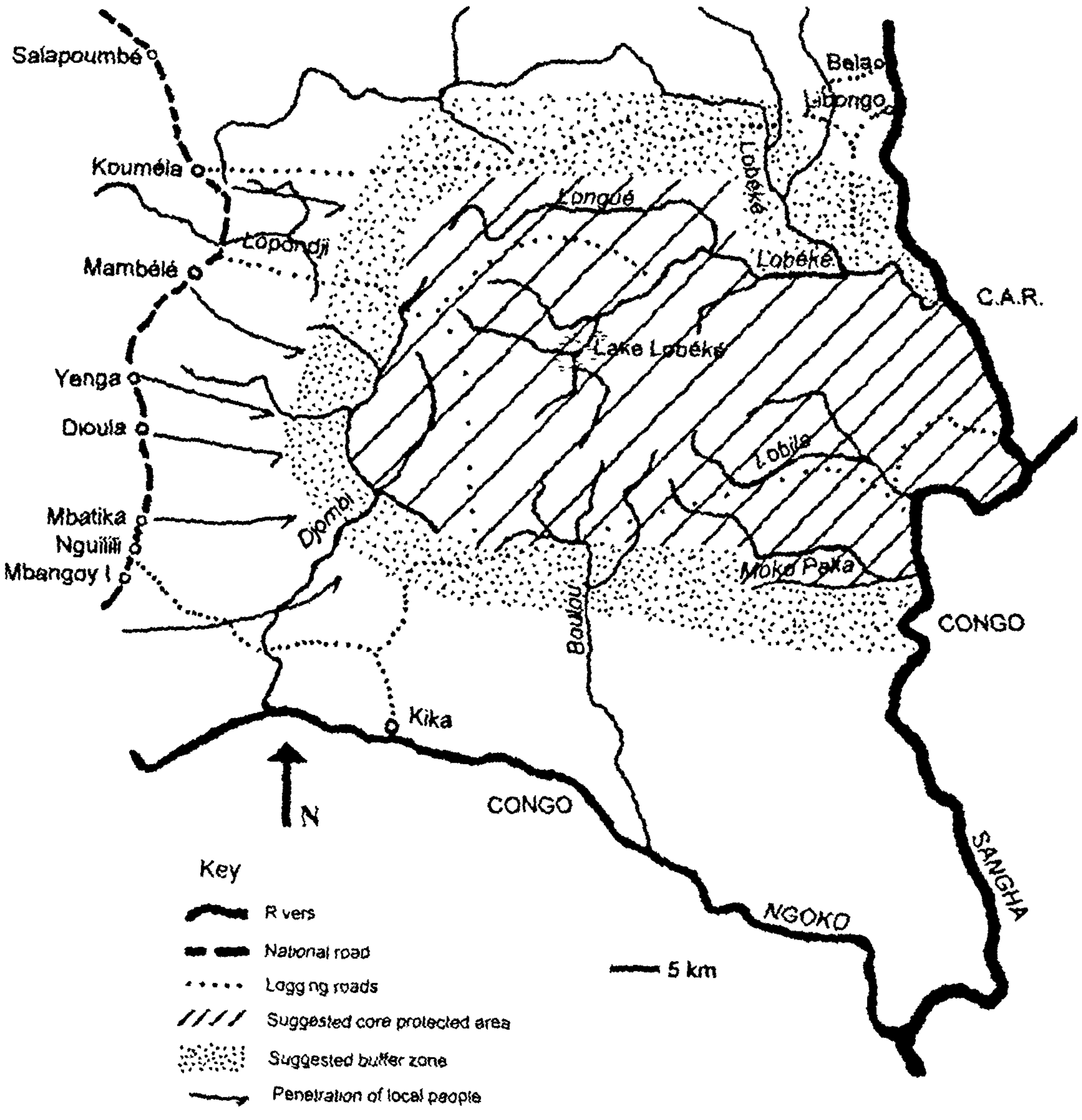


Figure 5-1: Map of the proposed Lobeke forest reserve showing the suggested core protected area and the buffer zone.

5.3.1.3 The Lobeke reserve managed by the indigenous peoples

Enforcement of wildlife regulations falls to the Department of Wildlife and Protected Areas (DWPA) which is placed under the Ministry of Environment. In reality, even rudimentary law enforcement is greatly handicapped by a general lack of resources and trained staff (Ekobo, 1994). It is not surprising that conservation laws have frequently been dismissed as unforceable.

For long-term development, management and sustainable utilisation of natural resources in the Lobeke forest, the DWPA might consider placing the custody and responsibility of the reserve with the resident communities, allowing them to benefit directly from the exploitation of natural resources within the reserve. The DWPA and conservation agencies would need to establish the administrative and institutional structures necessary to make the programme work. By enabling the indigenous population to derive real benefits from wild resources through controlled and sustainable utilisation, natural resources will be transformed into a valuable asset that is both protected and managed. The local community will reduce illegal harvesting and ensure that use is limited to sustainable off-takes. The indigenous peoples would thus be rational and cost-effective managers.

Chapter 6

RECOMMENDATIONS AND CONCLUSION

6.1 Recommendations

6.1.1 Research

Research on forest elephants is of the utmost importance. Their conservation and management in the Lobeke forest should involve active research and monitoring to establish a sound ecological basis for any major management decisions. The research unit of the conservation project must provide information whenever required. For this need to be fulfilled, the following recommendations are made:

1) Research should be undertaken to determine the total elephant range and possible migratory routes used. Two methods could be applied: the line-transect method and radio tracking. Radio tracking would yield good information only if many individuals (of different family units) are monitored. The sample must be representative of the population.

The result of the present work showed that a nucleus of elephants (about 2,125 individuals) stay permanently in the area. The monitoring of one or two individuals will bias results on elephant movements and range. However, radio-tracking a representative sample of individuals is very expensive, even if satellite tracking is used.

The transect method is labour intensive but it may yield good results if the area is well stratified. Both methods (radio tracking and line transect) should be used simultaneously. The maintenance of migratory routes will allow elephants to spread out and utilize a large and more heterogeneous total range. Thus, there will be a permanent efficient utilization of the total range, less danger of over utilisation in certain areas, higher assurance that the elephants' nutritional requirements will be fulfilled, and a greater potential for maintaining the elephant population compatible with the forest.

2) The Lobeke forest contains *the highest estimate of forest elephant density in* Africa (**Table 5-1**). Thus it is an important conservation area. Research and monitoring the status of this elephant population should be a top priority activity of the research unit. This should include seasonal distribution and movements. The method suggested here is the line transect. The stratification method design for this study should be reused. That will maintain continuity in data collection and make results comparable from year to year. It will also show changes in the distribution pattern over the years.

3) The research unit should collect data on defecation rates and dung decay rates to improve the accuracy of the population estimates. The striking point on the defecation rate is that it varies significantly over the seasons in the savanna ecosystem. Its fluctuations seem not to be significant in the forest, suggesting seasonal changes in food quality are not so marked. More data are needed before any final conclusion is drawn.

4) The elephant population structure and social organisation study should be expanded. There are three important clearings in the Lobeke forest that could be used for this work although data collection should not be limited to clearings as there will be variations due to vegetation type.

5) Dietary analysis should also continue. The present survey was concentrated on conspicuous feeding signs. The disadvantage of this method is that it takes longer to get an exhaustive list of the species used by elephants. It should however be used in conjunction with dung study. The data collected will show any relation between food distribution and elephant distribution.

6) The lack of records on elephant poaching in the Lobeke forest made it impossible for this survey to undertake a complete population study. Elephant poaching should therefore be monitored closely.

7) The research unit should consider establishing a computerized data base for elephant records. The data base would ensure data are readily available. Various

data analyses, including trends and projections for the future should be carried out. This would facilitate sound management policies and decisions based on up-to-date scientific data.

8) A detailed vegetation study should be undertaken in the Lobeke forest preferably in each cell established for elephant study. The location of the quadrats in each cell should be randomly determined as for elephant transects. This will re-define the distribution of elephants in relation to the vegetation type.

9) It is important to continue studies to determine appropriate non-destructive uses of the Lobeke forest resources, in order to both enhance the indigenous peoples socio-economic well being and protect the plants and animals of the area. A systematic study of the hunting and poaching activities inside and outside the reserve is very important as it allows assessment of hunting pressure.

10) The indigenous peoples have been fishing in the Lobeke river for centuries. The Lobeke river is located in the proposed protected core area. The research unit should consider studying the impact fishing activity in the Lobeke river would have on the reserve (animal distribution, edge effect). The local people should be allowed to go fishing if the results of that study shows a negligible impact.

6.1.2 Conservation

Conservation of the Lobeke forest should have a dual goal of improving the management of natural resources and the quality of life for people. If properly implemented, an integrated conservation and development project will offer new alternatives that will be successful at conserving elephants in the Lobeke forest. Baka and Bangando who will be most directly affected by the conservation project must perceive that it serves their economic and cultural interests. An approach based on barriers and punishment will not prevent unsustainable use of resources in the area over the long term. The following recommendations are made for planning the project.

1) Baka and Bangando are not a homogeneous group of community members; rather they differ in terms of their access to resources, their use of resources and their place within the community. It is essential that project planners identify and

take into account this diversity to ensure that these two ethnic groups, expected to adopt new behaviours, are in fact targeted and participate in the project.

2) The incorporation of Baka and Bangando knowledge systems, including information on specific aspects of resource management and use, trends in resource availability, and socio-cultural factors impacting the resource base, will have a critical role to play in the design of an integrated conservation and development project in the Lobeke forest. This will give the project design a better chance of meeting its development and conservation goals than if it tries to impose externally developed technologies and institutions.

3) During the conservation project design, relevant policies (e.g. the policy environment including economic, agricultural, and other resources policies) that can influence the project must be reviewed. Changes to enable project success must be identified and the feasibility of achieving the policies' changes assessed.

4) The stewardship and ownership of natural resources is at the heart of sustainable and conservation development planning. Maximizing local stewardship over resources must be considered vital for the success of a conservation project in the Lobeke forest. The onus of responsibility must be on project designers to guarantee, wherever feasible, that local communities receive the necessary training to allow them to meet their objectives and assume optimal management responsibility in the project. However, this should be done within the context of all stakeholders' interest. This means that planners must balance, or ensure a process for balancing, the long-term, collective interests of the government with the short-term individual of the resource users (Baka and Bangando).

5) It will be important to consider the relationship between the conservation and development objectives. All material benefits of the project must be clearly tied to its conservation actions. The Baka and Bangando must perceive development activities as incentive for sustainable management of the resources, the ultimate goal of the project.

6) It must be ensured that the conservation of the Lobeke forest offers viable, ecologically sound development alternatives, particularly if the conservation activities require the alteration of existing extraction of natural resources.

7) At least five components must be part of the conservation strategy of the Lobeke forest:

a) Research for planning, monitoring and evaluation

b) Conservation of the resource base and environmental management

c) Social and economic development

d) Institutional strengthening

e) Brokering and balancing the interests of stakeholder groups.

These project components must be supplemented by assistance to ensure an enabling policy environment.

8) It is highly recommended, given the wide range of activities, not to rely on a single institution to implement these varied components. Thus, the design phase must include a plan for who the actors are and what their responsibilities are, whether government bodies, local communities, development or conservation organisations. It will be important for participants to perceive themselves as partners in the project if management responsibilities are to be undertaken in a manner consistent with achieving project objectives.

6.2 Conclusion

Several aspects of elephant ecology in the Lobeke forest have been investigated as well as the ecology of the indigenous people. The results show that:

- The best method for elephant census in the forest is the line transect sampling of dung-piles. New developments in this technique by Buckland *et al.*(1993) have improved the methods of analysis.

- The highest density of forest elephants in Central Africa is found in the Lobeke forest.

- Elephant densities in the Lobeke forest show strong seasonal fluctuations, suggesting important movements in and out of the area.

- The Lobeke forest is an elephant refuge during the dry season.

- The Sangha drainage system is important for elephants in the Lobeke forest.

- The defecation rate in the forest ecosystem does not vary significantly over the seasons.

- Forest elephants tend to associate in smaller group sizes when compared with savanna elephants.

- Forest elephants spend the majority of each day feeding.

- Barks and leaves make up the bulk of the diet of forest elephants.

- Crop raiding by elephants is negligible in the Lobeke forest.

