STUDYING ELEPHANTS

EDITED BY KADZO KANGWANA AWF TECHNICAL HANDBOOK SERIES 7

AFRICAN WILDLIFE FOUNDATION

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THE AFRICAN WILDLIFE FOUNDATION

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INTRODUCTION

Concern for the survival of the African elephant*(Loxodonta africana)*, following the decimation of elephants through the 1970s and 1980s as a result of poaching for ivory, has led to an increased focus on the conservation of the species. However, conservation and management of the African elephant can only be done in light of a good understanding of the elephants themselves - their distribution and density, their movements, behaviour, impact on their ecosystems, and how they respond to contact with humans at the human-wildlife interface.

This book is a response to the need for better information on the African elephant. It aimed to collect the experience of biologists working in the field on the African elephant, and to inform protected area staff, research officers and research students of the principal techniques used in the study of African elephants. The book intends to encourage protected area and research staff to embark on studies of their own that would contribute to the information available. It is also recognised that local people are being brought into wildlife management, and encouraged to manage their own resource. It is hoped that this book will be of use to them in planning and carrying out their own wildlife inventories.

Ideally, research should be linked to the management objectives of an area, and the techniques used should flow from stated management objectives. This is not to say that research cannot be done for its own sake, but given the scarcity of resources suffered by many African protected area authorities, it is important to make the links between management and research. This book is structured to help the reader make these linkages. Chapter 1 provides an introduction to the African elephant, describing the elephant, its lifestyle and general ecology. Chapter 2 in Section 1 focuses on making management decisions from data, and provides a management context within which to view the rest of the chapters in the book on research techniques. This chapter is followed by Section 2 on counting elephants. Chapter 3 describes how to carry out aerial sample counts. Chapter 4 covers aerial total counts. Chapter 5 describes how to estimate the abundance of forest elephants, using dung counts and Chapter 6 describes how to count elephants directly from the ground. As you will see in this section, how one counts elephants depends on a number of factors including the ecology of a region, the kind of estimate required in terms of accuracy and precision and the resources available to carry out the count.

Section 3 provides a series of chapters on techniques applicable to the study of specific elephant populations. These include getting to know an elephant population (Chapter 7), studying elephant movements (Chapter 8), studying elephant-habitat interactions (Chapter 9) and studying the behaviour of elephants (Chapter 10).

Section 4 on developing research techniques describes how studies using modern and technologically advanced techniques are done. It is unlikely that all protected area staff will have the resources to carry out studies of this kind, but these chapters are included to give research officers and protected area staff a flavour of modern elephant research and to make them aware of innovations in elephant research.

Section 5 on elephants in their human context provides information on how to assess the impact of human-elephant contact both on the elephants and on the humans (Chapter 15), and how to assess the efficacy of our conservation efforts to protect the species and monitor illegal activities (Chapter 16).

Section 6 on handling elephants provides practical instructions on how to immobilise elephants (Chapter 17) and how to collect information from dead elephants (Chapter 18).

Written as this book is, by a variety of experts in elephant biology, the chapters vary in style and the depth to which they cover a topic. All have the advantage of being written by people who practice these techniques themselves, and should prove useful in guiding someone embarking on his or her own research. Where the length of the book and consequently that of chapters has not permitted authors to go into great depth on an aspect of the research, they have pointed the reader in the direction of literature sources on the topic. To meet the needs of a broad spectrum of protected area authorities with different levels of funding, and research capacities, you may find that the some of the techniques discussed are beyond your means. Some of the techniques are statistically complex, while others require a large amount of technologically advanced and expensive equipment. Do not let this discourage you from pursuing your own elephant research. Several chapters show you that research can begin with a minimum of a note book and an observant eye, and produce meaningful results.

To maximise the quality, and hence usefulness, of your research start by consulting experts in the field on technical issues if you have any questions, and find statisticians who can help you with some of the statistically complex aspects of analysing data. Should you wish to get in touch with anyone working in a particular area of elephant biology, you can contact the IUCN/SSC African Elephant Specialist Group, d/o WWF Regional Office, Eastern Africa, P.O. Box 62440 Nairobi, Kenya, which will put you in touch with relevant experts.

Every effort has been made to include the widest variety of research areas, both to instruct, and to inform. However, it is recognised that the topics covered have not fully exhausted the field. Perhaps the next volume will include any topic that has been left out, and the experience that you the reader gather as you embark on your elephant research.

CHAPTER 1

THE AFRICAN ELEPHANT

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1.1 INTRODUCTION

Over the last thirty years literally hundreds of studies on African elephants *(Loxodonta africana)* have been carried out across the continent. We have learned more about elephants than, perhaps, any other large undomesticated African mammal, and yet we are just beginning to understand their complex lives.

Elephants have captured man's imagination and respect for thousands of years. In some ways we can draw close parallels between humans and elephants. Like humans, elephants have the capacity to modify their habitats dramatically (Laws *et al*. 1970; Cumming 1982; Kortlandt 1984; Western 1989), and their need for space often brings them into direct conflict with expanding human populations (Kangwana 1993; Ngure 1993; Kiiru 1994; Thouless in press). Elephants, like our own species, are noted for their intelligence, close family ties and social complexity (Moss 1988). In other ways, they remain mysteriously different. Their uncanny ability to communicate with one another over long distances (Martin 1978), once referred to as 'extra sensory perception' (Rees 1963), is now known to be through the use of loud sounds below the level of human hearing (Poole *et al*. 1988). The African elephant is the largest living land mammal with males of the species weighing up to 6,000kg and standing 3.3m at the shoulder (Laws 1966; Laws & Parker 1968; Laws 1969; Hanks 1969). With a trunk weighing 140kg, an elephant can pick up the tiniest crumb, push over a mature tree, reassure a baby, pour 12 litres of water into its mouth or detect a smell from several kilometres away. Their two elongated incisors composed of ivory have been coveted by humans for hundreds of thousands of years, and ivory has played a significant role in the art and culture of many peoples (Ross 1993).

Elephants once populated the entire continent (Mauny 1956; Douglas-Hamilton 1979) and, formerly, within the last three centuries, *Loxodonta africana* inhabited all of sub-Saharan Africa in habitats ranging from tropical and montane forests to open grasslands, semi-arid bush and desert. In recent years, however, the poaching of elephants for ivory and human population growth and expansion have reduced the species' range and numbers drastically, and the majority of remaining elephants exist in small pockets of protected land isolated by human habitation and development, or in dense forest (United Republic of Tanzania 1989).

The African elephant and its close cousin, the Asian elephant *(Elephas maximus)*, are the only species surviving in the order Probocidea. Both genera originated in sub-Saharan Africa in the early Pleistocene (Maglio 1973); *Loxondonta* remained in Africa, but *Elephas* moved into Asia during the late Pleistocene.

Two subspecies of African elephant are recognised: the savanna elephant, *Loxodonta africana africana*, and the forest elephant, *Loxodonta africana cyclotis*. The savanna elephant is larger than the forest elephant, has sparser body hair, more triangular ears that are larger, and thick, curved tusks as opposed to the straighter, narrower downward pointing tusks of the forest elephant (Lausen & Beckoff 1978). Elephants intermediate between the two subspecies are found in hybridisation zones over large areas of Africa where forests and savannas merge (Western 1986).

This chapter serves to give a general introduction to the African elephant. In describing the lifestyle of a species, it is often convenient to lump all members of the species together and say, for example, "elephants live in families", "elephants prefer to aggregate", "elephants are seasonal breeders", or"“elephants are browsers". But the study of African elephants reveals their social complexity and flexibility, and their ecological adaptability. Simple labels can be very misleading, as you will see inthe rest of this chapter and in your own studies, when you undertake them.

1.2 SOCIAL STRUCTURE AND BEHAVIOUR

1.2.1 General

African elephants live in a fluid and dynamic social system in which males and females live in separate, but overlapping spheres (Douglas≠ Hamilton 1972; Martin 1978; Moss 1977, 1981; Moss & Poole 1983; Hall-Martin 1987; Poole 1994). Related females and their immature offspring live in tightly knit matriarchal family units (Buss *et al.* 1976), while males live a more solitary independent existence with few social bonds (Martin 1978; Moss & Poole 1983). Neither sex is territorial, although both utilise specific home areas during particular times of the year (Moss & Poole 1983; Hall-Martin 1987).

1.2.2 Female society

Female elephant society consists of complex multi-tiered relationships extending from the mother-offspring bond to family units, bond groups and clans (Douglas-Hamilton 1972; Moss 1977,1981; Moss & Poole 1983; Martin 1978). The basic social unit is the family which is composed of one to several related females and their immature offspring, and may range in size from two to 30 individuals. Elephants appear to benefit from being part of a large family. Related females will form defensive units against perceived danger and will form coalitions against other non-related females or males (Moss 1988; pers. obs.). Larger families with older matriarchs are able to dominate smaller families with younger matriarchs (Moss 1988; pers. obs.), thus competing more successfully for access to scarce resources. Kin-based alliances also have a significant impact on calf survival. Large families with more female caretakers have higher calf survival than smaller families (Lee 1987; Lee 1989).

Bond groups (Moss 1981; Moss & Poole 1983) or “kin groups” (Douglas-Hamilton 1972) are made up of several closely allied families and may be composed of as many as five families (Moss 1988). Most bond groups appear to be formed when family units become too large and split along family lines (Moss 1988). Members of families or bond groups display a special greeting ceremony (Moss 1977, 1981, 1988; Poole *et al.* 1988), show a high frequency of association over time, act in a coordinated manner, exhibit affiliative behaviour toward one another and are usually related (Moss 1981; Moss & Poole 1983).

Above the level of the bond group is the clan (Moss 1981), defined as families and bond groups which use the same dry season home-range (Moss 1981; Moss & Poole 1983). While the term ‘clan’ is a useful category for a biologist to use when describing levels of association and habitat use, it is still unclear whether it is a functioning social unit from an elephant’s perspective.

A female elephant may be found in a number of different types of groups ranging from a fragment of a family unit to an aggregation of elephants numbering in the thousands and composed of many clans. Except in unusual circumstances female elephants are never found alone. The size and structure of groups that a female elephant finds herself in may change hourly and depends upon a number of different social and environmental factors including: the basic size of her family unit, the number of individuals that make up her bond group, the strength of bonds between her and other families, her sexual state, the habitat, the season and in many cases the level of human threat (Moss 1981, 1988; Poole & Moss 1989; Kangwana 1993; Njumbi 1993; E. Abe pers. comm.).

Elephants are highly social animals and data suggest that where resources are both plentiful and evenly distributed they will tend to aggregate (Moss 1988; Poole & Moss 1988; Western & Lindsay 1984). Particularly noticeable in many places is the aggregation of elephants during and following the rains when resources are plentiful (Douglas-Hamilton 1972; Leuthold 1976; Western & Lindsay 1984; Moss 1988; Poole & Moss 1989). A number of explanations have been proposed for these large aggregations including access to mates (Moss 1988; Poole & Moss 1989) and the renewing of social bonds (Moss 1988).

Families that benefit from association when forage is abundant must divide to maintain foraging efficiency when resources are scarce (Barnes 1983; Western & Lindsay 1984) and, as the dry season progresses, the large aggregations and bond groups begin to split up. During drought years even family units may break up for prolonged periods of time (Moss 1977, 1981, 1988).

Elephants also tend to aggregate in response to poaching (Laws *et al.* 1975; Eltringham 1977; Eltringham & Malpas 1980; Poole 1989c; Njumbi 1993; Abe 1982) or to the threat of human hostility (Kangwana 1993) particularly in open savanna habitats. These aggregations can be distinguished from social aggregations by the tight bunching pattern of the elephants (pers. obs.; Moss 1988; I. Douglas-Hamilton pers. comm.).

There is a tendency for groups to be smaller in tropical forests (White *et al.* 1993; Merz 1986) and thick bushland (Leuthold 1976), than in more open savanna grassland. White *et al.* (1993) have reported that in the forests of Gabon, family unit size averaged only 3.5 individuals and that groups of more than eight elephants were exceptional. They suggest that small families are perhaps better able to exploit the patchily available resources (such as fruit) in forests than are larger groups.

1.2.3 Male society

Male elephants leave their natal families at about 14 years of age (Amboseli Elephant Research Project (AERP) long-term records). Newly independent young males may follow several different courses to social maturity. Some young males leave their families only to join up with another family for a couple of years. Others go off to bull areas and join up with bull groups, while still others stay in female areas moving from family to family (AERP long-term records; P. Lee & C. Moss unpublished data).

Once males have reached their early twenties they enter a highly dynamic world of changing sexual state, rank, behaviour and associations (Poole 1989a&b). The structure and size of groups with which an adult male associates, and the type of interactions he has with members of these groups are determined by his age, and hence body size, and sexual state (Poole 1989a; Hall-Martin 1987).