- The elephant population in the Lobeke forest has a sex ratio not significantly different from unity This is a sign of a healthy population. However, there is need for further field observations on the age structure of the population.

- For indigenous peoples, the forest contributes to their daily subsistence needs as well as providing the means of earning cash income. It also provides them with medicine, building materials, fuel wood and materials for all sorts of household articles as well as many less tangible benefits such as cultural symbols and ritual artifacts.

- Both elephants and the indigenous peoples are a totally integrated part of the complex Lobeke forest ecosystem.

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APPENDIX 1

SUMMARY OF DUNG DENSITIES (KM^{-2}) CALCULATED BY THE PROGRAMME DISTANCE FOR EACH CELL AND FOR EACH OF THE THREE SURVEYS

Cell number	Period of the survey		
	January-March 1993	May-August 1993	November 1993
1	4051.3	5072.2	327.83
2	0	725	0
3	736.6	3985.3	0
4	2578.1	1811.5	0
5	5892.8	0	0
6	11417	1449.2	327.83
7	24308	6521.3	1639.2
8	16574	6521.3	2622.7
9	1104.9	362.3	0
10	9207.6	362.3	327.83
11	11417	4347.6	1639.2
12	368.30	1086.9	0
13	20625	7970.5	983.5
14	7366	2898.4	1311.3
15	3314 7	7608.2	1311.3
16	2209 8	3623	655.66
17	6997.7	2898.4	5245.3
18	2946 4	6159	8523.6
19	4051.3	3260.7	3606.2
20	2209 8	5072.2	6884.5
21	1104.9	1086.9	3934
22	1473.2	2173.8	327.83
23	2578.1	7608.2	3934
24	736.6	5072.2	5573.1
25	2946.4	5434.4	3606.2
26	2946.4	2536.1	4589.6
27	1841.5	3985.3	0
28	2209.8	1449.2	655.66
29	4051.3	4709.9	2622.7
30	1841.5	5434.4	4261.8
31	5156.2	3623	1639.2
32	2578.1	6159	4917.5
33	368.3	7608.2	327.83
34	1473.2	7608.2	655.66
35	4051.3	3623	1311.3

Cell number	Period of the survey		
	January-March 1993	May-August 1993	November 1993
36	2209.8	1449.2	0
37	7734.3	3623	2622.7
38	1104.9	5434.4	4917.5
39	1473.2	2173.8	0
40	2209.8	6159	655.66
41	3683	724.59	0
42	1104.9	724.59	655.66
43	2209.8	6521.3	2622.7
44	3314.7	7608.2	6884.5
45	0	8332.8	4917.5
46	736.60	7970.5	1311.3
47	1473.2	2536.1	327.83
48	2209.8	1811.5	0
49	3314.7	16666	6556.6
50	14732	10144	3934
51	4419 6	7245.9	983.50
52	6997.7	7245.9	327.83
53	4051.3	4347.6	0
54	6261.1	10144	1967
55	2578.1	3623	5573.1
56	6997.7	7608.2	2622.7
57	4787.9	12680	327.83
58	7366	7608.2	327.83
59	19152	8332.8	327.83
60	18415	5434.4	0
61	3314 7	5796.7	4917.5
62	7366	8332.8	5901
63	18415	9782	655.66
64	22835	8332.8	983.5
65	19152	15941	983.5
66	23571	13043	5573.1
67	14732	6521.3	4261.8
68	10681	9782	327.83
69	11049	7608.2	2294.8
70	14364	9419.7	1967
71	16574	6883.6	4261.8
72	18047	5434.4	1967
73	13259	3260.7	1311.3
74	26886	3260.7	1311.3
75	7366	362.30	2294.8
76	9208	3261	1311

Cell number	Period of the survey		
	January-March 1993	May-August 1993	November 1993
77	368.30	2173.8	655.66
78	2578.1	2173.8	1311.3

2) Defecation rates of elephants in the Lobeke Forest during the dry period in 1993.

Date	Group size	Number of hours	Elephant hours	Number of defecation	Defecation rate per hour	Daily defecation rate (24 hours)
02/12/93	8	6	48	14	0.29	7.00
03/12/93	1	6.80	6.80	5	0.74	17.65
05/12/93	3	5.57	16.71	11	0.66	15.80
06/12/93	2	7.53	15.06	6	0.40	9.56
07/12/93	1	6.38	6.38	3	0.47	11.29
08/12/93	1	8.63	8.63	7	0.81	19.47
09/12/93	1	5.08	5.08	6	1.18	28.35
11/12/93	1	7.47	7.47	7	0.94	22.49
18/12/93	1	6.55	6.55	6	0.92	21.98
20/12/93	1	6.75	6.75	5	0.74	17.78
21/12/93	1	8.35	8.35	4	0.48	11.50
27/12/93	2	6.4	12.8	8	0.63	15.00
28/12/93	3	4.47	13.41	5	0.37	8.95
29/12/93	1	5.93	5.93	6	1.01	24.28
03/01/94	2	6 48	12.96	6	0.46	11.11
07/01/94	1	6 22	6.22	5	0.80	19.29
10/01/94	3	5.47	16.41	17	1.04	24.86
11/01/94	1	7.68	7.68	7	0.91	21.88
20/01/94	1	5 23	5.23	3	0.57	13.77
21/01/94	5	8.8	44	33	0.75	18.00
22/01/94	3	6 77	20.31	12	0.59	14.18
23/01/94	1	6.68	6.68	7	1.05	25.15
29/01/94	2	6.43	12.86	7	0.54	13.06
01/02/94	1	5.73	5.73	3	0.52	12.57
02/02/94	1	7.32	7.32	5	0.68	16.39

APPENDIX 3

Dung decay rate study in the Lobeke forest from May to November 1993.

t_d	t_D	t_E	R	$t_D + R$
25/05/93	08/06/93	15/06/93	2	16
25/05/93	15/06/93	22/06/93	3	24
25/05/93	18/06/93	25/06/93	2	26
25/05/93	22/06/93	29/06/93	0	28
25/05/93	29/06/93	06/07/93	1	36
25/05/93	13/07/93	20/07/93	6	55
25/05/93	20/07/93	27/07/93	0	56
25/05/93	20/07/93	27/07/93	2	58
25/05/93	20/07/93	27/07/93	4	60
25/05/93	27/07/93	03/08/93	1	64
25/05/93	03/08/93	10/08/93	6	76
25/05/93	03/08/93	10/08/93	6	76
25/05/93	18 08 93	25/08/93	3	88
25/05/93	24/08 93	31/08/93	7	98
25/05/93	31 08 93	07/09/93	4	102
25/05/93	14 09 93	21/09/93	0	112
25/05/93	14 09 93	21/09/93	1	113
25/05/93	14 09 93	21/09/93	2	114
25/05/93	14 09 93	21/09/93	6	118
25/05/93	21 09 93	28/09/93	1	120
25/05/93	21 09 93	28/09/93	3	122
25/05/93	21/09 93	28/09/93	4	123
25/05/93	21/09 93	28/09/93	5	124
25/05/93	28/09 93	05/10/93	1	127
25/05/93	05 10 93	12/10/93	1	134
25/05/93	05/10/93	12/10/93	7	140
25/05/93	12/10/93	19/10/93	3	143
25/05/93	12/10/93	19/10/93	3	143
25/05/93	12 10 93	19/10 93	3	143
25/05/93	12/10/93	19/10/93	3	143
25/05/93	12/10/93	19/10/93	5	145
25/05/93	09/11/93	16/11/93	2	170
25/05/93	09/11/93	16/11/93	3	171
25/05/93	09/11/93	16/11/93	3	171
25/05/93	09/11/93	16/11/93	5	173
25/05/93	09/11/93	16/11/93	6	174

t_d	t_D	t_E	R	$t_D + R$
25/05/93	09/11/93	16/11/93	7	175
25/05/93	16/11/93	23/11/93	2	177
25/05/93	16/11/93	23/11/93	7	182

t_d = date the dung-pile was deposited
t_D = last date recorded as D
t_E = first date recorded as E
R = random number between 0 and 7
t_D + R = survival or duration time

APPENDIX 4

ELEPHANT DENSITY IN EACH CELL FOR EACH OF THE THREE SURVEYS.

Cell number	Period		
	January-March 1993	May-August 1993	November 1993
1	1.8	2.3	0.1
2	0.0	0.3	0.0
3	0.3	1.8	0.0
4	1.2	0.8	0.0
5	2.7	0.0	0.0
6	5.2	0.7	0.1
7	11.0	3.0	0.7
8	7.5	3.0	1.2
9	0.5	0.2	0.0
10	4.2	0.2	0.1
11	5.2	2.0	0.7
12	0.2	0.5	0.0
13	9.3	3.6	0.4
14	3.3	1.3	0.6
15	1.5	3.4	0.6
16	1.0	1.6	0.3
17	3.2	1.3	2.4
18	1.3	2.8	3.9
19	1.8	1.5	1.6
20	1.0	2.3	3.1
21	0.5	0.5	1.8
22	0.7	1.0	0.1
23	1.2	3.6	1.8
24	0.3	2.3	2.5
25	1.3	2.5	1.6
26	1.3	1.1	2.1
27	0.8	1.8	0.0
28	1.0	0.7	0.3
29	1.8	2.1	1.2
30	0.8	2.5	1.9
31	2.3	1.6	0.7
32	1.2	2.8	2.2
33	0.2	3.4	0.1
34	0.7	3.4	0.3
35	1.8	1.6	0.6

Cell number	Period January-March 1993	May-August 1993	November 1993
36	1.0	0.7	0.0
37	3.5	1.6	1.2
38	0.5	2.5	2.2
39	0.7	1.0	0.0
40	1.0	2.8	0.3
41	1.7	0.3	0.0
42	0.5	0.3	0.3
43	1.0	3.0	1.2
44	1.5	3.4	3.1
45	0.0	3.8	2.2
46	0.3	3.6	0.6
47	0.7	1.1	0.1
48	1.0	0.8	0.0
49	1.5	7.5	3.0
50	6.7	4.6	1.8
51	2.0	3.3	0.4
52	3.2	3.3	0.1
53	1.8	2.0	0.0
54	2.8	4.6	0.9
55	1.2	1.6	2.5
56	3.2	3.4	1.2
57	2.2	5.7	0.1
58	3.3	3.4	0.1
59	8.7	3.8	0.1
60	8.3	2.5	0.0
61	1.5	2.6	2.2
62	3.3	3.8	2.7
63	8.3	4.4	0.3
64	10.3	3.8	0.4
65	8.7	7.2	0.4
66	10.7	5.9	2.5
67	6.7	3.0	1.9
68	4.8	4.4	0.1
69	5.0	3.4	1.0
70	6.5	4.3	0.9
71	7.5	3.1	1.9
72	8.2	2.5	0.9
73	6.0	1.5	0.6
74	12.2	1.5	0.6
75	3.3	0.2	1.0
76	4.2	1.5	0.6

Cell number	Period		
	January-March 1993	May-August 1993	November 1993
77	0.2	1.0	0.3
78	1.2	1.0	0.6

APPENDIX 5

ENVIRONMENTAL FACTORS AND HUMAN ACTIVITIES FOUND IN EACH CELL

Cell	Forest type	Road	Water	Hunting	Relief	Swamp
1	1	1	1	0	0	0
2	1	1	1	1	0	1
3	1	1	0	0	0	1
4	1	1	1	1	0	1
5	1	0	0	0	0	1
6	1	0	0	0	0	0
7	1	0	1	0	0	1
8	1	0	1	0	0	0
9	1	0	0	0	0	0
10	1	0	1	0	0	1
11	1	0	0	0	0	0
12	1	0	1	0	1	0
13	0	0	1	0	0	0
14	0	0	1	0	0	1
15	0	0	1	0	0	1
16	0	0	1	0	1	0
17	1	0	1	0	1	1
18	1	0	1	0	1	0
19	0	0	1	0	0	1
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	1	0	0	1
23	1	0	0	0	0	0
24	1	1	1	0	1	1
25	0	0	1	0	0	0
26	0	0	0	0	0	1
27	0	0	1	0	0	1
28	1	0	1	0	0	1
29	1	0	1	0	0	0
30	1	1	1	0	1	0
31	0	0	0	0	0	1
32	0	0	1	0	0	1
33	0	0	0	0	0	0
34	1	0	1	0	0	0
35	1	0	1	0	0	0
36	1	1	1	0	0	0
37	0	0	1	0	0	1
38	0	0	1	0	0	0
39	0	0	0	0	0	0
40	1	0	1	0	0	0
41	1	1	1	0	0	0
42	1	0	1	0	0	1
43	0	0	1	0	0	1
44	0	0	0	0	0	1

45	0	0	1	0	0	1
46	1	0	1	0	1	0
47	1	1	1	0	0	0
48	1	0	1	0	0	0
49	0	0	1	0	0	0
50	0	0	0	0	0	0
51	0	0	0	0	1	0
52	1	0	1	0	1	0
53	1	1	0	0	0	1
54	1	0	1	0	0	1
55	1	0	1	0	0	0
56	0	0	1	0	1	1
57	1	0	1	0	0	0
58	1	0	1	0	0	0
59	1	0	1	1	0	0
60	1	1	1	0	0	1
61	1	0	1	0	0	1
62	1	0	1	0	0	1
63	1	0	1	0	0	0
64	1	0	1	0	0	0
65	1	0	1	0	0	0
66	1	0	0	0	0	0
67	1	0	0	0	0	0
68	1	0	1	0	0	0
69	1	0	0	0	0	0
70	1	0	0	0	0	0
71	1	0	1	0	0	1
72	1	1	1	0	0	1
73	1	0	0	0	0	0
74	1	0	1	0	0	0
75	1	0	1	1	0	0
76	0	0	1	0	0	0
77	0	0	0	0	0	1
78	0	0	1	0	0	0

Note:
For the Forest type, 1 = Primary forest and 0 = Logged forest. For the Relief, 1 = Hilly and 0 = Flat. For Water, Swamp and Road, 1 = Present and 0 = Absent.