Adult male elephants exhibit a period of heightened sexual and aggressive activity known musth (Poole & Moss 1981; Poole 1987; Hall-Martin 1987). The word ‘musth’ comes from the word’ ‘*mast*’’meaning intoxicated. During sexually inactive and non-musth periods males spend time alone or in small groups of other males in particular bull areas, where their interactions are relaxed and amicable (Poole 1987). During)r active musth periods males leave their bull areas move in search of oestrus females, which time they are likely to be found alone or in association with groups of females (Poole 1987).

Among non-musth males dominance is determined by age and body size with larger, older males ranking above smaller, younger males (Poole 1989a). Once in the aggressive state of musth, a male ranks above all non-musth males (Poole 1989a). Among musth males, dominance is determined by a combination of body size and condition. Two closely matched males will often fight, sometimes to the death of one of them (Hall-Martin 1987; Poole 1989a).

1.3 SEXUAL DIMORPHISM, LIFE HISTORY AND REPRODUCTIVE PATTERNS

1.3.1 Sexual dimorphism

Male elephants can be distinguished from females by their larger, heavier build, their characteristic curved foreheads in profile (see Chapter 7), and their thicker tusks (see Chapter 14). Females are slighter, have an angular forehead in profile, slender, pointed tusks, and breasts located between their forelegs.

Elephants are long lived mammals. Age determines dominance, leadership and calf-survival among females (Moss 1988; Moss in prep.), and reproductive success through female choice and dominance among males (Poole 1989a&b). Early rapid growth of males, combined with a higher rate of growth throughout life, leads to the high degree of sexual dimorphism observed in adults (Lee & Moss 1986; Lee in press). By the time males are about 17 years old, they are taller than the largest females. Males continue to grow in height and weight throughout most of their lives, eventually reaching almost twice the weight of adult females (Laws 1966; Hanks 1969). The ability of elephants to continue growing beyond the age of sexual maturity, when most mammals cease to grow in height, is related to the unusual delayed fusion of the long bones, which is more pronounced in males than in females (Haynes 1991; L. Leakey pers. comm.). Among female elephants, fusion of the long bones occurs between 15 and 25 years of age, whereas in males fusion takes place between 30 and 45 years of age (Haynes 1991; L. Leakey pers. comm.). Undoubtedly, there has been strong selective pressure for large body size in male elephants.

1.3.2 Sexual maturity

The age of first ovulation ranges from population to population, from as young as seven to as old as 22 years (Laws & Parker 1968; Laws *et al.* 1975; Moss in prep.), depending upon population densities and resource availability. In a study of the Amboseli population, where there were 135 known age females between eight and 20 years old, the mean age at first conception leading to full term pregnancy was 11.3 years and the mean age at first parturition was 13.2 years (Moss in prep.). The youngest female to give birth was exactly eight years old at the time of conception (Moss in press).

Male elephants mature later than female elephants and although they begin producing sperm at around 14 years old (Laws & Parker 1968), they are not socially mature, and do not begin competing with older males for oestrus females until they are in their late teens or early twenties (Poole 1989a). Between 20 and 25 years of age, males begin to show distinct sexually active and inactive periods; and, by 30 years old, males have usually exhibited their first musth period (Poole 1987). The youngest elephant observed in musth in Amboseli was 22 years old (AERP long-term records).

1.3.3 Qestrus and musth

The oestrous period lasts for four to six days (Moss 1983; Poole 1989b; Mutinda 1994). It has been postulated that ovulation and conception occur during mid-oestrus when females are guarded and mated by a high-ranking musth male (Poole 1989a); Mutinda 1994). Oestrous females attract males by exhibiting conspicuous behaviour (Moss 1983; Mutinda 1994), calling loudly and frequently (Poole *et al.* 1988; Poole 1989b), and producing urine with particular olfactory components (Rasmussen *et al.* 1982; Mutinda 1994). If a female does not conceive she will come into oestrus again three months later if she is still in good condition (AERP long-term records).

During musth, males secrete a viscous liquid from swollen temporal glands just behind the eyes; they leave a trail of strong smelling urine (Poole & Moss 1981; Poole 1987; Hall-Martin 1987), and call repeatedly in very low frequencies (Poole 1987). A male's testosterone levels rise to over five times his non-musth levels (Poole *et al.* 1984), and musth males behave extremely aggressively toward other males, particularly those also in musth (Poole 1989a; Hall-Martin 1987).

The Musth periods of larger, older males last several months and occur at a predictable time each year. By contrast, the musth periods of younger males are short and sporadic, lasting a few days to a few weeks (Poole 1987; Poole 1989a).

Individual males attempt to locate, guard and mate with as many oestrous females as possible during their musth periods. Musth males are more successful at obtaining matings than non-musth males for two reasons. First, their large body size and aggressive behaviour makes them better able to compete for access to oestrous females and, second, females prefer to mate with musth males - they will not stand for younger non-musth males and if approached will solicit guarding behaviour from a musth male (Moss 1983; Poole 1989b). Older, larger musth males are more successful than younger musth males (Moss 1983; Poole 1989a&b). Under natural circumstances males probably do not father their first offspring until they are between 30 and 35 years old and they do not reach their prime until about 45 years old (Poole 1989a&b)

1.3.4 Seasonality of breeding

Although most elephant populations do not exhibit a pronounced breeding season (Poole 1987; Hall-Martin 1987; but see Hanks 1972 & Kerr 1969), the occurrence of oestrus and conception is sensitive to rainfall and resource availability (Laws & Parker 1968; Laws 1969; Poole 1987; Hall-Martin 1987; Moss 1988; Moss & Dobson in prep.). The degree of seasonality of oestrus varies from population to population, depending upon habitat and rainfall conditions (Laws & Parker 1968; Hanks 1969; Laws 1969; Poole 1987; Hall≠Martin 1987). In the Amboseli population, oestrous females may be observed in any month of the year, but the frequency of oestrus is significantly higher during and following the wet seasons (Poole 1987; Moss 1988) when females are in good condition.

The seasonality of male musth periods reflects the pattern exhibited by females (Poole 1987; Hall≠Martin 1987). Oldest, highest-ranking males come into musth during and following the rains when food is plentiful and most females come into oestrus (Poole 1987). At this time of year females aggregate into large groups, increasing the probability that a male will find an oestrous female (Poole & Moss 1989).

1.3.5 Birth and calf development

Elephants are born after a gestation period of 21.5 months with the average birth weight of males being 120kg, 20-30kg more than that for females. The sex ratio at birth is 50:50, although there is evidence that slightly more males are conceived during years of higher than average rainfall (Moss & Dobson in prep.). Calves born to older, larger females are bigger than those born to younger, smaller females (Lee 1986). Laws & Parker (1968) estimated that twinning occurred in less than 1% of conceptions. In Amboseli only one set of twins was recorded out of 147 births between 1976 to 1980 (Moss 1988).

The energetic requirements of calves are met exclusively by milk consumption for the first three months of life (Lee & Moss 1986). After this age calves begin to feed independently with the time spent feeding increasing rapidly between four and 24 months when it levels off to about 55% of daily time. The majority of calves suckle until the birth of the next calf, but some calves are weaned before the birth of the next calf, while others continue to suckle after their sibling's birth (Lee & Moss 1986). It is not uncommon to observe juveniles of up to eight years old suckling. The youngest calf in Amboseli to survive without milk was 26 months old at the time of its mother's death (Lee & Moss 1986).

1.3.6 Interbirth interval

Mean calving interval varies from population to population, from 2.9 to 9.1 years, with high density populations or otherwise nutritionally stressed populations exhibiting longer intervals (Laws & Parker 1968; Laws *et al*. 1975; Eltringham 1977). Most estimates of interbirth interval have been calculated from the placental scars of culled elephants and therefore do not take into consideration the survival of the previous calf. In the Amboseli study, the mean interbirth interval between two surviving calves was 4.4 years with a range of 2 years 7 months to 9 years 1 month (Moss in press). Females between the ages of 14 to 45 experience the highest fecundity with mean interbirth intervals increasing to five years by age 52 and six years by age 60 (Moss in press). Interbirth intervals of up to 13 years may occur depending upon habitat conditions and population densities (Laws 1969). With a typical calving interval of four years, females move into a synchronous wave pattern with birth peaks every four years (Moss in press).

1.3.7 Mortality

Calf mortality is highest in the first 12 months of life, and is generally low after this age (Lee & Moss 1986). The calves of younger and older females experience higher mortality rates than middle-aged females. Experience of the mother, her rank within the family and her general physical condition all affect calf survival (Moss in prep.).

Natural mortality of adults has been estimated at 2-3% on the basis of found jaws (Laws 1969; Corfield 1973) and observations of known-age elephants (Douglas-Hamilton 1972; Moss in prep.). Data from a 20-year-study of known individuals in Amboseli suggest that basing mortality rates on jaws may lead to an underestimate as not all jaws are found.

1.4 ELEPHANT COMMUNICATION

Elephants communicate with one another using numerous sounds (Berg 1983; Poole *et al.*1988; Poole 1994) and scents (Buss *et al.* 1976; Adams *et al.*1978; Rasmussen *et al.* 1982; Poole & Moss 1989) as well as numerous ear, trunk and body postures.

Elephants communicate vocally using a wide variety of sounds, from the higher frequency screams, trumpets, snorts and bellows to the lower frequency rumbles which contain components below the level of human hearing (Berg 1983; Poole *et al.* 1988), some as low as 14Hz (Poole *et al.*1988). The ability of elephants to produce these very low frequency sounds, at sound pressure levels of up to 102dB at 5m, means that they are, theoretically, able to communicate with one another over distances of 5-10km, even in thick forest (Poole *et al.*1988).

The fundamental differences in male and female elephant society are no better revealed than by the striking sex difference in the number and variety of vocalisations each uses (Poole 1994). Females use some 22 different vocalisations while males use only seven; only three of these calls are made by both sexes. It appears that most of the female vocalisations are related to family/group dynamics, cohesion and protection, while the few male vocalisations are primarily related to male≠-male dominance or reproduction (Poole 1994), but vocal communication in elephants is a relatively new field, and will, I am sure, provide many more surprises.

1.5 ELEPHANT ECOLOGY

Elephants are extremely adaptable, occupying a variety of habitats from desert to savanna to gallery forest (Lausen & Bekoff 1978). Environmental factors affect elephant population dynamics, home range, migration patterns, diet, group size and composition, all of which can vary tremendously, in turn influencing the dynamics of elephants and their habitats.

An elephant's diet may include grass, herbs, bark, fruit and tree foliage. In savanna habitats grass may make up 70% of the elephants' diet in the wet season, with larger proportions of browse contributing to their diet as the dry season progresses. In tropical forest, an elephant's diet may include as many as 230 species with leaves, twigs, bark and fruit constituting over 90% of all items eaten (White'*et al.*1993). Trees represent up to three-quarters of the species fed upon (White *et al.* 1993) and, in contrast to savanna elephants, fruit is an important component of a forest elephant's diet (White *et al.*1993; Alexandre 1977).

Estimates for mean daily intake range from 4% (Laws *et al.*1970) to 7% (Ruggiero 1992) of body weight, with lactating females consuming proportionately higher quantities (Laws *et al.*1970). Elephants digest only 40% of what they consume.

Elephants are capable of greatly affecting the structure of vegetation and perhaps animal communities (Laws 1970; Cumming 1982; Western 1989). At high densities elephants reduce woodlands, converting them to more open grassland (Laws *et al.*1970; Laws *et al.*1975; Cumming 1982; Western 1989).

In many areas human expansion and poaching have forced elephants to alter traditional migration patterns and concentrate in protected areas (Western 1989; Tchamba & Mahamat 1992; Poole *et al.*1992). At high densities, particularly where they have been compressed into protected areas, elephants can reduce biological diversity (Western 1989) and cause economic loss of timber in forests (Laws 1970; Afolayan 1975). In some cases the reduction of woody vegetation has been beneficial in opening up tsetse fly infested woodland and transforming bushland to grassland for livestock (Western 1989). Often fire or logging may initiate change with elephants playing a maintaining role (Dublin *et al.*1990; Dublin 1991).

Studies have also shown the ecological importance of elephants as agents of seed dispersal (Alexandre 1977) increasing habitat mosaic in forests (Kortlandt 1984) and diversifying mammalian communities (Western 1989). As a keystone species, elephants play a crucial role in maintaining linkages in the food web, and their extermination from some habitats may cause a cascade of change or extinctions in ecosystems (Western 1989). Evidence suggests that elephants diversify savanna and forest ecosystems when free to move (Western 1989).

1.6 HOME RANGE AND MIGRATION

As with other parameters elephant home ranges vary from population to population and habitat to habitat. Individual home ranges vary from 15 to 3,700km^2 (Douglas-Hamilton 1972; Leuthold 1977; Thouless in press). In most areas where they have been studied, females live in predictable dry season home ranges, but migrate over large areas during the wet season (Leuthold & Sale 1973; Leuthold 1977; Western & Lindsay 1984). Moving singly or in groups of up to several thousand, elephants may travel as far as 75km in a few days (Leuthold 1977). They may live at densities as low as 0.024 per km^2 (Poche 1974) or as high as 5 per km^2 (Douglas-Hamilton 1972).

Previously, elephants migrated over long distances throughout their range. The increasing compression of elephants into smaller and smaller protected areas with no allowance for seasonal migration is likely to lead to accelerated habitat destruction and loss of biodiversity in our national parks and reserves. Finding solutions to this problem is one of the most pressing management needs in elephant conservation today.

1.7 CONCLUSION

The more we, as biologists, learn about elephants, the more questions we find ourselves asking about their complex lives. Elephant research is a rewarding experience, and there is much scope to add to the existing body of knowledge on the African elephant. Undoubtedly, elephants will continue to present challenges to biologists and wildlife managers alike for as long as there are elephants.

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SECTION 1

ELEPHANT MANAGAMENT

CHAPTER 2

MAKING MANAGEMENT DECISIONS FROM DATA

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2.1 INTRODUCTION

In Africa, some of the most important decisions that have had to be made, and will continue to be made in wildlife management, revolve around elephants. Management decisions must be made about what to do with elephants both inside and outside protected areas, and the appropriate action which must follow. These decisions may occur at the park warden level or they may be taken at higher political levels. Either way, these decisions can have far-reaching consequences, and they need to be based as firmly as possible on sound information. This demonstrates the need to have as much accurate and up-to-date data as possible.

So, what exactly does a wildlife manager need to know about elephants in order to manage them and ensure their protection and conservation, now and in the future? In this chapter we note the types of problems confronting management authorities and the range of elephant management options available to them, and we discuss the kinds of data that can assist decision making.

2.2 DECIDING ON A MANAGEMENT OPTION

The protection of wildlife conservation areas is complex and involves political, social, economic, technical and ecological considerations as well as those of a financial, legal and administrative nature. All these considerations play a role in determining the ultimate choice of management options. A very useful workshop in Kruger National Park produced a set of guidelines (Ferrar 1983) for the management of large mammals in African conservation areas, including a chapter on how managers make decisions. The following ideas derive, in part, from these proceedings. Essentially, in managing a wildlife system there is a technical component and a subjective component to decision making.

The technical component of decision making relates to facts, and addresses questions such as “What is the current state of the system?” Because of the complexity of ecological systems, and because the necessary information is not always available, there is still a large amount of uncertainty about the technical aspect of decision making. This uncertainty emphasizes the need to monitor changes in ecological variables in relation to the objective of a management action. As new information becomes available, it can be used to improve or alter the management action. Thus, research, monitoring and feedback become integral components of management.

The subjective component of decision making relates to preferences and opinions, and addresses questions such as “What state of the system do we prefer?” and”“How would we like the system to change?” A value judgement is used to choose between options of equal merit.

Many wildlife management questions involve both technical and subjective aspects. For example, the question “Are there too many animals in this area?” is really two questions and requires two quite different answers:

i) “Will the number of animals cause the system to change in any way?” The answer here is purely a technical one.

ii) “What amount of change in the system is permissible in this area?” The answer depends on the objective for the area and ultimately rests on preference, i.e. it is subjective.

An important function of research is to provide information and data to answer the first part of the question, which is of a technical nature, thus enabling a decision to be made on the second part of the question which is a matter of preference. However, it is important to note that the distinction between these two parts of a question is rarely made, and subjective decisions often override most other considerations.

2.3 WHAT ELEPHANT MANAGEMENT OPTIONS ARE THERE?

There are three basic approaches to the management of elephants:

- minimal or *laissez-faire* management;
- management for ecological objectives; and
- management for economic objectives.

a) Minimal or *laissez-faire* management

Minimal or *laissez-faire* management implies the decision to do nothing or not to intervene with ecological processes. This is a management option practiced widely in many elephant range states. In some cases the decision to do nothing or not to intervene has arisen by default or inaction, and is not an intentionally selected option, clearly decided upon and explicitly stated.

The assumptions underlying minimal or *laissez-faire* management are that the natural systems under consideration, including those that support elephants, are able to regulate themselves without human interference, and that non-interference is a necessary pre-condition for the self-regulation of systems. While it is very difficult, and it may take years, to test this, not doing so could lead to delays in recognising the existence of serious problems. It, therefore, remains extremely important and valuable to test the assumptions on which *laissez-faire* management decisions are based.

b) Management for ecological objectives

The underlying assumption in management for ecological objectives is that natural systems are so disrupted under the conditions imposed on them by modern man that they can no longer regulate themselves. In order to meet stated ecological objectives, management intervention is therefore necessary. Whatever management intervention is chosen, it will require testing through appropriate monitoring and evaluation, and experimentation, if this is possible. In the context of elephant populations, management for ecological objectives can take a variety of forms, for example:

- habitat modification, such as management by fire or removal of vegetation;
- provision and/or manipulation of water supplies;
- population reduction either through culling or translocation; and
- control of population movement through the construction of physical barriers such as fences.

c) Management for economic objectives

Here systems, and more specifically, the animals within them, are exploited for economic gain.

With regard to elephants, economically-based consumptive exploitation may include safari hunting for trophies or cropping for meat or leather production. Economic objectives may also include increasing tourist viewing. For example, special water points may be constructed or fire management may be used to manipulate habitats to encourage the concentration of large numbers of elephants in open areas.

None of the above management approaches are necessarily mutually exclusive; one or more may be implemented. The manager should have stated goals, usually arising from higher level policy decisions, and needs to know not only the economic or financial implications of his intervention but also the ecological consequences. In the case of consumptive use, he may also need to know the consequences of such off takes for the population being exploited; the wildlife manager may need to consult with biologists tasked with monitoring the elephants and analysing the information gathered.

Ancillary activities that enhance the above three primary approaches include law enforcement and the implementation of community-based wildlife management and conservation programmes. Where implemented, these activities should also be part of an overall management strategy and plan, each with its own research, monitoring and evaluation components.

2.4 WHAT DO MANAGERS NEED TO KNOW ABOUT ELEPHANTS?

In seeking to define research priorities. Bell and McShane-Caluzi (1985) ask the question: 'What does management need to know in order to reach its objectives more effectively?" In asking this, one is confronted with the research priority paradox: if we do not understand a system or species how do we know what to study first?

Before we can begin to manage elephants and the habitats in which they occur, we need to know something about both. There are a number of key ecological attributes or characteristics of an elephant population that are important to management. Information about the life history of elephants and their biological make-up is an essential requirement. It should be noted, though, that it may not always be possible, or necessary to defer management action because not all the information on which to base management decisions has been collected. Whatever management action is taken, if it is properly executed and rigorously applied and monitored, it can be treated as an experiment to provide answers to some of the research questions being asked. So in managing elephants, what factors must a manager have some basic information on?

a) Abundance and trend

Data on elephant numbers and density are basic requirements for a manager, particularly if there are plans to exploit the population in any way. It is, therefore, important to know how many elephants there are in the population or area under consideration, and whether the population in question is increasing, decreasing or stable. Obviously trends in population size can only be answered over time, and this requires a suitable monitoring programme to be put in place.

Obtaining reliable counts of wild animals is not easy and there are a variety of ways in which elephant population numbers can be estimated. These include aerial counts, which may be sample or total counts (described in Chapters 3 & 4 respectively) and ground counts (described in Chapter 6). Such counts are widely applied in savanna areas, but in the dense forests of central Africa ground counts of elephant dung are used to provide estimates of elephant numbers (Chapter 5). In many circumstances, only an index of elephant abundance can be established and monitored over time.

Whichever counting method is used, it is important that the counts are consistent, reliable and repeatable over time. In addition, the manager needs to know something about the quality of the data. For aerial counts, confidence limits, sampling intensity and search rates are important factors which will provide information on the data quality, and its reliability through either its accuracy (for total counts) or its precision (for sample counts). Data quality categories have been developed by the African Elephant Specialist Group (AfESG) of IUCN's Species Survival Commission (Said *et al.* in press). These will be of value to managers in assessing the quality of elephant count data on which they must base their management decisions. Even if the numbers counted or estimated are not absolute and only reflect an index of abundance, provided the method used remains the same the manager can compare estimates over time.

b) Distribution and movement

A wildlife manager also needs to know where elephants are distributed across the area in question and the nature of that distribution. Are there, for example, seasonal shifts in distribution or regular movement patterns? Have traditional or established movement patterns become disrupted by recent changes in land use and settlement patterns, and what are the implications for the affected elephant and human populations? How these questions can be answered is described in Chapter 8 on studying elephant movements and in Chapter 12 on the satellite tracking of elephants. The answers will allow informed management decisions to be made. Chapter 17 outlines the practical details of immobilising elephants so that they can be fitted with radio or satellite transmitter collars; a costly but integral part of many studies on elephant movements.

Where possible, it is good to distinguish and describe elephant range as accurately as possible. Members of the AfESG (1993) recently suggested categories of elephant range. These are:

i) core range - where elephants are present throughout the year;

ii) seasonal range - where elephants are present seasonally;

iii) erratic range - where elephants may occur periodically but not necessarily every year; and

iv) unknown range - where elephants are known to occur, but where there is no further information available.

Elephant range and distribution data become particularly important where cross-border movements occur and two or more countries share the same elephant population. This of course has important management implications for the countries involved, and can become especially complicated if management policies between the countries differ markedly.

Data on the seasonal movement of elephants were used to make management decisions in Matusadona National Park in Zimbabwe (Taylor 1983). The management authority needed to know whether elephants moved in and o ut of the Park seasonally and if so, to what extent, in order to make decisions about reducing elephant numbers to protect escarpment woodlands. A three-year tracking study of radio-collared elephants indicated that animals in the south of the Park did indeed move into the adjacent communal lands where they were economically important, and these elephants were, therefore, not culled. In the north, however, elephants had much smaller home ranges and were resident year-round, and here culling the elephants to protect the habitat was prescribed.

c) Elephants and their habitats

Following on from a knowledge of how many elephants there are and where they are distributed, it is most likely a manager will want to understand how the elephants are utilising the habitats in which they live. Within these habitats it may be useful to know what the elephants are eating. Chapter 9 looks at how the interactions between elephants and their habitats may be studied.

A manager may want to know the rate of woodland loss or the rate of growth of a particular plant species under given or differing elephant densities in order to answer a management question relating to the objectives of a park. The influence of factors such as fire and water availability also needs to be taken into account when examining the relationships between elephants and their habitats. Fire and water may be natural or artificial components of the environment but their roles need to be assessed and monitored on a regular basis.

Causal effects are often difficult to establish in elephant-habitat dynamics. Sometimes ecosystem models, which may begin as simple flow diagrams and expand into complex computer models, can help a manager understand the system he is endeavouring to manage. Likewise, the models may impede, obscure or distort understanding. Models should be used with caution and only where they are based on good empirical evidence with a sound understanding of their limitations and the assumptions used in their formulation. A model, of whatever sort, will be of most use to a manager when he is familiar with the ecosystem he is managing and he can contribute to the development of the model and interact with it on the strength of his own knowledge and updated information which comes from regular and repeated monitoring. Simple models with predictive capacity can allow the manager to simulate and implement decisions on the computer and evaluate the consequences of such decisions before he actually carries them out. In this way the manager can assess the level of risk involved in taking a management decision before actually implementing it. Such simple modelling approaches have been effectively developed for the Tsavo ecosystem (Wijngaarden 1985) and the Serengeti-Mara ecosystem of East Africa (Dublin *et al.* 1990). However, the broader application of modelling to wildlife management is well covered by Starfield and Bleloch (1986).

d) Population biology

At the population level, there are three key points that have implications for elephant management.

i) Population dynamics

Individual growth rates, age and sex structure and rates of increase of the population as a whole, calving intervals, age at sexual maturity, age at birth of first calf and breeding senescence are all parameters which collectively help to define and characterise the dynamics of a population. Whereas much of this information was previously collected from culled animals (Laws *et al.* 1975; Hanks 1979), in recent years, similar data have been gathered from detailed observations of known individuals over time (Moss 1988). Data collected from both sources should be seen as complementary and corroborative to confirm our present understanding of elephant population biology and dynamics. Methods of gathering this information from a live population are described in Chapter 7 and details on how to collect material and data from dead elephants are given in Chapter 18. Chapter 13 describes how to study the reproductive physiology of elephants which will also contribute to the understanding of elephant population dynamics.

Population growth rates below the theoretical maximum imply that the ecological carrying capacity or equilibrium density ("K" in the logistic growth curve) is being approached or that mortality (natural and man-induced) is increasing or natality is depressed, due perhaps to disease or stress. Large, slow breeding and long-lived species such as elephants are more vulnerable to environmental setbacks, such as drought, or management errors, than those that are short-lived with high growth rates because their potential for rapid recovery following disruption is low. Details on how to study the population dynamics of large mammals are given in Caughley (1977) and Sinclair and Grimsdell (1982).

Sex and age structure estimates of a population are extremely important and valuable data for a manager trying to understand population dynamics. Ideally such information should be used in combination with additional and complementary population census data. This will guard against pitfalls due to imprecise or incomplete information in analysis and interpretation.