APPENDIX 6

SAMPLE OF THE QUESTIONNAIRE USED FOR THE STUDY OF HUMAN ECOLOGY

ENQUÊTE ELABORÉE PAR L'INSTITUT DURRELL DE L'UNIVERSITÉ DE KENT (ANGLETERRE) POUR LE COMPTE DU PROJET WWF. LAC LOBÉKÉ. CAMEROUN.

Nous sommes en train d'étudier comment vous vivez ici. Ceci nous permettra de connaître ce qu'il faudrait faire pour améliorer et protéger votre système de vie ainsi que les terres sur lesquelles vous vivez.

Enquête No: 1 Nom du village: [illegible] Date: 10-9-93
Nom de la personne à qui on pose les questions: [illegible] - Gasinado
Sexe: ([✓ masculin]/féminin) âge: 45 ans Ethnie: Bangando
Situation familiale: ([✓ marié(e)]/célibataire/veuf(ve)) Nombre d'épouses: 4
Nombre d'enfants: 4
1) Votre façon de vivre a-t-elle beaucoup changé depuis votre enfance? ([✓ Oui]/Non)
Si oui dans quels domaines? Santé - éducation [illegible]

2) Avez-vous déjà travaillé dans une société d'exploitation forestière? ([✓ Oui]/Non)
Si oui
-Dans quelle société? CCGS
-Pendant combien de temps? 2 ans (Période de 1972 à 1974)
-Vous y travailliez en qualité de quoi? tronçonneur
-Combien gagniez-vous par mois? [illegible]
-Aimiez-vous votre travail? (Oui/[✓ Non]) Pourquoi? [illegible]

3) Allez-vous souvent au Lac Lobéké? ([✓ Oui]/Non)
Si oui
-Combien de fois par année? 1 fois
-Pendant quelle saison y allez-vous? (grande saison sèche/grande saison des pluies/petite saison sèche/[✓ petite saison des pluies]).
-Y allez-vous seul, avec quelqu'un d'autre ou en groupe?
-Pourquoi y allez-vous? chasse

4) Faites-vous souvent la chasse?([✓ Oui]/Non).
Si oui
- Pourquoi chassez-vous? (Pour manger/pour vendre/ [✓ pour manger et vendre])
- Quelles sont les espèces animales que vous chassez généralement? (donnez les noms en Bagando, en Baka ou en Français) [illegible]
- Quelles sont les espèces d'oiseaux que vous chassez généralement? (donnez les noms en bagando, en Baka ou en Français) [illegible]

- Ramenez-vous tous les animaux que vous tuez au village? (Oui/[✓ Non])
Si Non
- Que faites-vous d'une partie de votre gibier? (Mange sur place/Vend sur place/[✓ mange une partie et vend une partie sur place])
- Ramenez-vous certains animaux vivants pour les garder au village? (Oui/[✓ Non])
- Mangez-vous toutes les espèces d'animaux ou d'oiseaux que vous capturez? ([✓ Oui]/Non)
Si non
Quel usage faites-vous de certaines de ces espèces? (remèdes/vente de la peau ou des plumes). Citez un ou deux exemples si possible.

- Est-ce que certains animaux sont un signe de malchance quand vous les trouvez dans vos pièges? (Oui/[✓ Non])
Si oui
- Donnez un ou deux exemples:
- Est-ce que certaines espèces vous sont taboues c'est-à-dire interdites d'être mangées ou chassées par votre clan ou par votre famille? ([✓ Oui]/Non)
Si oui
- Citez ces espèces (donnez les noms en Bagando, Baka ou en Français): Anvé

- Où chassez-vous souvent? (du côté de la Boumba/[✓ du côté de la Lobéké]/des deux côtés)
- Combien de jours de marche faites-vous de votre village à votre zone de chasse? 2 jours

- Pendant quelle saison chassez-vous (grande saison sèche/petite saison sèche/ grande saison des pluies/[✓ petite saison des pluies])
Dans le cas où vous chassez pour vendre ou pour manger et vendre.
- Que vendez-vous généralement? (animal entier vivant/[✓ animal entier mort]/ [✓ animal découpé en morceaux]/plumes/peaux/os)
- Combien d'argent gagnez-vous en vendant un animal? 2500 frs
- Combien d'animaux tuez-vous par semaine? 10 par mois?
- Que faites-vous de l'argent que vous gagnez? (garde/[✓ achète les habits]/[✓ les remèdes]/[✓ les choses pour la maison]/[✓ sel]/[✓ pétrole]/). Citez autres choses que vous faites de votre argent.
- Quelles sont les méthodes de chasse que vous utilisez? (fusil/[✓ piège]/filet/lance/arbalète/arc/trou). Encerclez les méthodes utilisées. Citez d'autres méthodes utilisées.

5) Faites-vous souvent la cueillette ou le ramassage des produits sauvages? ([✓ Oui]/Non)
Si oui
- Quels sont ces produits?
- Miel ([✓ oui]/non)
- Mangues sauvages ([✓ oui]/non)
- Autres fruits: (donnez les noms en Bagando, Baka ou en Français)

- Noix: (donnez les noms en Baka, Bagando ou en Français)

- Racines(comme les ignames) (donnez les noms en Baka, Bagando ou en Français)

- Feuilles:(donnez les noms en Baka, Bagando ou en Français)

- Ecorces:(donnez les noms en Baka, Bagando ou en Français)

- Où allez-vous souvent ramasser ou cueillir ces produits? ((du côté de la Boumba/du côté de la Lobéké/[✓ des deux côtés])
- Combien de jours de marche faites-vous de votre village à votre zone de ramassage ou de cueillette de ces produits sauvages? 2 jours
- Pendant quelle saison le faites-vous?(grande saison sèche/petite saison sèche/ [✓ grande saison des pluies]/petite saison des pluies)
- Pourquoi ramassez ou cueillez-vous souvent les produits sauvages? ([✓ pour manger]/pour vendre/pour manger et vendre)
Si c'est pour vendre ou manger et vendre
- Combien d'argent y gagnez-vous par saison?

- Que faites-vous de l'argent que vous y gagnez? (garde/achète les habits/les remèdes/les choses pour la maison/sel/pétrole/). Citez autres choses que vous faites de votre argent.

6) Faites-vous souvent la pêche? (Oui/[✓ Non])

Si oui

- Où allez-vous souvent pêcher? (à la Boumba/à la Lobéké/dans d'autres rivières)
- Citez les noms des autres rivières où vous allez souvent pêcher:

- Combien de jours de marche faites-vous de votre village à l'endroit où vous allez souvent pêcher?
- Pendant quelle saison faites-vous souvent la pêche? (grande saison sèche/petite saison sèche/ grande saison des pluies/petite saison des pluies)
- Combien de temps passez-vous à pêcher?
- Pourquoi faites-vous souvent la peche? (pour manger/pour vendre/pour manger et vendre)

Si c'est pour vendre ou pour manger et vendre.

- Combien d'argent gagnez-vous par saison de pêche?
- Que faites-vous de cet argent? (garde/achète les habits/les remedes/les choses pour la maison/sel/pétrole/) Citez autres choses que vous faites de votre argent.

7) Faites-vous souvent les champs? ([✓ Oui]/Non)

Si oui

- Quelles sont les cultures vivrieres que vous faites?: ([✓ plantain]/[✓ manioc]/[✓ macabo]/banane/igname/patate/tomate/pistache/arachide/ananas/[✓ gombo]/canne à sucre)
- Citez si possible d'autres cultures vivrières que vous faites: mais -

- Avez-vous une plantation de cacao? ([✓ Oui]/Non)
- Avez-vous une plantation de café? (Oui/[✓ Non])

Dans le cas ou vous avez une cacaoyère ou une caféière.

- Quelle est la superficie de votre plantation? 4 hectare
- Combien d'argent gagnez-vous par saison? 300 mille francs
- Que faites-vous de cet argent? (garde/[✓ achète] les habits/[✓ les remèdes]/[✓ les choses pour la maison]/[✓ sel]/[✓ petrole]/) Citez autres choses que vous faites de votre argent.
- A combien de jours ou d heures de marche sont situés vos champs et plantations? 50 mn
- Est-ce que vous vendez certaines de vos cultures vivrières? ([✓ Oui]/Non)
- Si oui lesquelles? plantain, manioc
- Combien vous rapporte la vente des produits vivriers: par semaine? 5 mille frs par mois? 20 mille -
- Que faites-vous de cet argent? (garde/[✓ achète les habits]/les remedes/les choses pour la [✓ maison]/[✓ sel]/petrole/) Citez autres choses que vous faites de votre argent.
- Comment préparez-vous vos champs? ([✓ défriche]/[✓ abat les arbres]/brûle)
- Qui vous aide dans vos travaux champêtres? (mes enfants/les Bakas/les Bagandos/ma femme/mon mari/les autres membres de la famille)
- Payez-vous ceux qui vous aident? ([✓ Oui]/Non)
- Si oui combien par jour de travail? 250
- Combien de champs faites-vous par année? 2
- Après la récolte combien de temps laissez-vous votre ancienne plantation avant d'aller y travailler encore? 4 ans
- Quelle est la superficie de votre champ de cultures vivrières? 1 hectare
- Les animaux sauvages détruisent-ils les cultures dans vos champs? ([✓ Oui]/Non)

Si oui

- Citez les noms de ces animaux: Singe

-Pendant quelle saison?([✓ grande saison sèche]/petite saison sèche/ grande saison des pluies/petite saison des pluies)
- Citez les noms des plantes qu'ils détruisent: plantain, maïs

8)- Avez-vous un poulailler? ([✓ oui]/non) Si oui combien de poules et coqs? 14 poules 1 coqs
- Avez-vous des chèvres? (oui/[✓ non]) Si oui combien?
- Avez-vous des moutons? (oui/[✓ non]) Si oui combien?
- Avez-vous un enclos pour votre bétail? (oui/non)
- Mangez-vous souvent vos poules et coqs? ([✓ oui]/non)
- Mangez-vous souvent vos chèvres et moutons? (oui/[✓ non])
- Si oui à quelles occasions les mangez-vous? réception des amis, fête
- Vendez- vous souvent vos poules et coqs? ([✓ oui]/non)
- Vendez-vous souvent vos chèvres? (oui/non)
- Vendez-vous souvent vos moutons? (oui/non)
- Si oui à quelles occasions les vendez-vous? manque d'argent
- A combien vendez-vous une poule? 800 frs un coq? 1000 frs
une chèvre? un mouton?