The age and sex composition of a population can be influenced by conception rates, birth and death rates, calf survival and other behavioural characteristics. The proportion of individuals of each sex in each age class is changing continuously and the theoretical concept of a stable age distribution almost never exists. Populations with a preponderance of young can be expected to increase whereas a population whose age distribution is skewed towards the older age classes will remain either stable or decrease. Likewise, elephants of different sex and age classes respond differentially to environmental stimuli, such as rainfall or other stochastic events which can induce nutritional stress or pulses of growth. Chance effects alone can cause annual population growth rates in elephant populations to vary from 2% to 6% in any given year.

Depending on the management objective, manipulating sex and age composition through management action needs to take these considerations into account. Martin and Conybeare (1992) describe a management regime for an elephant population which includes sport hunting, culling for ecological reasons and problem animal control. Each treatment predicts a different effect on the managed population with respect to its sex and age structure.

ii) Behaviour and social organisation
The dynamics of a population may be affected through changes in group size or other social disruptions such as the removal of age classes which are important to the group's social structure and functioning. Over time, studies on the behaviour of elephants can provide a manager with an understanding of the effects of different management strategies on the behavioural and social organisation of a population (see Chapter 10 on how to study elephant behaviour). In elephants, social disruption may occur when the sex and age distribution of a population is manipulated through culling, poaching or translocation of individuals. Behavioural studies have particular relevance to the translocation of live elephants to new areas and may provide important insights into the residual effects on both source and destination populations. In the future, elephant vocalisation studies may shed even more light on the effects of such manipulations (see Chapter 11).

Elephant group size and changes in group size, whether seasonal or long-term, are influenced by many factors and may have important effects on the ecology of any ecosystem (Western & Lindsay 1984; Dublin 1986). Therefore, elephant group size is another important variable to monitor. In some cases, group size may be influenced by habitat type and food abundance. For example, elephants often form large groups in grasslands and swamps, where food abundance allows the congregation of large numbers into a small area. In other cases, very large co-ordinated groups of elephants may be a manifestation of human disturbance such as excessive control shooting in which matriarchs are killed, or large-scale poaching. It is important for the manager to understand the cause of changes in grouping behaviour, and this can only be determined by knowing what the normal grouping patterns are for the population under consideration.

iii) Body condition and disease
Assessments of body condition will reflect nutritional stress in response to unfavourable habitat conditions. Such assessments can be made visually and from examination of live animals, as described by Riney (1960) and others, or by post-mortem inspection of condition indices such as fat, muscle weight and size. The collection and use of data from dead elephants are discussed in Chapter 18.

Disease is a factor in elephant mortality. On the southern shores of Lake Kariba in Zimbabwe a small number of elephant males have developed the "floppy trunk" syndrome, a form of trunk paralysis the cause of which is still unknown. Elephants so afflicted are unable to feed, and death from starvation results. Anthrax outbreaks are endemic in Etosha National Park in Namibia (Lindeque 1988). and encephalomyocarditis, a fatal viral infection in adult male elephants occurs in Kruger National Park, South Africa (Grobler *et al.* 1994). The rapid growth of rodent populations during drought spreads the virus, and in Kruger the management response has been to develop a vaccine. As well as endeavouring to discover the cause of any disease outbreak, monitoring its incidence is important in establishing whether the disease is localised or likely to spread. On the basis of such data, managers can decide what to do. They may want to collect post-mortem samples for analysis, or they may want to destroy the afflicted animals if a suitable treatment is unavailable. In the event of an extensive disease outbreak it may become necessary to monitor mortality rates by counting carcasses, as well as live elephants, to provide carcass ratios (Douglas-Hamilton & Burrill 1991).

2.5 THE INTERACTION BETWEEN HUMANS AND ELEPHANTS

Wildlife managers cannot ignore the fact that elephants share much of their range with humans. Over 75% of elephant range lies totally outside the protected area network (Douglas-Hamilton *et al.* 1992), and in many countries there are more elephants outside the protected area network than there are inside. Elephants are, therefore, often sharing land with rural people, and with the growing human population throughout the continent, the interaction between people and elephants, and any resulting conflict, will increase. Land use practices, human demography and economic practices are, therefore, important aspects of elephant conservation. There is an urgent need for elephant conservation to be integrated into broader land use policies and for strategies aimed at conserving elephants to include the considerations of local people, their lifestyles and their economies in all management and planning.

People and elephants interact directly in a number of ways. Elephants cause damage to human property, kill people and compete with humans for water and forage resources. People kill elephants for their ivory, and also in retaliation when elephants have killed someone or destroyed human property.

In the case of the illegal killing of elephants for their ivory, managers may need methods of monitoring this illegal activity and testing whether their management actions have had anyeffect. The methods to do this are described in Chapter 16 on monitoring law enforcement and illegal activities. Using data collected from law enforcement activities in the field, it is possible to evaluate the impacts of management actions such as anti-poaching efforts, and policy decisions such as the international ban on trade in ivory (Dublin & Jachmann 1992; Dublin *et al.* 1995). This kind of information is important for both wildlife managers and high-level policy makers. Parallel studies on the sourcing of elephant tusks (see Chapter 14) may assist in identifying the origins of ivory entering the trade and, subsequently, distinguishing ivory obtained legally from ivory obtained illegally.

In order to formulate strategies to minimise conflict and increase tolerance of elephants amongst rural people, wildlife managers need to know how elephants impact on people. Quantitative measurements of damage to crops, livestock and property help the wildlife manager to assess the economic and social costs of elephant-related damage. Some methods required to do this are described in Chapter 15. Answers to who, where, what, how and why come from simple monitoring procedures which need to be in place whenever elephants cause problems on a regular basis. Avery useful and practical system for measuring problem elephant activity, the appropriateness, cost effectiveness, and practicalities of overcoming these problems through the use of fencing is given by Hoare and Mackie (1993) and Hoare (1995).

Elephant managers also need to balance the costs to people of living with elephants, with the value of elephants as a resource. Innovative integrated conservation and development programmes such as the Zimbabwean Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) (Child 1993; Taylor 1993) can help to educate local communities, increase their level of tolerance towards elephants, promote better and more sustainable land-use practices and contribute to the larger goal of maintaining biological diversity. Extensive wildlife areas and the wildlife they support, whether formally protected or not, will have a greater chance of survival if management authorities take into account the development needs of the local people. By making communities responsible and accountable for managing their own resources (such as elephants), while allowing them to benefit directly from the wise use of these resources, more elephants are likely to survive longer. Such approaches may be most effective where management policies allow the consumptive use of elephants through safari hunting or culling. For example, in Nyaminyami District on Lake Kariba in Zimbabwe experiments are being done on the marketing of problem elephants to trophy hunting clients in an attempt to alleviate the problem of local crop raiding (Taylor 1993). In this way culprit elephants are removed, benefits from hunting revenues and meat are returned to the affected community, and the level of offtake from the elephant population is minimised by combining problem animal control with trophy hunting.

In dealing with human-elephant conflict managers also need to monitor their response or lack of response to problems, in order to evaluate the methods used to minimise the problem. Once equipped with the basic information, wildlife management authorities, researchers and other land use and administrative agencies working together can develop the most appropriate solution for the specific problem they face (Clark & Westrum 1989).

2.6 ADAPTIVE MANAGEMENT

Conservation in Africa should not separate research from management. Wherever possible, the two activities should operate together under a system of adaptive management. Adaptive management (Holling 1973; Bell & McShane-Caluzi 1985) can be defined simply as learning by trial and error, and as a concept it is particularly relevant to the management of the African elephant today. Changes are occurring rapidly throughout the elephants' range and there is little time for elaborate experimentation to produce fruitful results.

The practice of adaptive management involves selecting a management objective or option, implementing one or more management actions designed to meet the desired objective, and monitoring and evaluating the results of those management actions. Depending on the outcome of the chosen management action, subsequent management actions may be modified, or the original management objectives changed. Adaptive management can, thus, be seen as a team effort; one which requires inputs from all levels of the research and management staff.

Choosing an option is the prerogative of the management authority and is usually a subjective decision which is made in the light of the best available information. The chosen option, however, must take into account three primary constraints:

i) The availability of administrative backup. Insufficient funds, personnel, equipment, skills and other logistical issues could limit the timing, extent or ability of management authorities to implement a management option and to then monitor and evaluate its effects. These factors need to be critically evaluated before implementing a management decision.

ii) The availability of management tools. The few necessary tools include the ability to implement fire management actions; manipulate water supplies; introduce and/or remove animals, through capture and/or culling; manipulation of vegetation and control of soil erosion.

iii) The degree of uncertainty. Underlying adaptive management is the uncertainty that the chosen management option will achieve its intended objective. Management action should be designed in such a manner that managers will learn equally from success or failure.

Ideally management practice should be effected as an experiment with a full set of “before” and “after” records, and also control areas set aside where the management action is not carried out but where the same “before” and “after” sets of records are kept. Natural perturbations to an ecosystem can be used as experiments very effectively in the place of manipulative experimentation or active management intervention. Careful monitoring of large-scale natural perturbations may also allow the study of ecosystem functions which would not be possible through direct experimentation.

The management of elephants in Africa is becoming a complex matter If elephants are to survive outside strictly protected parks and reserves, they can no longer be viewed in isolation from the people with whom they share much of their range. Elephant managers will need to integrate our knowledge of elephants and their requirements with the development challenges facing Africa as a whole, and managers, scientists and planners, at all levels will need to work together for years to come. The studies that can be carried out according to the methods described in this book provide the fundamental building blocks towards the long-term management of elephants in Africa.

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SECTION 2

COUNTING ELEPHANTS

COUNTING ELEPHANTS

Numbers and distributions of animal species, along with information on habitat and land use parameters, are essential for drawing up management and conservation plans. This section covers four of the main methods of obtaining data on elephant numbers.

Elephant census techniques fall into two classes. The first comprises those surveys where the elephants themselves are counted. These are “direct counts”. The second class includes surveys where signs of elephants (dung-piles, tracks, feeding signs) are counted. These are “indirect counts”.

Direct counts of elephants can either be carried out from the air, or from the ground. In savanna habitats aerial counts remain the most effective means of elephant census (Douglas-Hamilton *et al.* 1992). There are two kinds of aerial counts:
sample counts and total counts. In a sample count only part, or a sample, of the area is searched and counted, and the number of animals in the whole area is then estimated from the number in the sampled area (Norton-Griffiths 1978). These methods are covered in Chapter 3. In a total count, on the other hand, the whole of the designated area is searched, and it is assumed that all groups are located and counted accurately (Norton-Griffiths 1978). Total aerial counts are covered in Chapter 4.

Aerial sample methods are today widely used for censusing elephants and monitoring their movement and habitat use. It is also only by aerial methods that areas that are not accessible on the ground can be censused. The choice of whether to use total or sample aerial counts will depend on the area to be covered, the size of the populations and the resources available in terms of trained manpower, aircraft, funding and time available. Sample counts tend to be cheaper than total counts, simply because only part of the area is searched. Total counts are, however, suitable in relatively small study areas (of the order of 1000km^2), and the results are easy to understand because they are not confounded by the statistical assumptions of sample counts.

Where it is impossible to count elephants directly, as in the extensive forests of west and central Africa, signs of elephants such as dung piles are used to provide an estimate of elephant numbers. Dung counting methods are covered in Chapter 5.

Elephants themselves can be counted from the ground either on foot or from a vehicle, and the methods involved are described in Chapter 6. Ground counts from vehicles are practicable and give excellent results in small to medium sized areas where the country can be traversed by vehicles, and where the vegetation is reasonably open and the animals tame to vehicles (Norton-Griffiths 1978). Carrying out counts on foot is not common nowadays, but where resources are limiting they can provide good information on a population, as you will see in Chapter 6.

The appropriate technique to use in counting elephants, thus, depends on the type of habitat (i.e. vegetation density and topography), the size of the area to be surveyed, the elephant density, and also the type of estimate required. Does one need an accurate estimate, one that approaches the true population size, but may have wide confidence limits, or does one need a precise estimate, preferably at regular intervals, for a population subject to legal off-take, in the form of safari hunting and culling operations. In most cases, however, a precise estimate will be sufficient, and will enable one to monitor population trends. These statistical considerations are covered in more detail in the following chapters.

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CHAPTER 3

COUNTING ELEPHANTS FROM THE AIR - SAMPLE COUNTS

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3.1 INTRODUCTION

This chapter describes how to carry out a sample count of elephants using aerial survey techniques. In a sample count, only part of the study area is searched and a count made. A series of samples, which are representative of the study area are taken (Cochran 1963; Campbell 1967; Norton-Griffiths 1978). The study area, or the census zone, is the whole area for which the elephant population count is to be carried out, e.g., national park, district, etc., while the sample zone is that part of the census zone in which the elephants are actually searched for and counted. The total number of elephants in the census zone is then extrapolated from the number counted in the sample zone.

3.2 THE ASSUMPTIONS AND RATIONALE OF A SAMPLE COUNT

In a sample count, we take a few observations, but the conclusions we draw have a wider application. In other words, we observe a sample, but apply the conclusions to a population. For example, the assumption might be that if 10% of the area is sampled, then it will contain 10% of the elephants in the census zone.

The foregoing would hold if elephant distribution and vegetation conditions were uniform, in which case any kind of sample would give similar results. However, elephant numbers and distributions are far from uniform in any one census area. Similarly, elephants will be more easily seen, and thus counted, in open areas as opposed to thickly vegetated country. The sample zone, i.e., that portion of the census zone in which the elephants are counted, must, therefore, reflect any variations as much as possible.

The census zone is divided into sample units which are chosen at random, meaning that every one unit, **n**, has an equal chance of being selected for sampling from the possible N such units in the census zone (Cochran 1963; Norton-Griffiths 1978; Figs. 3.1 & 3.2). The sample zone is, therefore, randomly distributed in the census zone, thus, theoretically, representing the variations in elephant numbers and distribution.

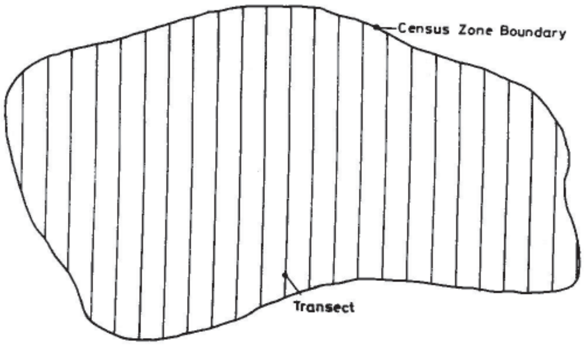

Fig. 3.1: Possible transects in a census zone.

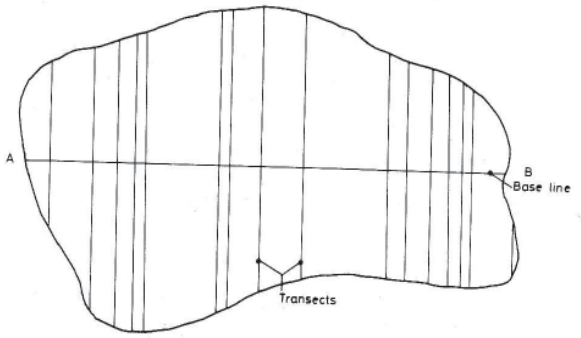

Fig. 3.2. Transects randomly selected for sampling.

The population estimate of the elephants is then calculated, based on the average counted number of animals in the sample units. Since the units are randomly selected, the average number of elephants per unit in the sample will correspond to the average number of elephants per unit in the sample will correspond to the average number in the whole population. The total population estimate is then obtained by multiplying the sample mean by the total number of units in the census zone.

Thus, let
N = total number of units in census zone
n = number of units sampled
y = sample mean

Then sample estimate Y*[INSERT ACCENT]* = $y.N$ or ‘y’ multiplied by ‘N’.

Equally, if X elephants were counted in 10% of the census zone, then the total estimate is obtained by:

$$X/10.100$$
where 100= census zone

Detailed and easy to follow examples for calculating estimates and their variances are given by Norton-Griffiths (1978). Despite ensuring that samples units are randomly selected, the nature of elephant distribution may necessitate further refinement of sample units.

3.3 ACCURACY AND PRECISION

Sample counting assumes that the area actually sampled (sample zone) contains a corresponding percentage of the “true” population in the census zone. Due to various factors, however, this may not be the case. To start with, elephants (as indeed other animals), are not evenly distributed. Thus, different sample units in the census zone will contain varying numbers of elephants. It follows then that different population estimates will be obtained depending on the units selected for sampling, i.e., there will be large numbers of alternative estimates. This result is due to what is referred to as sampling error, and the larger the variation in numbers of elephants between the units, the larger the range of alternative estimates or confidence limits. Sampling error results from the uneven distribution of animals and the sampling technique used (Norton-Griffiths 1978). In addition to sampling error,biases also affect the population estimates. Biases are errors in one direction, e.g. underestimating. They result from various factors - such as spotting and counting, photo counting, aircraft operations, etc. See Norton-Griffiths (1978) and ILCA (1979) for more explanation on confidence limits, sampling error and biases, and ways of minimizing them.

At this point let us examine the words accuracy and precision. Consider a hypothetical population of 94 elephants. Suppose that during three different surveys, we get 50, 72 and 160 elephants, giving an average of 94; alternatively we could also get 92, 97 and 93, also giving an average of 94. The latter is more precise, as the “true” population lies within a narrow range, i.e., the confidence limits are low. On the other hand, an accurate estimate is very near the “true” population, but the confidence limits may be wide.

Whether we aim for an accurate or precise estimate is determined by the objectives of the survey. Accurate estimates are more important if a culling operation is to take place, while precise ones are important for detecting changes in population trends. The ideal estimate would be one that is both accurate and precise.

3.4 STRATIFICATION

Elephants tend to be clumped in distribution, such that even when sample units are randomly selected, the estimate will have high variances. Stratification or division into areas or strata of more or less homogenous elephant density reduces the variance (see Chapter 5 - Box 5.1). Stratification can also be carried out according to vegetation type or density or other major sources of variation. Through stratification, sampling effort can be more efficiently allocated to areas of greater interest or ecological importance. The strata so identified are then sampled separately and the estimates combined for the entire census zone (Cochran 1963).

3.5 SAMPLE COUNTING METHODS

Several techniques of sample count have been used in elephant studies. The choice of the method to use is left to the researcher/manager, but will be heavily influenced by the following:

i) objectives of the count
ii) level of data accuracy required
iii) time within which the results must be obtained
iv) availability and level of training of personnel
v) financial resources

After the above have been given careful

consideration, the most appropriate method, in view of the circumstances, can be decided upon. Broadly, sampling methods fall into two main categories: transects and block counts.

3.6 TRANSECTS

Transect sample counts are the more widely used for counting elephants, with the sampling units being the transects. These are straight parallel lines which run from one end of the census zone to the other and usually follow a grid system (Fig. 3.1). They must be clearly marked on a topographical map of the census zone.

The pilot flies along each transect in turn, maintaining the prescribed height and speed. The observers spot and count all elephants seen in the sampling zone as demarcated by rods (see Section 3.7). Herds numbering more than five are photographed. The records must be entered directly onto data forms, or tape-recorded for later transcribing onto the data forms. The latter is more efficient, and allows the observer more time for scanning and counting.

Two major transect sampling techniques are currently used for elephant counts. They are both very similar and use similar analysis formulae, differing only in the sampling pattern.

i) random transect sampling

ii) systematic transect sampling

Depending on the situation and aims of the survey, stratification can be carried out. Before I go into the sampling techniques, I will describe how to define and calibrate the sampling strip.

3.7 DEFINING THE SAMPLING STRIP

The sampling strip has been described by various authors (Pennycuick *et al.* 1972; Norton-Griffiths 1978; Ottichilo *et al.* 1985), and will be described only briefly here.

The sampling strip is the area on the ground in which counts are made; it is defined by metal rods attached to the wing struts of an aircraft. A pair of parallel rods are attached on one or both sides of the aircraft, the strip width being determined by the distance between the rods, and the flying height.

Wider rod spacing and higher flying height give wider sampling strips, and vice versa. Having decided on the flying height and strip width, the rods must then be placed at the correct spacing. By knowing what area the observer can see while the plane is on the ground, the area observed at any height can be calculated. This is carried out as follows:

i) The aircraft is propped into flying position. The observer sits in a relaxed and comfortable manner, from which an eye position is chosen (Fig. 3.3). This should allow effective scanning.

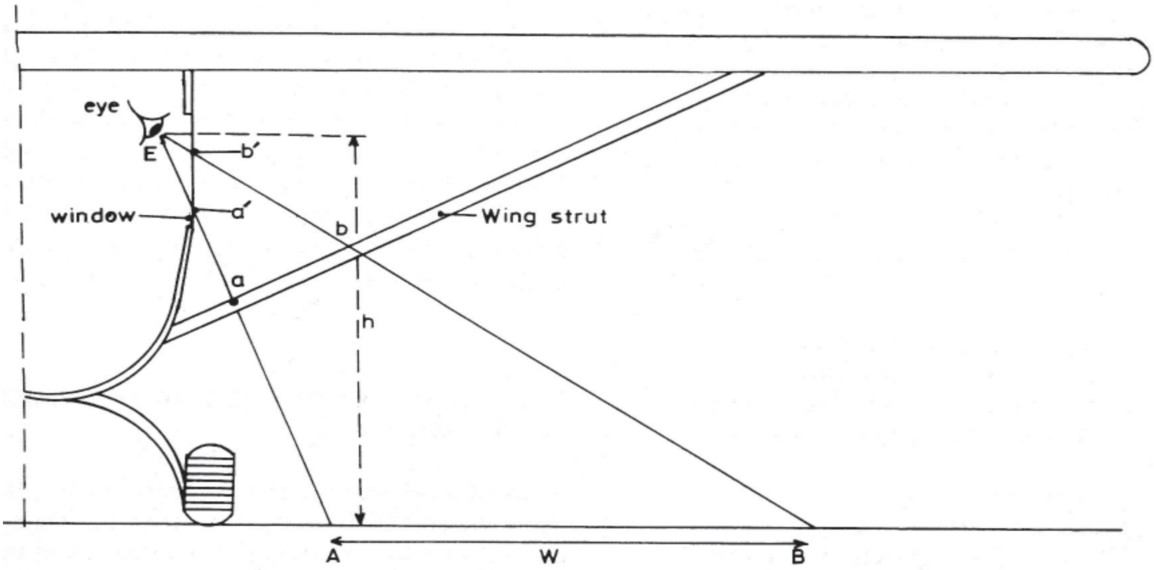

Fig. 3.3: Defining the Sampling strip (source: Norton-Griffiths 1978).

ii) The position of the inner rod a, is then selected. It should allow the observer's line of sight to be clear of the wheel, but close to the aircraft body The lower window marker a´, is then so fixed that it falls in line with the eye position and the inner rod, a (Fig. 3.3).

iii) Mark A is then placed on the ground, in line with the marker a' and the inner rod. The height of the observer's eye level from the ground, h, is measured. A second marker B, is then placed on the ground, the distance between A and B being denoted by w, and calculated as follows:-

w = W.h/H
Where W = required strip width
H = required flying height

iv) The outer rod is then placed at b, in line with point B. The observer, while maintaining his line of sight a´- a - A, makes a second mark b´ to establish a second line of b´ - b - B. If correctly positioned, the observers' two lines of sight should be in line while he sits comfortably. Marks a´ and b´ ensure the observer's eye position will be correct during flight, and must be kept in line with marks a and b.

3.8 CALIBRATING THE STRIP WIDTH

In order to ensure that the strip width set up as described above is correct, aerial calibration must be carried out. Markers are laid out on flat ground or an airstrip, at intervals of 20m. The aircraft then flies at the required height and makes passes, at right angles, to the markers. The observer(s) count and photograph the number of markers between the rods.

The strip width is then calculated as follows:-
Let
h = average height of aircraft
w = average strip width
H = selected census flying height
W = nominal strip width at H
Then
W=w.H/h

If W is widely off the required strip width, the rods are repositioned, and another calibration flight carried out.

3.9 RANDOM TRANSECT SAMPLING

After stratification, transects are selected at random, at right angles to a suitably chosen axis (Norton-Griffiths 1978). The number of transects selected should correspond to the desired sampling intensity. The transects are then drawn on the census area map. Data analysis is done separately for each stratum, and ultimately combined to give the total population estimate. If desired, data can be related to positions along the transect. This method has been extensively used to count elephants and gather data for other resources (Watson *eta!*. 1969a & b; Bell *eta!*. 1973)

3.10 SYSTEMATIC TRANSECT SAMPLING

This method is also referred to as systematic reconnaissance flight (SRF). The transects are spaced at the same interval repeatedly throughout the census zone. Each transect is divided into subunits of desired length, and during sampling, elephants are counted within the sampling strip of each subunit (see Section 3.7).

This technique has been adapted by a Kenyan government department that carries out multispecies animal counting (Ottichillo *et a!*. 1985; Mbugua 1986). It is highly flexible, and can be modified according to objectives and constraints. In a census to establish the status of elephants in two game reserves and the surrounding areas, systematic reconnaissance flights were used (Mbugua 1992). Due to time constraints which could not allow for an initial reconnaissance flight, elephants sighted outside the sampling strip were counted. The pilot deviated from the transect, and circled the groups until they were counted and photographed, and then resumed the flight path. Thus, total sample counts of the groups were obtained while ensuring a systematic search of the area. However, the transect and 'group' counts were analysed separately.

3.11 FLIGHT PLANNING FOR TRANSECT SAMPLING

As mentioned earlier, transects are flown in order, from one end of the census zone to the other. If the census zone is large, it must be broken into areas that can be covered in one census flight. These areas must be well marked on the maps.