9)- Avez-vous un campement en brousse? ([✓ oui]/non)
Si oui
- A combien de jours ou d'heures de marche du village est-il situé? 30 mns
- Pendant quelle période de l'année y habitez-vous? saison cacaoyère
- Pourquoi avez-vous construit un campement en brousse? garder le champ

10)- A part la nourriture, quels autres produits prenez-vous de la forêt? ([✓ remèdes]/[✓ matériel de construction]/matériel pour faire les ustensiles de maison/[✓ feuilles pour emballage])
- Où prenez-vous ces produits? (dans les anciennes plantations/dans les forêts vierges)
- Combien de jours ou d'heures de marche faites-vous pour aller chercher ces produits? 3 jours

- Faire la conservation c'est ne pas tuer trop d'animaux, ne pas abattre trop d'arbres si bien qu'à l'avenir nos enfants ne manquent ni de quoi manger, ni de quoi se construire une maison.

11)- Que pensez-vous de la conservation? ([✓ bonne chose]/mauvaise chose/indifférent)
- Que pensez-vous si on établit un projet de conservation au Lac Lobéké? ([✓ bonne chose]/mauvaise chose/indifférent)

Si mauvaise chose, dire pourquoi?

- Et si on vous demande de ne plus aller au Lac Lobéké? pas de mécontentement

- Qu'attendriez-vous d'un tel projet? bonne exploitation [illegible]

- Que vous manque t-il dans votre village? eau, électricité, [illegible] médicament

APPENDIX 7

SAMPLE DATA SHEET USED IN THE DISTANCE SAMPLING IN THE LOBEKE FOREST

DATA SHEET RECORDING: DROPPING DENSITY

Date: 28/01/93 **Location:** [illegible] 1 **General vegetation type:** logged Forest
Season: LDS **Transect No:** LDS 1 **Topography:** Flat
Compass bearing: N **Weather:** Sunny **Sheet No:** 1
Starting time: 8:30 **Finishing time:** 14:30 **Observer:** AE

Dist.(m)	Xi (m)	(1)A – D	(2)Location of Dung	(3)Elephant signs	(4)Visibility index	Streams	Other notes: Change in vegetation, human signs, physical features, etc...
					VD		
145	0.00	C2					
15[illegible].50	0.55	C2			VD		
[illegible]61.5	1.76	D			VD		
					VD		
[illegible]	[illegible]	D			VD		
501.45	2.00	D					
514.30	1.47	C2					
515.60	2.67	C2					
5[illegible]	[illegible]	D			VD		
					VD		
					D		Cleaned logging road
491.50	1.00	C1			D		
9[illegible].70	2.65	D					
882.30	1.60	D					
958.75	0.00	D					
9[illegible].28	0.76	D			D		
1012.00	2.75	C1					
1045.20	4.05	D					
106[illegible]	2.30	D					
1066.00	1.20	D					
1066.45	2.20	D					
1078.64	2.20	D					
[illegible]	0.50	D					
[illegible]	1.55	D			D		
1104.70	0.00	C1					
[illegible].30	[illegible]	C2			D		old logging road
					D		
–					D		
1415.[illegible]	1.77	C2					
1433.[illegible]	2.20	D			VD		end of [illegible]
150[illegible]	[illegible]	C2			VD		
					D		
					D	1	Malapa Forest (at 1800m)
					D		

(1) A = Boli intact, fresh, moist with odour; B = Boli intact, fresh but dry, no odour; C1 = Some of the boli have disintegrated, but more than half are still distinguishable as boli; C2 = < 50% of the boli are distinguishable; D = dung-pile forms an amorphous flat mass.
(2) S= Shade; SO= Semi-open; O= Open canopy; PF= Primary forest; SF= Secondary forest; C= Clearing (savannah); SW= Swamps; FG= Forest Gap.
(3) Every 100m (Very dense (VD) = visibility < 5m; Dense (D) = visibility > 5m but < 10m; Open (O) = visibility > 10m)
(4) Feeding sign = FS; Foot print = FP; Digging = D;

DATA SHEET RECORDING: DROPPING DENSITY

Date: 28/01/93
Season: LDS
Compass bearing: W
Starting time:

Location: SQ 1
Transect No: LDS1
Weather: Sunny
Finishing time: 12:30

General vegetation type: Secondary
Topography: Flat
Sheet No: 2
Observer: AE

Dist.(m)	Xi (m)	(1)A - D	(2)Location of Dung	(3)Elephant signs	(4)Visibility index	Streams	Other notes: Change in vegetation, human signs, physical features, etc...
					D		
					D		
2152.45	1.50	C2					
[illegible]	[illegible]	C2					
2174.50	0.70	C1			D		
					D		
[illegible]	[illegible]	[illegible]					
					D		
[illegible]	[illegible]	[illegible]			[illegible]		
[illegible]	[illegible]	[illegible]			[illegible]		
[illegible]	[illegible]	[illegible]			[illegible]		[illegible]

(1) A = Boli intact, fresh, moist with odour; B = Boli intact, fresh but dry, no odour; C1 = Some of the boli have disintegrated, but more than half are still distinguishable as boli; C2 = < 50% of the boli are distinguishable; D = dung-pile forms an amorphous flat mass.
(2) S= Shade; SO= Semi-open; O= Open canopy; PF= Primary forest; SF= Secondary forest; C= Clearing (savannah); SW= Swamps; FG= Forest Gap.
(3) Every 100m (Very dense (VD) = visibility < 5m; Dense (D) = visibility > 5m but < 10m; Open (O) = visibility > 10m)
(4) Feeding sign = FS; Foot print = FP; Digging = D;

APPENDIX 8

EXAMPLE OF DATA INPUT FOR ANALYSIS BY DISTANCE PROGRAMME

```
; Line Transect - Perpendicular Distance, Ungrouped,
Unclustered
;
Options;
   Title='Lobeke Forest: January-March, 1993';
   Distance=Perp/Exact;
   Object=Single;
   Distance/Units='Meters';
   Length/Units='Kilometers';
   Area/Units='Sq. Kilometers';
End;
Data;
Sample /Effort=2.5 /Label='Transect 1';
0
.55
1.76
4.8
2.0
1.4
.
.
.
.
.
.
.
.
.
.
.
Sample /Effort=2.5 /Label='Transect 78';
0
1.04
1.12
1.8
3.2
.86
4.3
1.9
2.4
0
0
1.31
1.8
4.15
3.4
4.5
2.05
.73;
End;
Estimate;
   Estimator /Key=Uniform /Adjust=Cosine;
   Estimator /Key=Uniform /Adjust=Polynomial;
   Estimator /Key=HNormal /Adjust=Hermite;
   Estimator /Key=Hazard  /Adjust=Cosine;
End;
```

APPENDIX 9

OUTPUT OF RESULTS FROM DISTANCE PROGRAMME (ESTIMATION OPTIONS LISTING AND ENCOUNTER RATES ONLY)

```
                    ************************************
                    *        Estimation Options        *
                    *            Listing               *
                    ************************************

ameter Estimation Specification
-------------------------------
ounter rate by sample
ection probability for all data combined
sity by sample
led estimate of density is made from sample estimates treated as replicates

tances:
-------
lysis based on distance intervals
th specified as:     1.200000

imators:
--------
imator  1
: Uniform, k(y) = 1/W
justments - Function                 : Cosines
          - Term selection mode      : Sequential
          - Term selection criterion: Likelihood ratio test
imator  2
: Uniform, k(y) = 1/W
justments - Function                 : Simple polynomials
          - Term selection mode      : Sequential
          - Term selection criterion: Likelihood ratio test
timator  3
: Half-normal, k(y) = Exp(-y**2/(2*A(1)**2))
justments - Function                 : Hermite poynomials
          - Term selection mode      : Sequential
          - Term selection criterion: Likelihood ratio test
timator  4
: Hazard Rate, k(y) = 1 - Exp(-(y/A(1))**A(2))
justments - Function                 : Cosines
          - Term selection mode      : Sequential
          - Term selection criterion: Likelihood ratio test

timator selection: Choose estimator with minimum AIC
timation functions: constrained to be nearly monotone non-increasing

riances:
--------
riance of n: Empirical estimate from sample
riance of f(0): MLE estimate

odness of fit:
--------------
sed on grouped distance data intervals
 graph output created



ossary of terms
---------------

ta items:
   - number of observed objects (single or clusters of animals)
   - total length of transect line(s)
   - number of samples
   - point transect effort, typically K=k
   - length of time searched in cue counting
   - encounter rate (n/L or n/K or n/T)
   - width of line transect or radius of point transect
i) - distance to i-th observation
i) - cluster size of i-th observation
```

- probability for regression test
-p- probability for chi-square goodness-of-fit test