Animal movements within the zone at different times of the day must also be taken into consideration while flight planning.

If more than two aircrafts are used, they should be assigned to different strata or parts of the census zone. Ideally, the flight should not exceed three hours to avoid fatigue of the flight crew.

3.12 BLOCK SAMPLING

In this method, blocks are the sampling units. They are chosen by locating random points in space, and then counting those blocks in which a point falls. Alternatively, the whole census zone can be marked off in grids, and the necessary number for sampling selected randomly (Norton-Griffiths 1978). The block boundaries should be delineated by physical ground features. In this age of sophisticated technology, boundary definition and navigation can also be aided by high precision equipment.

The observer must search the entire block, and count every elephant. To ensure this, and ascertain that no double counting occurs, the observer must keep track of the aircraft position by marking on the map the flight path, and the area covered (Fig. 3.4). Each group is counted and given an identifying number, and entered onto a data sheet. The location of individuals or groups is also entered on the map. Photographs are also taken for later counting.

The flight pattern can be spiral for difficult terrain, zig-zag for valley bottoms and ridges, or systematic. Of importance is that there must be some degree of overlap between the strips.

Blocks are increasingly being used in counting elephants. Their use is unsurpassed in areas where transect counts are impossible due to crew safety, e.g. in hilly country or in thick vegetation, and they have been used to check the accuracy of other counts (Thouless 1992).

3.13 FLIGHT PLANNING FOR BLOCK SAMPLING

The planning for block sampling is similar to that used in transect sampling. The blocks should be of a size that can be covered in a day’s flight (2.5-3 hours) or less. Smaller sized blocks have been used in test flights.

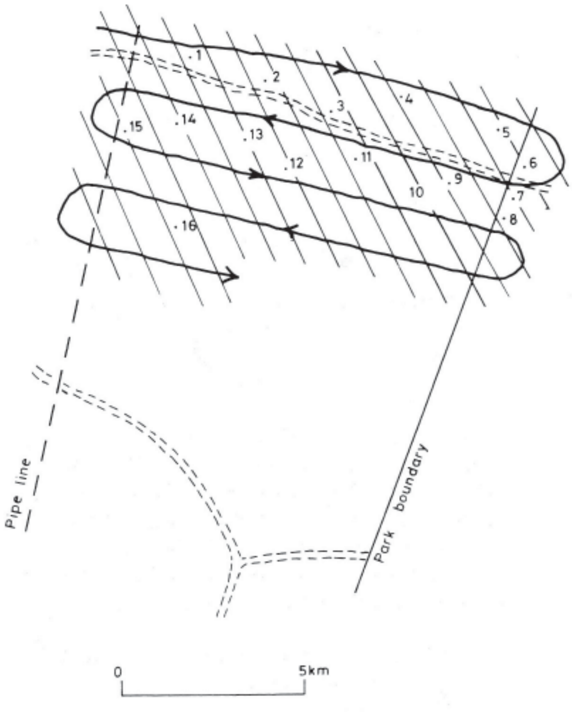

Fig. 3.4. Block count using the zig-zag flight lines. The flight path is marked, and every group observed is given a number and plotted on the map. (Source: Norton-Griffiths 1978).

3.14 DATA ANALYSIS

Detailed explanations on analysing the data are given by Jolly (1969) and Norton-Griffiths (1978), and reference to basic statistical texts should be useful.

If the sampling units (transects or blocks) are all of the same size, then Jolly’s Method I (1969) is used. The estimate is based on average number of animals in each unit, and the variance is calculated from the variance between number of animals in each unit.

The results are worked out as follows:-

N = total number of units in population
n = number of sampled units
y = number of elephants counted in any one unit

y = sample mean = $\frac{y}{n}$

s_y^2 = sample variance (variance between elephants counted in all units)

$$= \frac{1}{n-1} \{\sum y^2 - \frac{(\sum y)^2}{n}\}$$ where $\sum$ is 'the sum of'

Then population total $Y = N.y$

Population variance $Var(Y) = \frac{N(N-n)}{n} . s_y^2$

Population standard error $SE(Y) = \sqrt{Var(Y)}$

95% confidence limits of $Y = t.SE(Y)$

$t = n-1$ degrees of freedom

In some cases, particularly in transect sampling, the units will be of varying size. Jolly's Method 11(1969) is specifically suited for these units since it eliminates the effect of difference in size of the sampling units. It is based on the calculation of the ratio between animals counted and the area searched, and the following must be known:

N = total number of units from which sample was drawn
n = number of units sampled
Z = area of census zone
z = area of each sample unit
y = number of animals counted in each sample unit

We first calculate R, which is an estimate of average density of elephants per unit area.

$$\text{Thus } R = \frac{\text{total animals counted}}{\text{total area searched}} = \frac{\sum y}{\sum z}$$

Then Population total $Y = R.Z$

To calculate the population variance, we must first establish the variance between animals in each unit, and the variance between areas of each unit. Finally, we must calculate the variance between the elephants counted in each unit, and the size of the same unit. Thus

1) s_y^2 variance between animals counted in all units

$$= \frac{1}{n-1} \{\sum y^2 - \frac{(\sum y)^2}{n}\}$$

2) s_y^2 = variance between the area of all sample units

$$= \frac{1}{n-1} \{\sum z^2 - \frac{(\sum z)^2}{n}\}$$

3) s_{zy} = covariance between animals counted and the area of each unit

$$= \frac{1}{n-i} \{\sum z.y - \frac{(\sum z).(\sum y)}{n}\}$$

Population variance

$$= Var(Y)$$

$$= \frac{N(N-n).}{n} (s_y^2 - 2.R.s_{zy} + R^2.s_z^2)$$

Population standard error $SE(Y) = \sqrt{Var(Y)}$

95% confidence limits of $Y = +/-t. SE(Y)$
where $t = n-1$ degrees of freedom

The same steps are followed for blocks, with N = numbers of blocks into which census zone was divided.

These formulae have been extracted from Norton-Griffiths (1978).

3.15 CENSUS CREW AND EQUIPMENT

The ideal crew should consist of a pilot, a Front Seat Observer (PSO) and two Rear Seat Observers (RSOs). In addition to helping in spotting elephants, the PSO calls out units, records survey time, speed and height, and habitat parameters if desired. The RSOs count and photograph the elephants. A crew of three; pilot, PSO and RSO can also be used, if the situation so warrants.

Each member of the crew should be well trained and competent. Details of training can be found in Norton-Griffiths (1978) and in Distil *et al.* (1979).

The main survey equipment should include good topographical maps, cameras and tape recorders. A 50mm wide lens is recommended. The aircraft must be slow flying and high-winged to allow unobstructed ground view by the observers. For transect counts, it must have wing struts for attachment of rods.

3.16 FLYING HEIGHT, SPEED AND STRIP WIDTH FOR SAMPLE COUNTING

Various combinations of the above are used in transectsampling. Heights of between 9im and 122m, and strip widths of 200m and 500m are recommended. They should be varied for open and thickly vegetated country, i.e., narrower strip widths and low heights while surveying thickly vegetated areas, arid vice-versa. The speed should be between 130km/hr and 150km/hr.

In block sampling, heights ranging between 152m and 213m should be used to facilitate spotting, with strips of between 1km and 1.5km on each side, again depending on vegetation. The aircraft can then fly low for the actual counting and photographing of the group(s).

Flying height, speed and strip width all affect the observer's ability to spot and count animals, thus introducing errors arid bias in the population estimate. An appropriate combination of height arid strip width should be decided upon depending on the nature of vegetation, elephant density and experience of observers.

3.17 TRANSECTS OR BLOCKS?

The transect count is superior to block count in terms of costs, navigation, fatigue and sampling error. However, transects are impossible to fly in difficult terrain, and may give unreliable results where vegetation is thick. Block sampling would be preferable in these situations. The choice of technique should be guided by the specific objectives of the count, and the prevailing circumstances.

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CHAPTER 4

COUNTING ELEPHANTS FROMTHE AIR-TOTAL COUNTS

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4.1 INTRODUCTION

Total counting of elephants has been adopted in many national parks, reserves and other parts of the elephants' range in Africa. One of the reasons that total aerial counting of elephants wins favour is that elephants, being large animals, are relatively easy to spot and count compared to other animals. A review of the method and references to earlier work has been made by Norton-Griffiths (1978) which is recommended for further reading. Recent advances are given here.

The aim of an elephant total aerial count is to scan the entire surface of a selected census area, and to record the position and number of each elephant or group of elephants. A total count is similar to the sample block counts described in Chapter 3, but in this case the blocks, when joined, cover the whole census zone.

The flight lines should be designed with the intention of being able to spot all the elephant groups and individuals; there are a number of variations as to how this may be done.

Errors can arise in failing to spot elephant groups, counting them inaccurately, or in double-counting the same groups. These errors can be greatly reduced by training and careful attention to technique.

The census zone should be divided into discrete counting blocks. By common practice these are usually defined by features such as roads, cut-lines, mountains, protected area boundaries or rivers. Rivers, however, are unsuitable as block boundaries because they tend to attract concentrations of elephants. A movement of elephants across the river while the count is going on could cause that group either to be double-counted, or to be missed altogether. It is better to use water-sheds as boundaries, as is done in the Kruger National Park in South Africa,because elephants tend to be relatively sparsely distributed near them.
A block should usually be of a size that can easily be covered by one aircraft in one flying day. In the case of Kenya's Tsavo National Park, blocks vary in size from 500km^2 to 1,500km^2, but the average size is 1,100km^2. Each flight crew should be allocated one or more blocks to be counted per day and should be provided with flight maps of the blocks. In the Tsavo elephant count of 1994 flight crews on average spent 5.5 hours a day counting with another 1.3 hours flying to and from the block. Scanning rates on average were 210km^2/hr (Douglas-Hamilton *et al.* 1994)

These days it is highly desirable to use a Geographical Positioning System (GPS) in the aircraft, both to assist in navigation and for recording waypoints (a waypoint is the location of an observation point along one's line of flight). With a GPS block boundaries can be set conveniently using the Universal Transverse Mercator (UTM) kilometre grid on a north-south or east-west axis. This also makes the calculation of block areas easier.

4.2 AIRCRAFT AND FLIGHT CREW

4.2.1 Number and type of aircraft

The number of aircraft used depends on the size of the census zone and what is available in terms of aeroplanes, personnel, fuel, funds and time. Availability of resources may dictate whether one aircraft is used over an extended period or many aircrafts are used for a shorter period. For example, in the Kruger National Park elephant count of 1993 two helicopters were used with two pilots alternating four days on and four days off.

The crew covered 20,000km^2 in three weeks. By contrast the Tsavo elephant count of 1994 used eight aeroplanes, each with a single pilot, flying for five days, and covered some 39,000km^2.

A helicopter is an ideal aircraft to use in carrying out aerial counts, as it affords observers superior visibility and it has the ability to hover while observers make an exact count of an elephant group. However, cost puts it beyond the reach of most protected area authorities. A single exception is the Kruger National Park where annual elephant counts have been conducted by helicopter since the mid 1960s, and the authorities have thus accumulated probably the most coherent total elephant count data set for any large area (Hall-Martin 1984; Whyte & Wood 1992).

Fixed wing aircraft with high wings giving a clear downward field of view are also widely used and recommended. These may be four-seaters, usually Cessnas (170s, 180s, 182s, 185s, 206s, 210s), or tandem two seaters such as Piper Supercubs or Huskies.

For serious total counting it is essential for the aircraft to be equipped with a functional intercom. The noise levels in the plane make it impossible for crew members to communicate otherwise.

4.2.2 Flight Crew

Experience is of the greatest importance and it is generally thought that the quality of the crew affects the final number of elephants spotted and counted, although this has never been tested. The more local knowledge the pilot and observers possess the better. Observers need to be sharp-eyed and able to endure long hours in the plane, even in turbulent conditions, without airsickness.

4.2.3 Routine and timings

The aircraft should aim to enter the block and start scanning about one hour after dawn so that the shadows are not too long, as these make elephants difficult to spot and count. Ideally, counting should not be carried out in the heat of the day, when elephants tend to seek shade, since this increases the risk of failing to spot groups altogether or under-counting clumped groups. The hours of the "heat of the day" will obviously vary across the elephant range of Africa, and with season. On a cool day in the rainy season elephants may stay loosely dispersed and be much easier to spot and count all day long, but generally in most seasons there is a tendency for elephants to gravitate to shade from late morning to mid-afternoon. Counting should not be conducted too late either, once again to avoid long shadows. In practice, however, in the course of a major count of a big census area these niceties tend to be ignored. Pilots and crew may fly up to nine hours a day, stopping only for refueling.

4.3 FLIGHT PATTERNS

4.3.1 General

A pilot must be able to navigate with skill. Classically, this has meant that a pilot must be able to use small landmarks to keep exact, track on a map of the aircraft's flight path. With the invention of Global Positioning Systems (GPS) accurate navigation and recording of the position of observations has become much easier. From the moment that a block is entered the flight path can be recorded. The easiest way to do this is to switch on the logging facility of a recording GPS unit. A scale map of the exact route of the aircraft can then be printed out after the flight, with pre-digitized block boundaries and a 10km by 10km UTM grid superimposed. This map is a great help in compiling block totals and subsequent analysis.