ameters or functions of parameters:
- number of parameters in the model
) - i-th parameter in the estimated probability density function(pdf)
) - 1/u = value of pdf at zero for line transects
- W*p = ESW, effective detection area for line transects
) - 2*PI/v
- PI*W*W*p, is the effective detection area for point transects
- probability of observing an object in defined area
- for line transects, effective strip width = W*p
- for point transects, effective detection radius = W*sqrt(p)
- estimate of density of clusters
) - estimate of expected value of cluster size
- estimate of density of animals
- estimate of number of animals in specified area

```
                    ******************************
                    *     Estimation Summary     *
                    *      Encounter rates       *
                    ******************************

atum:
                     Estimate       %CV      df      95% Confidence Interval
                  ------------------------------------------------------------
nple: Transect 1
              n      11.000
              k      1.0000
              L      2.5000
              n/L    4.4000        30.15      0      2.4681        7.8441
nple: Transect 2
              n      .00000
              k      1.0000
              L      2.5000
              n/L    .00000
nple: Transect 3
              n      2.0000
              k      1.0000
              L      2.5000
              n/L    .80000        70.71      0      .22965        2.7868
mple: Transect 4
              n      7.0000
              k      1.0000
              L      2.5000
              n/L    2.8000        37.80      0      1.3681        5.7307
mple: Transect 5
              n      16.000
              k      1.0000
              L      2.5000
              n/L    6.4000        25.00      0      3.9500        10.370
mple: Transect 6
              n      31.000
              k      1.0000
              L      2.5000
              n/L    12.400        17.96      0      8.7448        17.583
mple: Transect 7
              n      66.000
              k      1.0000
              L      2.5000
              n/L    26.400        12.31      0      20.760        33.573
mple: Transect 8
              n      45.000
              k      1.0000
              L      2.5000
              n/L    18.000        14.91      0      13.461        24.070
mple: Transect 9
              n      3.0000
```

```
                          ******************************
                          *      Estimation Summary    *
                          *       Encounter rates      *
                          ******************************

                         Estimate          %CV      df     95% Confidence Interval
                        ----------------------------------------------------------------
                 k       1.0000
                 L       2.5000
                 m/L     1.2000           57.74      0      .41939          3.4335
mple: Transect 10
                 m       25.000
                 k       1.0000
                 L       2.5000
                 m/L     10.000           20.00      0      6.7830          14.743
mple: Transect 11
                 m       31.000
                 k       1.0000
                 L       2.5000
                 m/L     12.400           17.96      0      8.7448          17.583
mple: Transect 12
                 m       1.0000
                 k       1.0000
                 L       2.5000
                 m/L     .40000           100.00     0      .78230E-01      2.0452
mple: Transect 13
                 m       56.000
                 k       1.0000
                 L       2.5000
                 m/L     22.400           13.36      0      17.258          29.07
mple: Transect 14
                 m       20.000
                 k       1.0000
                 L       2.5000
                 m/L     8.0000           22.36      0      5.1888          12.33
mple: Transect 15
                 m       9.0000
                 k       1.0000
                 L       2.5000
                 m/L     3.6000           33.33      0      1.9055          6.801
ple: Transect 16
                 m       6.0000
                 k       1.0000
                 L       2.5000
                 m/L     2.4000           40.82      0      1.1117          5.1810
ple: Transect 17
                 m       19.000
                 k       1.0000
```

```
                           *******************************
                           *     Estimation Summary      *
                           *      Encounter rates        *
                           *******************************

                          Estimate        %CV       df      95% Confidence Interval
                         ------------------------------------------------------------
                L         2.5000
                n/L       7.6000         22.94       0      4.8756          11.847
imple: Transect 18
                n         8.0000
                k         1.0000
                L         2.5000
                n/L       3.2000         35.36       0      1.6331          6.2702
mple: Transect 19
                n         11.000
                k         1.0000
                L         2.5000
                n/L       4.4000         30.15       0      2.4681          7.8441
mple: Transect 20
                n         6.0000
                k         1.0000
                L         2.5000
                n/L       2.4000         40.82       0      1.1117          5.1810
mple: Transect 21
                n         3.0000
                k         1.0000
                L         2.5000
                n/L       1.2000         57.74       0      .41939          3.4335
mple: Transect 22
                n         4.0000
                k         1.0000
                L         2.5000
                n/L       1.6000         50.00       0      .63390          4.0385
iple: Transect 23
                n         7.0000
                k         1.0000
                L         2.5000
                n/L       2.8000         37.80       0      1.3681          5.7307
iple: Transect 24
                n         2.0000
                k         1.0000
                L         2.5000
                n/L       .80000         70.71       0      .22965          2.7868
ple: Transect 25
                n         8.0000
                k         1.0000
                L         2.5000
```

```
                          ******************************
                          *     Estimation Summary     *
                          *      Encounter rates       *
                          ******************************

                         Estimate        %CV      df      95% Confidence Interval
                        ----------------------------------------------------------
              n/L        3.2000         35.36      0      1.6331          6.2702
mple: Transect 26
              n          8.0000
              k          1.0000
              L          2.5000
              n/L        3.2000         35.36      0      1.6331          6.2702
mple: Transect 27
              n          5.0000
              k          1.0000
              L          2.5000
              n/L        2.0000         44.72      0      .86610          4.6184
mple: Transect 28
              n          6.0000
              k          1.0000
              L          2.5000
              n/L        2.4000         40.82      0      1.1117          5.1810
mple: Transect 29
              n          11.000
              k          1.0000
              L          2.5000
              n/L        4.4000         30.15      0      2.4681          7.8441
mple: Transect 30
              n          5.0000
              k          1.0000
              L          2.5000
              n/L        2.0000         44.72      0      .86610          4.6184
ple: Transect 31
              n          14.000
              k          1.0000
              L          2.5000
              n/L        5.6000         26.73      0      3.3466          9.3707
ple: Transect 32
              n          7.0000
              k          1.0000
              L          2.5000
              n/L        2.8000         37.80      0      1.3681          5.7307
le: Transect 33
              n          1.0000
              k          1.0000
              L          2.5000
              n/L        .40000        100.00      0      .78230E-01      2.0452
```

```
                      ******************************
                      *     Estimation Summary     *
                      *      Encounter rates       *
                      ******************************

                     Estimate        %CV      df     95% Confidence Interval
                    ---------------------------------------------------------
le: Transect 34
             n        4.0000
             k        1.0000
             L        2.5000
             n/L      1.6000        50.00      0     .63390          4.0385
le: Transect 35
             n        11.000
             k        1.0000
             L        2.5000
             n/L      4.4000        30.15      0     2.4681          7.8441
le: Transect 36
             n        6.0000
             k        1.0000
             L        2.5000
             n/L      2.4000        40.82      0     1.1117          5.1810
le: Transect 37
             n        21.000
             k        1.0000
             L        2.5000
             n/L      8.4000        21.82      0     5.5041          12.820
le: Transect 38
             n        3.0000
             k        1.0000
             L        2.5000
             n/L      1.2000        57.74      0     .41939          3.4335
le: Transect 39
             n        4.0000
             k        1.0000
             L        2.5000
             n/L      1.6000        50.00      0     .63390          4.0385
le: Transect 40
             n        6.0000
             k        1.0000
             L        2.5000
             n/L      2.4000        40.82      0     1.1117          5.1810
le: Transect 41
             n        10.000
             k        1.0000
             L        2.5000
             n/L      4.0000        31.62      0     2.1841          7.3257
le: Transect 42
             n        3.0000
```

```
                    ******************************
                    *     Estimation Summary     *
                    *      Encounter rates       *
                    ******************************

                    Estimate      %CV     df     95% Confidence Interval
                  -----------------------------------------------------------
          k         1.0000
          L         2.5000
          n/L       1.2000       57.74     0      .41939        3.4335
ple: Transect 43
          n         6.0000
          k         1.0000
          L         2.5000
          n/L       2.4000       40.82     0      1.1117        5.1810
le: Transect 44
          n         9.0000
          k         1.0000
          L         2.5000
          n/L       3.6000       33.33     0      1.9055        6.8015
le: Transect 45
          n         .00000
          k         1.0000
          L         2.5000
          n/L       .00000
le: Transect 46
          n         2.0000
          k         1.0000
          L         2.5000
          n/L       .80000       70.71     0      .22965        2.7868
le: Transect 47
          n         4.0000
          k         1.0000
          L         2.5000
          n/L       1.6000       50.00     0      .63390        4.0385
le: Transect 48
          n         6.0000
          k         1.0000
          L         2.5000
          n/L       2.4000       40.82     0      1.1117        5.1810
le: Transect 49
          n         9.0000
          k         1.0000
          L         2.5000
          n/L       3.6000       33.33     0      1.9055        6.8015
le: Transect 50
          n         40.000
          k         1.0000
```

```
                             ******************************
                             *     Estimation Summary     *
                             *      Encounter rates       *
                             ******************************

                            Estimate        %CV       df      95% Confidence Interval
                         ------------------------------------------------------------
                  L         2.5000
                  n/L       16.000         15.81       0      11.759          21.771
ple: Transect 51
                  n         12.000
                  k         1.0000
                  L         2.5000
                  n/L       4.8000         28.87       0      2.7569          8.3573
ple: Transect 52
                  n         19.000
                  k         1.0000
                  L         2.5000
                  n/L       7.6000         22.94       0      4.8756          11.847
ple: Transect 53
                  n         11.000
                  k         1.0000
                  L         2.5000
                  n/L       4.4000         30.15       0      2.4681          7.8441
ple: Transect 54
                  n         17.000
                  k         1.0000
                  L         2.5000
                  n/L       6.8000         24.25       0      4.2560          10.865
ple: Transect 55
                  n         7.0000
                  k         1.0000
                  L         2.5000
                  n/L       2.8000         37.80       0      1.3681          5.7307
ple: Transect 56
                  n         19.000
                  k         1.0000
                  L         2.5000
                  n/L       7.6000         22.94       0      4.8756          11.847
ple: Transect 57
                  n         13.000
                  k         1.0000
                  L         2.5000
                  n/L       5.2000         27.74       0      3.0498          8.8660
ple: Transect 58
                  n         20.000
                  k         1.0000
                  L         2.5000
```

```
                    ******************************
                    *     Estimation Summary     *
                    *      Encounter rates       *
                    ******************************

                    Estimate      %CV     df     95% Confidence Interval
                   ------------------------------------------------------
               n/L   8.0000      22.36     0     5.1888       12.334
mple: Transect 59
               n     52.000
               k     1.0000
               L     2.5000
               n/L   20.800      13.87     0     15.870       27.261
mple: Transect 60
               n     50.000
               k     1.0000
               L     2.5000
               n/L   20.000      14.14     0     15.179       26.352
mple: Transect 61
               n     9.0000
               k     1.0000
               L     2.5000
               n/L   3.6000      33.33     0     1.9055       6.8015
mple: Transect 62
               n     20.000
               k     1.0000
               L     2.5000
               n/L   8.0000      22.36     0     5.1888       12.334
mple: Transect 63
               n     50.000
               k     1.0000
               L     2.5000
               n/L   20.000      14.14     0     15.179       26.352
mple: Transect 64
               n     62.000
               k     1.0000
               L     2.5000
               n/L   24.800      12.70     0     19.354       31.778
mple: Transect 65
               n     52.000
               k     1.0000
               L     2.5000
               n/L   20.800      13.87     0     15.870       27.261
mple: Transect 66
               n     64.000
               k     1.0000
               L     2.5000
               n/L   25.600      12.50     0     20.056       32.676
```

```
                         ******************************
                         *      Estimation Summary    *
                         *       Encounter rates      *
                         ******************************

                          Estimate        %CV      df     95% Confidence Interval
                        -------------------------------------------------------------
le: Transect 67
               n          40.000
               k          1.0000
               L          2.5000
               n/L        16.000         15.81      0      11.759          21.771
le: Transect 68
               n          29.000
               k          1.0000
               L          2.5000
               n/L        11.600         18.57      0      8.0859          16.641
le: Transect 69
               n          30.000
               k          1.0000
               L          2.5000
               n/L        12.000         18.26      0      8.4148          17.113
le: Transect 70
               n          39.000
               k          1.0000
               L          2.5000
               n/L        15.600         16.01      0      11.420          21.309
le: Transect 71
               n          45.000
               k          1.0000
               L          2.5000
               n/L        18.000         14.91      0      13.461          24.070
le: Transect 72
               n          49.000
               k          1.0000
               L          2.5000
               n/L        19.600         14.29      0      14.834          25.897
le: Transect 73
               n          36.000
               k          1.0000
               L          2.5000
               n/L        14.400         16.67      0      10.410          19.919
le: Transect 74
               n          73.000
               k          1.0000
               L          2.5000
               n/L        29.200         11.70      0      23.232          36.700
le: Transect 75
               n          20.000
```

```
                        ******************************
                        *     Estimation Summary     *
                        *      Encounter rates       *
                        ******************************

                       Estimate        %CV      df      95% Confidence Interval
                      ----------------------------------------------------------
              k        1.0000
              L        2.5000
              n/L      8.0000         22.36      0      5.1888          12.334
iple: Transect 76
              n        25.000
              k        1.0000
              L        2.5000
              n/L      10.000         20.00      0      6.7830          14.743
iple: Transect 77
              n        1.0000
              k        1.0000
              L        2.5000
              n/L      .40000        100.00      0      .78230E-01      2.0452
iple: Transect 78
              n        7.0000
              k        1.0000
              L        2.5000
              n/L      2.8000         37.80      0      1.3681          5.7307
```

```
                       ******************************
                       *     Estimation Summary     *
                       *      Encounter rates       *
                       ******************************

atum:
                        Estimate        %CV      df       95% Confidence Interval
                      ----------------------------------------------------------------
ple: Transect 1
             n          14.000
             k          1.0000
             L          2.5000
             n/L        5.6000         26.73      0       3.3466          9.3707
ple: Transect 2
             n          2.0000
             k          1.0000
             L          2.5000
             n/L        .80000         70.71      0       .22965          2.7868
ple: Transect 3
             n          11.000
             k          1.0000
             L          2.5000
             n/L        4.4000         30.15      0       2.4681          7.8441
ple: Transect 4
             n          5.0000
             k          1.0000
             L          2.5000
             n/L        2.0000         44.72      0       .86610          4.6184
ple: Transect 5
             n          .00000
             k          1.0000
             L          2.5000
             n/L        .00000
ple: Transect 6
             n          4.0000
             k          1.0000
             L          2.5000
             n/L        1.6000         50.00      0       .63390          4.0385
ple: Transect 7
             n          18.000
             k          1.0000
             L          2.5000
             n/L        7.2000         23.57      0       4.5646          11.357
ple: Transect 8
             n          18.000
             k          1.0000
             L          2.5000
             n/L        7.2000         23.57      0       4.5646          11.357
ple: Transect 9
             n          1.0000
```

```
                              ******************************
                              *     Estimation Summary     *
                              *      Encounter rates       *
                              ******************************

                             Estimate        %CV      df      95% Confidence Interval
                           -----------------------------------------------------------
              k              1.0000
              L              2.5000
              n/L            .40000        100.00      0      .78230E-01    2.0452
ple: Transect 10
              n              1.0000
              k              1.0000
              L              2.5000
              n/L            .40000        100.00      0      .78230E-01    2.0452
ple: Transect 11
              n              12.000
              k              1.0000
              L              2.5000
              n/L            4.8000         28.87      0      2.7569        8.3573
ple: Transect 12
              n              3.0000
              k              1.0000
              L              2.5000
              n/L            1.2000         57.74      0      .41939        3.4335
ple: Transect 13
              n              22.000
              k              1.0000
              L              2.5000
              n/L            8.8000         21.32      0      5.8212        13.303
ple: Transect 14
              n              8.0000
              k              1.0000
              L              2.5000
              n/L            3.2000         35.36      0      1.6331        6.2702
ple: Transect 15
              n              21.000
              k              1.0000
              L              2.5000
              n/L            8.4000         21.82      0      5.5041        12.820
ple: Transect 16
              n              10.000
              k              1.0000
              L              2.5000
              n/L            4.0000         31.62      0      2.1841        7.3257
ple: Transect 17
              n              8.0000
              k              1.0000
```

```
                            ******************************
                            *     Estimation Summary     *
                            *      Encounter rates       *
                            ******************************

                        Estimate        %CV      df      95% Confidence Interval
                       -----------------------------------------------------------
               L        2.5000
               n/L      3.2000         35.36      0      1.6331          6.2702
mple: Transect 18
               n        17.000
               k        1.0000
               L        2.5000
               n/L      6.8000         24.25      0      4.2560          10.865
mple: Transect 19
               n        9.0000
               k        1.0000
               L        2.5000
               n/L      3.6000         33.33      0      1.9055          6.8015
mple: Transect 20
               n        14.000
               k        1.0000
               L        2.5000
               n/L      5.6000         26.73      0      3.3466          9.3707
mple: Transect 21
               n        3.0000
               k        1.0000
               L        2.5000
               n/L      1.2000         57.74      0      .41939          3.4335
mple: Transect 22
               n        6.0000
               k        1.0000
               L        2.5000
               n/L      2.4000         40.82      0      1.1117          5.1810
mple: Transect 23
               n        21.000
               k        1.0000
               L        2.5000
               n/L      8.4000         21.82      0      5.5041          12.820
mple: Transect 24
               n        14.000
               k        1.0000
               L        2.5000
               n/L      5.6000         26.73      0      3.3466          9.3707
mple: Transect 25
               n        15.000
               k        1.0000
               L        2.5000
```

```
                    *******************************
                    *     Estimation Summary      *
                    *     Encounter rates         *
                    *******************************

                   Estimate      %CV      df     95% Confidence Interval
                  ------------------------------------------------------
           n/L     6.0000       25.82      0     3.6467        9.8718
ple: Transect 26
           n       7.0000
           k       1.0000
           L       2.5000
           n/L     2.8000       37.80      0     1.3681        5.7307
ple: Transect 27
           n       11.000
           k       1.0000
           L       2.5000
           n/L     4.4000       30.15      0     2.4681        7.8441
ple: Transect 28
           n       4.0000
           k       1.0000
           L       2.5000
           n/L     1.6000       50.00      0     .63390        4.0385
ple: Transect 29
           n       13.000
           k       1.0000
           L       2.5000
           n/L     5.2000       27.74      0     3.0498        8.8660
ple: Transect 30
           n       15.000
           k       1.0000
           L       2.5000
           n/L     6.0000       25.82      0     3.6467        9.8718
ple: Transect 31
           n       10.000
           k       1.0000
           L       2.5000
           n/L     4.0000       31.62      0     2.1841        7.3257
ple: Transect 32
           n       17.000
           k       1.0000
           L       2.5000
           n/L     6.8000       24.25      0     4.2560        10.865
ple: Transect 33
           n       21.000
           k       1.0000
           L       2.5000
           n/L     8.4000       21.82      0     5.5041        12.820
```

```
                          ******************************
                          *     Estimation Summary     *
                          *      Encounter rates       *
                          ******************************

                          Estimate        %CV      df      95% Confidence Interval
                         ----------------------------------------------------------
ple: Transect 34
                n         21.000
                k         1.0000
                L         2.5000
                n/L       8.4000        21.82      0      5.5041         12.820
ple: Transect 35
                n         10.000
                k         1.0000
                L         2.5000
                n/L       4.0000        31.62      0      2.1841         7.3257
mple: Transect 36
                n         4.0000
                k         1.0000
                L         2.5000
                n/L       1.6000        50.00      0      .63390         4.0385
mple: Transect 37
                n         10.000
                k         1.0000
                L         2.5000
                n/L       4.0000        31.62      0      2.1841         7.3257
mple: Transect 38
                n         15.000
                k         1.0000
                L         2.5000
                n/L       6.0000        25.82      0      3.6467         9.8718
mple: Transect 39
                n         6.0000
                k         1.0000
                L         2.5000
                n/L       2.4000        40.82      0      1.1117         5.1810
mple: Transect 40
                n         17.000
                k         1.0000
                L         2.5000
                n/L       6.8000        24.25      0      4.2560         10.865
mple: Transect 41
                n         2.0000
                k         1.0000
                L         2.5000
                n/L       .80000        70.71      0      .22965         2.7868
mple: Transect 42
                n         2.0000
```

```
                        ******************************
                        *     Estimation Summary     *
                        *      Encounter rates       *
                        ******************************

                      Estimate      %CV      df      95% Confidence Interval
                      -------------------------------------------------------
             k        1.0000
             L        2.5000
             n/L      .80000       70.71      0      .22965         2.7868
ple: Transect 43
             n        18.000
             k        1.0000
             L        2.5000
             n/L      7.2000       23.57      0      4.5646         11.357
ple: Transect 44
             n        21.000
             k        1.0000
             L        2.5000
             n/L      8.4000       21.82      0      5.5041         12.820
ple: Transect 45
             n        23.000
             k        1.0000
             L        2.5000
             n/L      9.2000       20.85      0      6.1402         13.785
ple: Transect 46
             n        22.000
             k        1.0000
             L        2.5000
             n/L      8.8000       21.32      0      5.8212         13.303
ple: Transect 47
             n        7.0000
             k        1.0000
             L        2.5000
             n/L      2.8000       37.80      0      1.3681         5.7307
ple: Transect 48
             n        5.0000
             k        1.0000
             L        2.5000
             n/L      2.0000       44.72      0      .86610         4.6184
ple: Transect 49
             n        46.000
             k        1.0000
             L        2.5000
             n/L      18.400       14.74      0      13.803         24.527
ple: Transect 50
             n        28.000
             k        1.0000
```

```
                     *******************************
                     *     Estimation Summary      *
                     *      Encounter rates        *
                     *******************************

                    Estimate       %CV      df     95% Confidence Interval
                   --------------------------------------------------------
          L         2.5000
          n/L       11.200        18.90      0      7.7582        16.169
le: Transect 51
          n         20.000
          k         1.0000
          L         2.5000
          n/L       8.0000        22.36      0      5.1888        12.334
le: Transect 52
          n         20.000
          k         1.0000
          L         2.5000
          n/L       8.0000        22.36      0      5.1888        12.334
ple: Transect 53
          n         12.000
          k         1.0000
          L         2.5000
          n/L       4.8000        28.87      0      2.7569        8.3573
ple: Transect 54
          n         28.000
          k         1.0000
          L         2.5000
          n/L       11.200        18.90      0      7.7582        16.169
ple: Transect 55
          n         10.000
          k         1.0000
          L         2.5000
          n/L       4.0000        31.62      0      2.1841        7.3257
ple: Transect 56
          n         21.000
          k         1.0000
          L         2.5000
          n/L       8.4000        21.82      0      5.5041        12.820
ple: Transect 57
          n         35.000
          k         1.0000
          L         2.5000
          n/L       14.000        16.90      0      10.075        19.454
ple: Transect 58
          n         21.000
          k         1.0000
          L         2.5000
```

```
                          ******************************
                          *     Estimation Summary     *
                          *      Encounter rates       *
                          ******************************

                        Estimate       %CV      df      95% Confidence Interval
                      ----------------------------------------------------------
               n/L       8.4000       21.82      0      5.5041        12.820
mple: Transect 59
               n        23.000
               k         1.0000
               L         2.5000
               n/L       9.2000       20.85      0      6.1402        13.785
mple: Transect 60
               n        15.000
               k         1.0000
               L         2.5000
               n/L       6.0000       25.82      0      3.6467        9.8718
mple: Transect 61
               n        16.000
               k         1.0000
               L         2.5000
               n/L       6.4000       25.00      0      3.9500        10.370
mple: Transect 62
               n        23.000
               k         1.0000
               L         2.5000
               n/L       9.2000       20.85      0      6.1402        13.785
mple: Transect 63
               n        27.000
               k         1.0000
               L         2.5000
               n/L      10.800        19.25      0      7.4318        15.695
mple: Transect 64
               n        23.000
               k         1.0000
               L         2.5000
               n/L       9.2000       20.85      0      6.1402        13.785
mple: Transect 65
               n        44.000
               k         1.0000
               L         2.5000
               n/L      17.600        15.08      0      13.119        23.611
mple: Transect 66
               n        36.000
               k         1.0000
               L         2.5000
               n/L      14.400        16.67      0      10.410        19.919
```

```
                     ******************************
                     *     Estimation Summary     *
                     *      Encounter rates       *
                     ******************************

                     Estimate      %CV     df     95% Confidence Interval
                    ---------------------------------------------------------
ple: Transect 67
             n       18.000
             k       1.0000
             L       2.5000
             n/L     7.2000       23.57     0     4.5646        11.357
ple: Transect 68
             n       27.000
             k       1.0000
             L       2.5000
             n/L     10.800       19.25     0     7.4318        15.695
ple: Transect 69
             n       21.000
             k       1.0000
             L       2.5000
             n/L     8.4000       21.82     0     5.5041        12.820
ple: Transect 70
             n       26.000
             k       1.0000
             L       2.5000
             n/L     10.400       19.61     0     7.1067        15.219
ple: Transect 71
             n       19.000
             k       1.0000
             L       2.5000
             n/L     7.6000       22.94     0     4.8756        11.847
ple: Transect 72
             n       15.000
             k       1.0000
             L       2.5000
             n/L     6.0000       25.82     0     3.6467        9.8718
ple: Transect 73
             n       9.0000
             k       1.0000
             L       2.5000
             n/L     3.6000       33.33     0     1.9055        6.8015
ple: Transect 74
             n       9.0000
             k       1.0000
             L       2.5000
             n/L     3.6000       33.33     0     1.9055        6.8015
ple: Transect 75
             n       1.0000
```

```
                    *******************************
                    *     Estimation Summary      *
                    *      Encounter rates        *
                    *******************************

                    Estimate       %CV      df     95% Confidence Interval
                  -----------------------------------------------------------
          k         1.0000
          L         2.5000
          n/L       .40000       100.00     0      .78230E-01    2.0452
ple: Transect 76
          n         9.0000
          k         1.0000
          L         2.5000
          n/L       3.6000        33.33     0      1.9055        6.8015
ple: Transect 77
          n         6.0000
          k         1.0000
          L         2.5000
          n/L       2.4000        40.82     0      1.1117        5.1810
ple: Transect 78
          n         6.0000
          k         1.0000
          L         2.5000
          n/L       2.4000        40.82     0      1.1117        5.1810
```

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                       ******************************
                       *     Estimation Summary     *
                       *      Encounter rates       *
                       ******************************

atum:
                       Estimate      %CV      df     95% Confidence Interval
                      ------------------------------------------------------
ple: Transect 1
            n          1.0000
            k          1.0000
            L          2.5000
            n/L        .40000       100.00     0      .78230E-01    2.0452
ple: Transect 2
            n          .00000
            k          1.0000
            L          2.5000
            n/L        .00000
ple: Transect 3
            n          .00000
            k          1.0000
            L          2.5000
            n/L        .00000
ple: Transect 4
            n          .00000
            k          1.0000
            L          2.5000
            n/L        .00000
ple: Transect 5
            n          .00000
            k          1.0000
            L          2.5000
            n/L        .00000
ple: Transect 6
            n          1.0000
            k          1.0000
            L          2.5000
            n/L        .40000       100.00     0      .78230E-01    2.0452
ple: Transect 7
            n          5.0000
            k          1.0000
            L          2.5000
            n/L        2.0000        44.72     0      .86610        4.6184
ple: Transect 8
            n          8.0000
            k          1.0000
            L          2.5000
            n/L        3.2000        35.36     0      1.6331        6.2702
ple: Transect 9
            n          .00000
```

```
                             ******************************
                            .*     Estimation Summary     *
                             *      Encounter rates       *
                             ******************************