If a GPS is not available the pilot and Front Seat Observer (PSO) are responsible for recording the flight path as best they can on a map, and recording the observations of animals on a check sheet as will be described below. The flight lines may vary according to the circumstances.

4.3.2 Parallel lines

Parallel lines set apart at intervals from 500m to 3km are the most commonly used flight pattern on total counts and they are particularly suitable for flat and relatively featureless land. These lines may be drawn on a map before the flight is begun, which greatly facilitates the pilot's task. The spacing of lines may be determined by several factors, such as the visibility of the elephants, itself a consequence of colour, contrast, vegetation cover, light and shade), the amount of flying hours available (ideally, flying hours should not be a limitation, but they often are in practice).

There are two errors associated with the spacing of parallel flight lines: the further apart the lines are, the greater the risk of failing to spot groups altogether; and the closer together the lines are, the greater the risk of counting the same group twice. As a rule of thumb a spacing of 1.5km has proved to be a realistic compromise for relatively open areas like the Tsavo National Park (see Fig. 4.1) or the Kruger National Park. In dense habitats such as the Addo National Park in South Africa or Lake Manyara National Park in Tanzania a spacing of 500m with short flight lines of 10km to 15km has been used, in very open plains a separation of up to 3km may be justified. Short flight lines reduce the risk of double counting as the elephants do not have a chance to wander far between runs.

In most cases east-west lines should be chosen, which have the advantage of equal light for the observers on both sides, but topography, wind direction or the shape of the block may make a north-south or other orientation preferable.

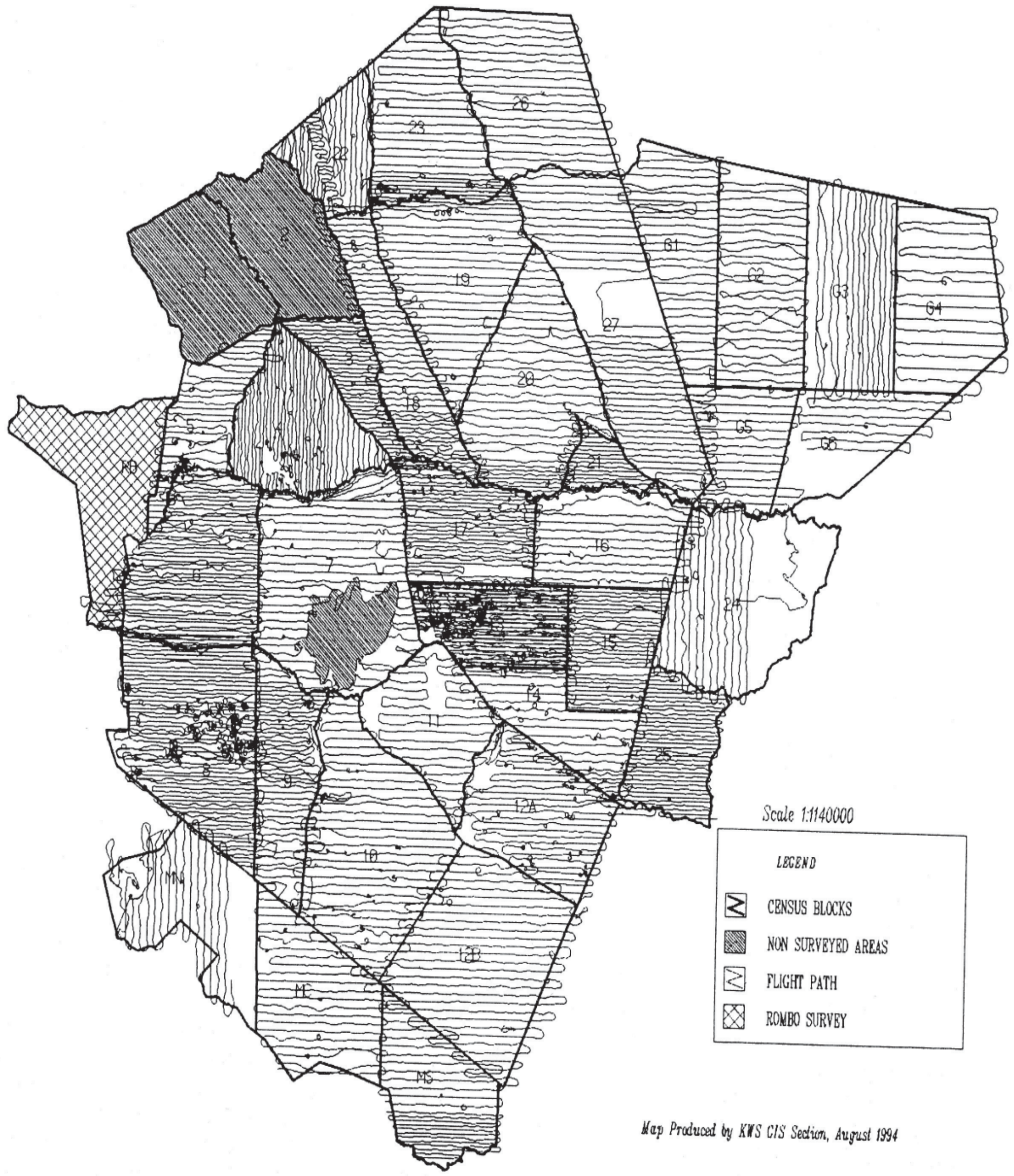


Fig 4.1: Right paths for the 1994 Tsavo elephant

4.3.3 Variable lines

A variable flight pattern adapted to drainage or topography is often used. The best known instance where the drainage lines are used to determine the flight pattern is in the annual elephant count in the Kruger National Park. A helicopter flies up and down each tributary scanning as far as the watershed of the next tributary. The advantage of the kruger method is that the pilot can navigate without having to look at a map or a GPS, which means that he can take part in the spotting.

Lines may also be related to the shape of hills or mountains, where the slopes are so steep that they dictate a flight pattern that cannot ignore the contours. In this case the pilot will fly in and out of valleys in such a way that the observers have a chance to scan all the slopes that lie below them.

4.3.4 Inward Spirals

When a patch of thick vegetation, in which elephants maybe concealed, is found in the middle of relatively open country, an inward spiral flight pattern can be appropriate. In this case, the observers scan the inner side of the spiral and work inwards to the centre: The advantage of this pattern is that it is easy for the pilot to maintain orientation and to remember where elephants have already been spotted.

4.4 WHAT SHOULD BE COUNTED?

Both live and dead elephants should be counted in an elephant count. Dead elephants give a great deal of information on the status of the population. In some cases it may be desirable to add in another species or two. For example, buffalos are often included as they have also have a clumped distribution like elephants and can be included without much extra effort. Rhinos are now so rare that any information on them should also be collected. It is a mistake, however, to try to include too many other species, as most of these are harder to see than elephants and will require a degree of extra effort that may detract from the efficiency of the elephant count.

Dead elephants should be recorded in the following categories (Douglas-Hamilton & Hillman 1981):

i) "Fresh", in which the carcass still has flesh beneath the skin giving the body a rounded appearance, where vultures are probably present, and where the liquid pool of putrescent body fluids is still moist on the ground. This category applies to carcasses thought to be no more than three weeks old.

ii) "Recent", in which the carcass is less than one year old and may be distinguished by the presence of a rot patch around the body where the decomposition fluids have killed the vegetation; the skin is usually present and the bones are relatively unscattered, except in areas of high predator density.

iii) "Old", in which the carcass has usually decomposed to a skeleton, with bright white bones clearly visible, but where the rot patch has disappeared, or where the vegetation is beginning to regrow; the skin may still be present in arid areas, but will have disappeared in wetter zones. This category applies to elephants that have died more than one year previously.

iv) "Very Old", in which the bones are beginning to crack and turn grey; the skeletons from the air no longer stand out as distinct entities and are difficult to see; bones may exist in this form for ten years or more, but for the purposes of aerial survey almost all have vanished after seven years.

Usually, the first and second categories, and the third and fourth are pooled in analysis and referred to as "Recent" and "Old". The proportion of "Recent" in relation to the live population is an indicator of the previous year's mortality.

4.5 FLIGHT PROCEDURES

The success of a count depends greatly on the degree of cooperation between the crew members. It is advisable to have one day of training and rehearsal before beginning serious counting. A great many errors can be removed by this practice. In any case, the count should begin with the least important blocks or those likely to have the fewest elephants, and work towards the high density blocks at the end.

Each member of a flight crew has a specific role. The pilot must maintain the flight pattern and make sure that the ground is adequately covered. Common errors arise when a pilot turns back before the end of the block, or allows the flight line to wander away from the desired track. Speed and height are largely determined by the type of aircraft used but 130km/hr. and heights between 200ft and 400ft. are suitable for most conditions of visibility and elephant density.

When herds cannot be counted properly from the flight line the pilot should divert towards them and circle while the crew counts, and takes photographs, if necessary. If you have a helicopter there is no need to circle, you can hover while the crew counts. As mentioned earlier the most advanced helicopter counting is done in the Kruger National Park. Here, the helicopter, in a series of low passes, divides the herd into convenient units and counts them one by one until the whore herd is covered. In this case photography is unnecessary.

Great care must be taken, however, to resume the original flight line at the spot at which it was broken off. This can be done by referring to ground features or using a GPS to check that you are back online. The pilot is also responsible for flying a 2-3km overlap into the adjacent block on each block boundary. Elephants on the edge of a block may cross over to another block, and either be missed by both crews or double counted. It is important, therefore, to note if they are walking in any particular direction, and to keep in touch with the neighbouring counting crew and advise them of likely crossovers on the radio. In any event, it is necessary to fly overlaps and compare results with the adjacent crew to decide in which block peripheral groups of elephants should be located for the purposes of data analysis.

The pilot is responsible for all aspects of safety. He should be aware of power lines and other hazards, and should arrange with other pilots what radio frequencies are to be used and what search and rescue procedures will be followed in the event of an accident. Each pilot should keep in touch with the neighbouring crew when flying in the overlap areas of blocks, keep out of each other’s way, and liaise on elephant sightings in the areas commonly searched. The pilot may participate in the counting only in so far as he or she can comfortably do so, and this will depend on his or her experience. In many cases, the pilot’s vantage point can prove particularly useful in drawing the observers’ attention to animals coming up in the- plane’s flight path.

For those aircraft equipped with a GPS the pilot should also make waypoint recordings of each observation. Such waypoints should be made directly overhead the elephant group if possible.

The Front Seat Observer (FSO) is responsible for recording observations and the corresponding waypoint on specially designed data-sheets. The data-sheet includes columns for waypoint, species, estimate, film number, frames taken, revised photocount and comments (see Fig 4.2). All flight times should be recorded, including take-off, start of count, end of count, and landing. From these data the count intensity can be calculated, that is the square kilometres scanned per hour, or the hours taken to scan 1000km^2 (the average block size). The total hours flown are important for calculating the cost of the count.

If a GPS is unavailable, the position of the elephant group may be written directly on to a map at the time the observation is made. In this case the FSO must maintain a continuous record of the flight path including deviations and circling. It is difficult to do this with any real accuracy and the GPS recording is greatly preferable, but not to the extent that it should be considered that total counts are impossible without it.