                           Estimate         %CV      df     95% Confidence Interval
                         ----------------------------------------------------------------
             k              1.0000
             L              2.5000
             n/L            .00000
iple: Transect 10
             n              1.0000
             k              1.0000
             L              2.5000
             n/L            .40000       100.00      0      .78230E-01    2.0452
iple: Transect 11
             n              5.0000
             k              1.0000
             L              2.5000
             n/L            2.0000        44.72      0      .86610        4.6184
iple: Transect 12
             n              .00000
             k              1.0000
             L              2.5000
             n/L            .00000
iple: Transect 13
             n              3.0000
             k              1.0000
             L              2.5000
             n/L            1.2000        57.74      0      .41939        3.4335
iple: Transect 14
             n              4.0000
             k              1.0000
             L              2.5000
             n/L            1.6000        50.00      0      .63390        4.0385
iple: Transect 15
             n              4.0000
             k              1.0000
             L              2.5000
             n/L            1.6000        50.00      0      .63390        4.0385
iple: Transect 16
             n              2.0000
             k              1.0000
             L              2.5000
             n/L            .80000        70.71      0      .22965        2.7868
ple: Transect 17
             n              16.000
             k              1.0000
```

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                          ******************************
                          *     Estimation Summary     *
                          *      Encounter rates       *
                          ******************************

                         Estimate       %CV      df      95% Confidence Interval
                        ------------------------------------------------------------
               L         2.5000
               n/L       6.4000        25.00      0       3.9500         10.370
le: Transect 18
               n         26.000
               k         1.0000
               L         2.5000
               n/L       10.400        19.61      0       7.1067         15.219
le: Transect 19
               n         11.000
               k         1.0000
               L         2.5000
               n/L       4.4000        30.15      0       2.4681         7.8441
le: Transect 20
               n         21.000
               k         1.0000
               L         2.5000
               n/L       8.4000        21.82      0       5.5041         12.820
le: Transect 21
               n         12.000
               k         1.0000
               L         2.5000
               n/L       4.8000        28.87      0       2.7569         8.3573
le: Transect 22
               n         1.0000
               k         1.0000
               L         2.5000
               n/L       .40000       100.00      0      .78230E-01      2.0452
le: Transect 23
               n         12.000
               k         1.0000
               L         2.5000
               n/L       4.8000        28.87      0       2.7569         8.3573
le: Transect 24
               n         17.000
               k         1.0000
               L         2.5000
               n/L       6.8000        24.25      0       4.2560         10.865
le: Transect 25
               n         11.000
               k         1.0000
               L         2.5000
```

```
                           *****************************
                           *    Estimation Summary     *
                           *     Encounter rates       *
                           *****************************

                         Estimate       %CV      df      95% Confidence Interval
                        -----------------------------------------------------------
                 n/L     4.4000        30.15      0       2.4681          7.8441
mple: Transect 26
                 n       14.000
                 k       1.0000
                 L       2.5000
                 n/L     5.6000        26.73      0       3.3466          9.3707
mple: Transect 27
                 n       .00000
                 k       1.0000
                 L       2.5000
                 n/L     .00000
mple: Transect 28
                 n       2.0000
                 k       1.0000
                 L       2.5000
                 n/L     .80000        70.71      0       .22965          2.7868
mple: Transect 29
                 n       8.0000
                 k       1.0000
                 L       2.5000
                 n/L     3.2000        35.36      0       1.6331          6.2702
mple: Transect 30
                 n       13.000
                 k       1.0000
                 L       2.5000
                 n/L     5.2000        27.74      0       3.0498          8.8660
mple: Transect 31
                 n       5.0000
                 k       1.0000
                 L       2.5000
                 n/L     2.0000        44.72      0       .86610          4.6184
mple: Transect 32
                 n       15.000
                 k       1.0000
                 L       2.5000
                 n/L     6.0000        25.82      0       3.6467          9.8718
mple: Transect 33
                 n       1.0000
                 k       1.0000
                 L       2.5000
                 n/L     .40000       100.00      0       .78230E-01      2.0452
```

```
                         ******************************
                         *      Estimation Summary     *
                         *       Encounter rates       *
                         ******************************

                        Estimate       %CV      df     95% Confidence Interval
                       ----------------------------------------------------------
le: Transect 34
               n         2.0000
               k         1.0000
               L         2.5000
               n/L       .80000        70.71     0      .22965         2.7868
le: Transect 35
               n         4.0000
               k         1.0000
               L         2.5000
               n/L       1.6000        50.00     0      .63390         4.0385
le: Transect 36
               n         .00000
               k         1.0000
               L         2.5000
               n/L       .00000
le: Transect 37
               n         8.0000
               k         1.0000
               L         2.5000
               n/L       3.2000        35.36     0      1.6331         6.2702
le: Transect 38
               n         15.000
               k         1.0000
               L         2.5000
               n/L       6.0000        25.82     0      3.6467         9.8718
le: Transect 39
               n         .00000
               k         1.0000
               L         2.5000
               n/L       .00000
le: Transect 40
               n         2.0000
               k         1.0000
               L         2.5000
               n/L       .80000        70.71     0      .22965         2.7868
le: Transect 41
               n         .00000
               k         1.0000
               L         2.5000
               n/L       .00000
le: Transect 42
               n         2.0000
```

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                      ********************************
                      *      Estimation Summary      *
                      *       Encounter rates        *
                      ********************************

                      Estimate       %CV      df      95% Confidence Interval
                     --------------------------------------------------------
            k         1.0000
            L         2.5000
            n/L       .80000        70.71      0      .22965         2.7868
ple: Transect 43
            n         8.0000
            k         1.0000
            L         2.5000
            n/L       3.2000        35.36      0      1.6331         6.2702
ple: Transect 44
            n         21.000
            k         1.0000
            L         2.5000
            n/L       8.4000        21.82      0      5.5041         12.820
ple: Transect 45
            n         15.000
            k         1.0000
            L         2.5000
            n/L       6.0000        25.82      0      3.6467         9.8718
ple: Transect 46
            n         4.0000
            k         1.0000
            L         2.5000
            n/L       1.6000        50.00      0      .63390         4.0385
ple: Transect 47
            n         1.0000
            k         1.0000
            L         2.5000
            n/L       .40000       100.00      0      .78230E-01     2.0452
ple: Transect 48
            n         .00000
            k         1.0000
            L         2.5000
            n/L       .00000
ple: Transect 49
            n         20.000
            k         1.0000
            L         2.5000
            n/L       8.0000        22.36      0      5.1888         12.334
ple: Transect 50
            n         12.000
            k         1.0000
```

```
                        ******************************
                        *     Estimation Summary     *
                        *      Encounter rates       *
                        ******************************

                     Estimate      %CV      df      95% Confidence Interval
                    ------------------------------------------------------
          L          2.5000
          n/L        4.8000       28.87      0      2.7569        8.3573
le: Transect 51
          n          3.0000
          k          1.0000
          L          2.5000
          n/L        1.2000       57.74      0      .41939        3.4335
le: Transect 52
          n          1.0000
          k          1.0000
          L          2.5000
          n/L        .40000      100.00      0      .78230E-01    2.0452
le: Transect 53
          n          .00000
          k          1.0000
          L          2.5000
          n/L        .00000
le: Transect 54
          n          6.0000
          k          1.0000
          L          2.5000
          n/L        2.4000       40.82      0      1.1117        5.1810
ple: Transect 55
          n          17.000
          k          1.0000
          L          2.5000
          n/L        6.8000       24.25      0      4.2560        10.865
ple: Transect 56
          n          8.0000
          k          1.0000
          L          2.5000
          n/L        3.2000       35.36      0      1.6331        6.2702
ple: Transect 57
          n          1.0000
          k          1.0000
          L          2.5000
          n/L        .40000      100.00      0      .78230E-01    2.0452
ple: Transect 58
          n          1.0000
          k          1.0000
          L          2.5000
```

```
                      ******************************
                      *     Estimation Summary     *
                      *      Encounter rates       *
                      ******************************

                      Estimate     %CV      df    95% Confidence Interval
                     ----------------------------------------------------------
             n/L      .40000      100.00     0    .78230E-01    2.0452
le: Transect 59
             n        1.0000
             k        1.0000
             L        2.5000
             n/L      .40000      100.00     0    .78230E-01    2.0452
le: Transect 60
             n        .00000
             k        1.0000
             L        2.5000
             n/L      .00000
le: Transect 61
             n        15.000
             k        1.0000
             L        2.5000
             n/L      6.0000       25.82     0    3.6467        9.8718
le: Transect 62
             n        18.000
             k        1.0000
             L        2.5000
             n/L      7.2000       23.57     0    4.5646        11.357
le: Transect 63
             n        2.0000
             k        1.0000
             L        2.5000
             n/L      .80000       70.71     0    .22965        2.7868
le: Transect 64
             n        3.0000
             k        1.0000
             L        2.5000
             n/L      1.2000       57.74     0    .41939        3.4335
le: Transect 65
             n        3.0000
             k        1.0000
             L        2.5000
             n/L      1.2000       57.74     0    .41939        3.4335
le: Transect 66
             n        17.000
             k        1.0000
             L        2.5000
             n/L      6.8000       24.25     0    4.2560        10.865
```

```
                         ******************************
                        .*      Estimation Summary      *
                         *       Encounter rates        *
                         ******************************

                        Estimate      %CV     df     95% Confidence Interval
                      ------------------------------------------------------
le: Transect 67
              n         13.000
              k         1.0000
              L         2.5000
              n/L       5.2000       27.74     0     3.0498        8.8660
le: Transect 68
              n         1.0000
              k         1.0000
              L         2.5000
              n/L       .40000      100.00     0     .78230E-01    2.0452
le: Transect 69
              n         7.0000
              k         1.0000
              L         2.5000
              n/L       2.8000       37.80     0     1.3681        5.7307
le: Transect 70
              n         6.0000
              k         1.0000
              L         2.5000
              n/L       2.4000       40.82     0     1.1117        5.1810
le: Transect 71
              n         13.000
              k         1.0000
              L         2.5000
              n/L       5.2000       27.74     0     3.0498        8.8660
le: Transect 72
              n         6.0000
              k         1.0000
              L         2.5000
              n/L       2.4000       40.82     0     1.1117        5.1810
le: Transect 73
              n         4.0000
              k         1.0000
              L         2.5000
              n/L       1.6000       50.00     0     .63390        4.0385
le: Transect 74
              n         4.0000
              k         1.0000
              L         2.5000
              n/L       1.6000       50.00     0     .63390        4.0385
le: Transect 75
              n         7.0000
```

```
                              ******************************
                             .*      Estimation Summary     *
                              *      Encounter rates        *
                              ******************************

                             Estimate        %CV      df      95% Confidence Interval
                            ---------------------------------------------------------
               k             1.0000
               L             2.5000
               n/L           2.8000         37.80      0      1.3681        5.7307
ple: Transect 76
               n             4.0000
               k             1.0000
               L             2.5000
               n/L           1.6000         50.00      0      .63390        4.0385
ple: Transect 77
               n             2.0000
               k             1.0000
               L             2.5000
               n/L           .80000         70.71      0      .22965        2.7868
ple: Transect 78
               n             4.0000
               k             1.0000
               L             2.5000
               n/L           1.6000         50.00      0      .63390        4.0385
```

APPENDIX 10

ANALYSIS OF DISTANCE SAMPLING DATA OF NOVEMBER 1993 USING A THREE-TERM FOURIER SERIES.

```
                    ***********************************
                    *  Probability Function Estimation *
                    *     Model Selection/Fitting      *
                    ***********************************


fort          :     195.0000
samples       :     78
ith           :     1.200000
bservations:    500

el
 Uniform key, k(y) = 1/W
 Cosine adjustments of order(s) :  1, 2, 3
    Results:
    Convergence was achieved with   19 function evaluations.
    Final Ln(likelihood) value =     -635.94307
    Akaike information criterion =     1277.88600
    Final parameter values:      .678976     .201004     .095487
```

```
                    ************************************
                    *  Probability Function Estimation *
                    *      Parameter Estimates         *
                    ************************************


ort           :    195.0000
amples        :    78
th            :    1.200000
bservations:   500

el
Uniform key, k(y) = 1/W
Cosine adjustments of order(s) :  1, 2, 3


          Point         Standard     Percent Coef.         95 Percent
rameter  Estimate         Error      of Variation    Confidence Interval
-------  -----------  -----------  --------------  ----------------------
A( 1)     .6790         .6059E-01        8.92
A( 2)     .2010         .6965E-01       34.65
A( 3)     .9549E-01     .7675E-01       80.38
f(0)     1.6462        .12121            7.36      1.4253       1.9014
-------  -----------  -----------  --------------  ----------------------

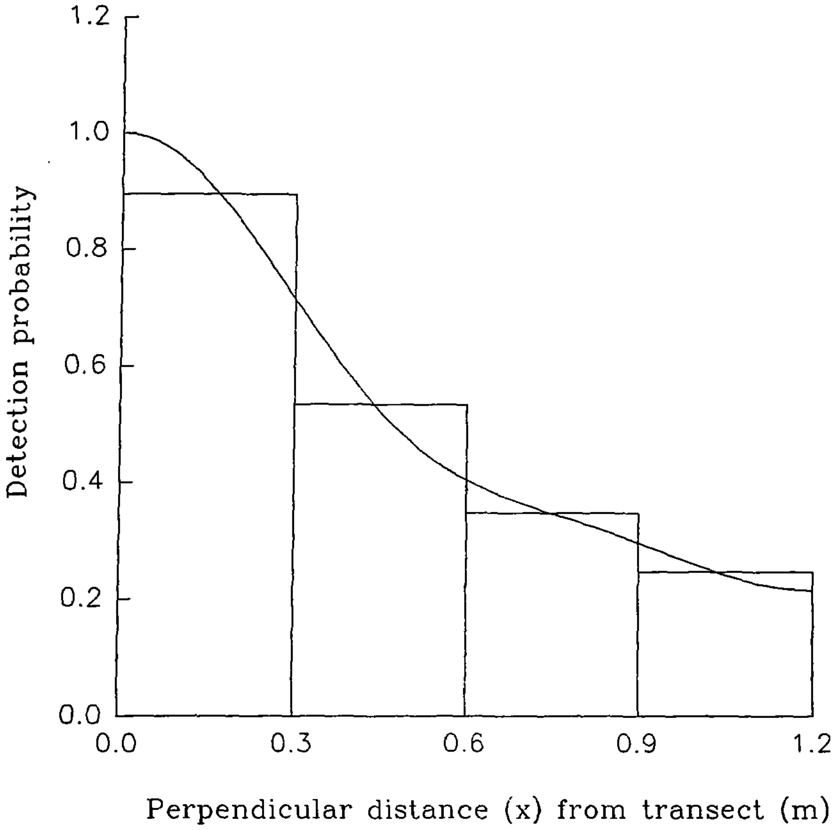

pling Correlation of Estimated Parameters


    A( 1)    A( 2)    A( 3)
1)  1.000     .333     .074
2)   .333    1.000     .303
3)   .074     .303    1.000
```

```
am DISTANCE - Analysis of Distance Sampling Data V2.1      07/20/95 13:10

                         ******************************
                         *     Estimation Summary     *
                         *    Detection probability   *
                         ******************************

ed Estimates:
                        Estimate      %CV     df      95% Confidence Interval
                       ------------------------------------------------------
orm/Cosine
                m       3.0000
                AIC     1277.9
                f(0)    1.6462        7.36    497     1.4253          1.9014
                p       .50621        7.36    497     .43827          .58468
                ESW     .60745        7.36    497     .52592          .70162
```



Histogram of the survey of November 1993, truncated at 1.2 m with cut points at 0.3m. A three -term Fourier series detection function is fitted to the data.

```
                     *******************************
                     *     Estimation Summary      *
                     *      Density/Abundance      *
                     *******************************

atum:
                      Estimate      %CV     df     95% Confidence Interval
                     -----------------------------------------------------
ple: Transect 1
form/Cosine
            D         329.24      100.27    497     64.188        1688.8
ple: Transect 2
form/Cosine
            D         .00000
ple: Transect 3
form/Cosine
            D         .00000
ple: Transect 4
form/Cosine
            D         .00000
ple: Transect 5
form/Cosine
            D         .00000
ple: Transect 6
form/Cosine
            D         329.24      100.27    497     64.188        1688.8
ple: Transect 7
form/Cosine
            D         1646.2       45.32    497     705.60        3840.8
ple: Transect 8
form/Cosine
            D         2634.0       36.11    497     1326.1        5231.7
ple: Transect 9
form/Cosine
            D         .00000
ple: Transect 10
form/Cosine
            D         329.24      100.27    497     64.188        1688.8
ple: Transect 11
form/Cosine
            D         1646.2       45.32    497     705.60        3840.8
ple: Transect 12
form/Cosine
            D         .00000
ple: Transect 13
form/Cosine
            D         987.73       58.20    497     342.67        2847.1
ple: Transect 14
form/Cosine
            D         1317.0       50.54    497     517.13        3354.0
```

```
                          *******************************
                          *     Estimation Summary      *
                          *      Density/Abundance      *
                          *******************************

                        Estimate        %CV     df      95% Confidence Interval
                       ---------------------------------------------------------
ple: Transect 15
form/Cosine
            D           1317.0          50.54   497     517.13          3354.0
ple: Transect 16
form/Cosine
            D           658.49          71.09   497     187.98          2306.6
ple: Transect 17
form/Cosine
            D           5267.9          26.06   497     3187.4          8706.5
ple: Transect 18
form/Cosine
            D           8560.4          20.95   497     5702.8          12850.
ple: Transect 19
form/Cosine
            D           3621.7          31.04   497     1998.8          6562.3
ple: Transect 20
form/Cosine
            D           6914.1          23.03   497     4428.2          10796.
ple: Transect 21
form/Cosine
            D           3950.9          29.79   497     2230.9          6997.1
ple: Transect 22
form/Cosine
            D           329.24         100.27   497     64.188          1688.8
ple: Transect 23
form/Cosine
            D           3950.9          29.79   497     2230.9          6997.1
ple: Transect 24
form/Cosine
            D           5597.2          25.35   497     3432.1          9127.9
ple: Transect 25
form/Cosine
            D           3621.7          31.04   497     1998.8          6562.3
ple: Transect 26
form/Cosine
            D           4609.4          27.72   497     2704.1          7857.1
ple: Transect 27
form/Cosine
            D           .00000
ple: Transect 28
form/Cosine
            D           658.49          71.09   497     187.98          2306.6
```

```
                        ******************************
                        *     Estimation Summary      *
                        *      Density/Abundance      *
                        ******************************

                       Estimate      %CV     df     95% Confidence Interval
                      ------------------------------------------------------
ample: Transect 29
niform/Cosine
              D        2634.0       36.11   497     1326.1         5231.7
ample: Transect 30
niform/Cosine
              D        4280.2       28.70   497     2466.1         7428.6
ample: Transect 31
niform/Cosine
              D        1646.2       45.32   497     705.60         3840.8
ample: Transect 32
niform/Cosine
              D        4938.7       26.85   497     2944.6         8283.0
ample: Transect 33
niform/Cosine
              D        329.24      100.27   497     64.188         1688.8
ample: Transect 34
niform/Cosine
              D        658.49       71.09   497     187.98         2306.6
ample: Transect 35
niform/Cosine
              D        1317.0       50.54   497     517.13         3354.0
ample: Transect 36
niform/Cosine
              D        .00000
ample: Transect 37
niform/Cosine
              D        2634.0       36.11   497     1326.1         5231.7
ample: Transect 38
niform/Cosine
              D        4938.7       26.85   497     2944.6         8283.0
ample: Transect 39
niform/Cosine
              D        .00000
ample: Transect 40
niform/Cosine
              D        658.49       71.09   497     187.98         2306.6
ample: Transect 41
niform/Cosine
              D        .00000
ample: Transect 42
niform/Cosine
              D        658.49       71.09   497     187.98         2306.6
```

```
                        ******************************
                        *     Estimation Summary     *
                        *      Density/Abundance     *
                        ******************************

                       Estimate       %CV     df      95% Confidence Interval
                      ---------------------------------------------------------
ple: Transect 43
form/Cosine
              D        2634.0        36.11    497     1326.1         5231.7
ple: Transect 44
form/Cosine
              D        6914.1        23.03    497     4428.2         10796.
ple: Transect 45
form/Cosine
              D        4938.7        26.85    497     2944.6         8283.0
ple: Transect 46
form/Cosine
              D        1317.0        50.54    497     517.13         3354.0
ple: Transect 47
form/Cosine
              D        329.24       100.27    497     64.188         1688.8
ple: Transect 48
form/Cosine
              D        .00000
ple: Transect 49
iform/Cosine
              D        6584.9        23.54    497     4176.9         10381.
mple: Transect 50
iform/Cosine
              D        3950.9        29.79    497     2230.9         6997.1
mple: Transect 51
iform/Cosine
              D        987.73        58.20    497     342.67         2847.1
mple: Transect 52
iform/Cosine
              D        329.24       100.27    497     64.188         1688.8
mple: Transect 53
iform/Cosine
              D        .00000
mple: Transect 54
iform/Cosine
              D        1975.5        41.48    497     904.64         4313.8
mple: Transect 55
iform/Cosine
              D        5597.2        25.35    497     3432.1         9127.9
mple: Transect 56
iform/Cosine
              D        2634.0        36.11    497     1326.1         5231.7
```

```
                         *******************************
                         *      Estimation Summary     *
                         *       Density/Abundance     *
                         *******************************

                        Estimate      %CV      df      95% Confidence Interval
                       ------------------------------------------------------
mple: Transect 57
iform/Cosine
                D       329.24      100.27    497      64.188       1688.8
mple: Transect 58
iform/Cosine
                D       329.24      100.27    497      64.188       1688.8
mple: Transect 59
iform/Cosine
                D       329.24      100.27    497      64.188       1688.8
mple: Transect 60
iform/Cosine
                D       .00000
mple: Transect 61
iform/Cosine
                D       4938.7       26.85    497      2944.6       8283.0
mple: Transect 62
iform/Cosine
                D       5926.4       24.69    497      3678.7       9547.4
mple: Transect 63
iform/Cosine
                D       658.49       71.09    497      187.98       2306.6
mple: Transect 64
iform/Cosine
                D       987.73       58.20    497      342.67       2847.1
mple: Transect 65
iform/Cosine
                D       987.73       58.20    497      342.67       2847.1
mple: Transect 66
iform/Cosine
                D       5597.2       25.35    497      3432.1       9127.9
mple: Transect 67
iform/Cosine
                D       4280.2       28.70    497      2466.1       7428.6
mple: Transect 68
iform/Cosine
                D       329.24      100.27    497      64.188       1688.8
mple: Transect 69
iform/Cosine
                D       2304.7       38.51    497      1112.0       4776.7
mple: Transect 70
iform/Cosine
                D       1975.5       41.48    497      904.64       4313.8
```

```
                         *******************************
                         *      Estimation Summary     *
                         *       Density/Abundance     *
                         *******************************

                        Estimate        %CV     df      95% Confidence Interval
                       ------------------------------------------------------
ple: Transect 71
form/Cosine
                D       4280.2          28.70   497     2466.1        7428.6
ple: Transect 72
form/Cosine
                D       1975.5          41.48   497     904.64        4313.8
ple: Transect 73
form/Cosine
                D       1317.0          50.54   497     517.13        3354.0
ple: Transect 74
form/Cosine
                D       1317.0          50.54   497     517.13        3354.0
ple: Transect 75
form/Cosine
                D       2304.7          38.51   497     1112.0        4776.7
ple: Transect 76
form/Cosine
                D       1317.0          50.54   497     517.13        3354.0
ple: Transect 77
form/Cosine
                D       658.49          71.09   497     187.98        2306.6
ple: Transect 78
form/Cosine
                D       1317.0          50.54   497     517.13        3354.0
```

```
                        *******************************
                        *     Estimation Summary      *
                        *      Density/Abundance      *
                        *******************************

led Estimates:
                       Estimate       %CV    df      95% Confidence Interval
                      ------------------------------------------------------
form/Cosine
               D       2110.5        13.68   149     1616.2         2756.2
```

One-Way Analysis of Variance

```
Analysis of Variance
Source     DF        SS         MS         F        p
Factor      1      3096       3096      0.00    0.979
Error     154 708281920    4599233
Total     155 708285056
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
 Level          N   Mean     StDev  ------+---------+---------+---------+
Fourier series 78   2102      2140  (---------------*---------------)
Hazard rate    78   2111      2149  (---------------*---------------)
                                   ------+---------+---------+---------+
Pooled StDev =      2145               1800      2100      2400      2700
MTB >
```