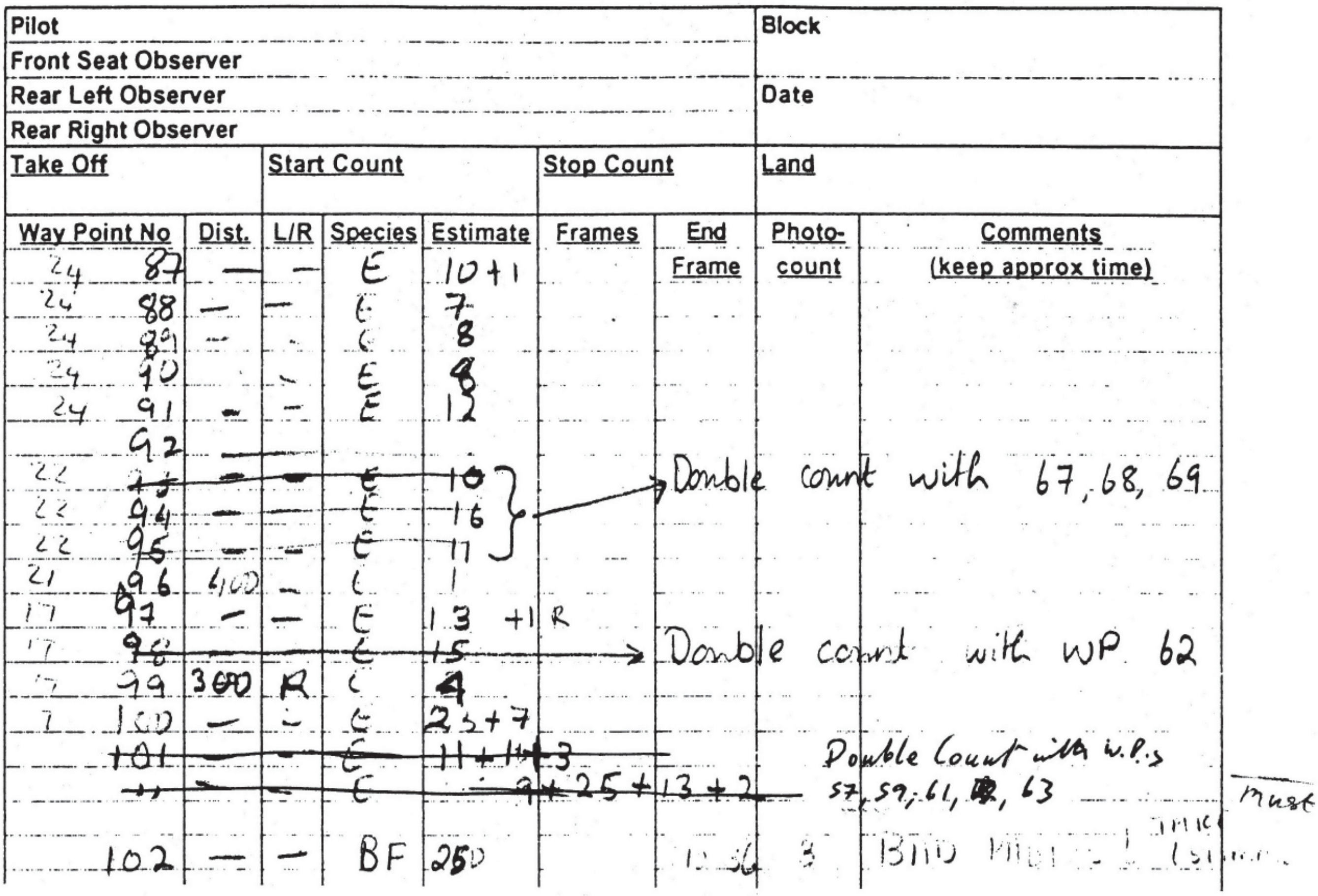
The Rear Seat Observer’s (RSO) role is to spot and count. Each RSO must scan his or her side of the plane and when an animal is spotted must call out clearly and loudly to the pilot and FSO indicating the species, the side of the aeroplane, and the range of the animals from the plane. He or she must also indicate if there is a need to circle in order to make a proper count. If a count can be made without circling, the RSO must call out the result, and the FSO must read it back so that each member of the crew can hear what has actually been recorded. This process helps to eliminate many errors in comprehension.

If the herd is too large to count and needs to be photographed the RSO still needs to make an estimate and listen to the FSO’s read-back to make sure the FSO got the details right.

RSO’s should make every effort not to call out their data at the same time as their fellow RSO is calling out his or hers. They must commit their information to memory and call it out to the FSO at the earliest possible opportunity or when requested by the FSO.

The dialogue might go something like this:

> *RSO: “Elephants left, 300 metres estimate 12”*
> *Pilot: “That is waypoint 22.”*



Pilot	Block
Front Seat Observer	
Rear Left Observer	Date
Rear Right Observer	

Take Off	Start Count	Stop Count	Land

Way Point No	Dist.	L/R	Species	Estimate	Frames	End Frame	Photo-count	Comments (keep approx time)
24 87	—	—	E	10+1				
24 88	—	—	E	7				
24 89	–	-	E	8				
24 90		-	E	8				
24 91	-	-	E	12				
92	—							
22 ~~93~~	~~—~~	~~—~~	~~E~~	~~10~~		Double	count with	67, 68, 69
22 94	—	—	E	16				
22 95	—	—	E	11				
21 96	400	—	E	1				
17 97	—	—	E	13 +1	R			
17 ~~98~~	~~—~~	~~—~~	~~E~~	~~15~~		Double	count	with WP 62
17 99	300	R	E	4				
7 100	—	-	E	23+7				
~~101~~	~~—~~	~~-~~	~~E~~	~~11+11+3~~				Double Count with W.P.s
~~11~~	~~—~~	~~—~~	~~E~~	~~9+25+13+2~~				57, 59, 61, [illegible], 63 must
102	—	—	BF	250		10:56	3	BHD [illegible]

Fig 4.2: Parts of a data sheet used in the 1994 Tsavo elephant count.

FSO *read back: "Elephants left, 300, 12 in number, waypoint 22."*

Or

RSO: "Elephants right, 4 o'clock, about 20, *please circle"*

Pilot: "OK", then later, "I have them in sight, coming up on the right as waypoint 23"

The pilot must fly as close as possible over the elephants, tipping the wing down so that the appropriate RSO is able to get a clear view and make a good count. When he comes overhead of the elephants the pilot should wait for two to three seconds and then press the waypoint toggle on the GPS to record the exact position. The delay is necessary so that the GPS has time to catch up with the actual position

RSO: "Count 28"

FSO reads back: "Elephants, overhead, 28, waypoint 23".

These are the data which are recorded on the datasheet.

4.6 COMPLEX HERDS

Most errors arise from spotting and counting complex herds. The greater the density of elephants the greater the likelihood of confusion. It is well known that when one group of elephants is spotted and the pilot leaves the pre-planned flight path to count it, other groups tend to come into view. Very often one group will lead to another and another, until so many groups in close proximity have been counted that it becomes confusing to remember exactly which has been counted and which has not. This can lead both to double counting of the same group or to omitting a group that is in plain view because the crew thinks erroneously it has already been counted!

There are several ways to minimize these errors. Firstly the pilot and FSO must keep a clear head on what has been counted and what has not. It is best not to wander so far from the current flight line that you cross the path of the next flight line. Secondly, before tackling a complex group it is essential that the pilot and FSO should make a systematic plan of attack. The best way to do this is to climb up until all the elephant groups can clearly be located below you and take time to work out the order in which they are to be counted. Sometimes it is possible to allocate specific herds to be counted by individual crew members. It is vital that the order of counting be adhered to and that the RSOs do not to interrupt each other when reading out their individual counts. The RSO, therefore, should make his or her count and then listen and wait until he or she can get the full attention of the FSO. It is also vital that the FSO should give a clear read back of what he or she has written on the data-sheet.

Errors in counting complex herds are most likely to occur with inexperienced crews, thus it is better to leave blocks with heavy concentrations of elephants to experienced crews. Another possibility is to send a helicopter if one is available, once the fixed-wing aircraft have identified the locations of the heavy concentrations. The helicopter, by hovering, allows observers to take their time in counting very complex aggregations of elephants.

4.7 PHOTOGRAPHY

When elephants are in a group too numerous to count easily, which may be anything in excess of 25, they should be photographed, provided the country is open enough to offer an unobstructed view. For large groups in the open, photography significantly improves the accuracy of counting. However, if there is a great deal of cover, photography of large herds may not make counting easier, since a significant fraction of the herd will be obscured by canopy at any one time.

The pilot and FSO must coordinate closely to decide the best possible alignment for taking the photographs. The FSO will then record the waypoint on the GPS or flight map, and the waypoint number, species, film number, number of frames shot, end frame number and an estimate of herd size onto the data sheet. Fig. 4.3, after Norton-Griffiths (1978) is a model of how to make the photographs overlap properly.

It is imperative that an estimate be made of the number of elephants, in the quite possible event that the films are destroyed or the camera is malfunctioning, or the shots do not cover the whole the group.

A blank should be shot into the lens cap or the photographer’s hand in between different herds or between different series of shots of one herd to allow for accurate separation in the final photographic analysis.

Make sure that all your films are properly labelled. Films should be numbered in advance. The individual film number should be scratched into the emulsion on the film leader - check to make certain before you put the film in the camera.

Generally, the best angle for photography is slightly oblique, but not too oblique, as young animals may be obscured by larger ones. Do not take pictures from far away or too high, as the images of the elephants may be too small to count. If the first run of photographs is unsuccessful, this fact should be recorded on the data-sheet, and further runs should be attempted until a satisfactory result is achieved.

Camera speeds should 1/500th. of a second or above. Anything less will be too blurred and useless. It is essential, therefore, to use film with a speed of not less than 400A5A. Make certain that the focus is set to infinity. It is often a good idea to tape it secure for the duration of the count. You may use a 50mm or 55mm lens but a 105mm or 135mm lens is preferable. Ideally, a medium range zoom lens, say 70mm to 200mm zoom should be used when available.

In general, aerial count photography is a skill which needs considerable training if it is to be performed to an adequate standard, and observers and pilots should be well prepared before beginning a serious count.

4.8 EXPERIMENTAL BLOCKS

The accuracy of a total count and bias in the method can be assessed in experimental blocks. One approach is to census a number of plots within the census zone at an intensity high enough that the crew is confident that no elephant groups are missed. These results can be compared with the results from the same areas searched by other crews at the normal intensity to measure if there is any significant bias related to searching intensity.

Another method is to send several crews into a counting block in succession and to measure the

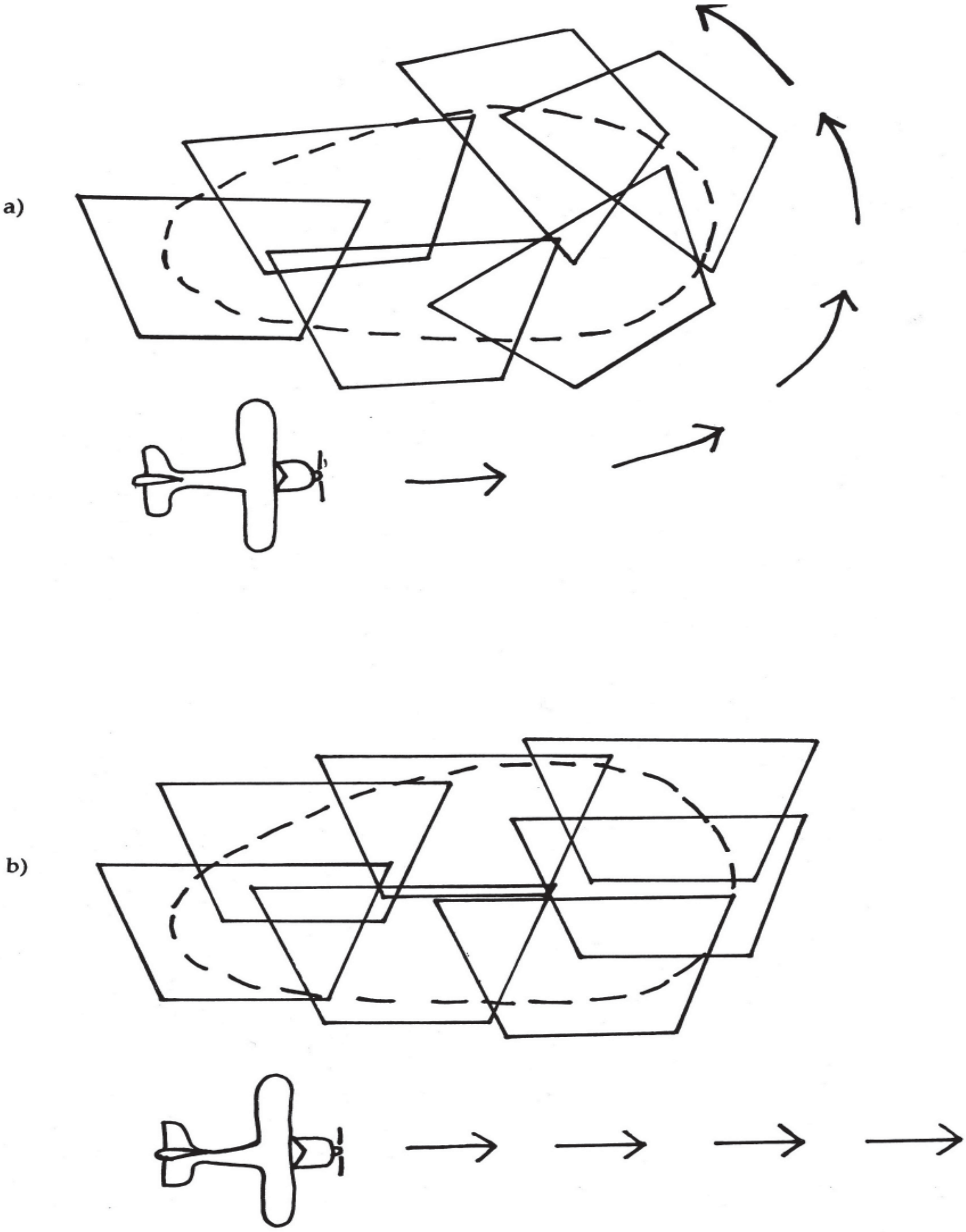


Fig 4.3: When photographing a large herd the pilot must make a straight line pass along it. He must not circle, a) Wrong flight path. Some areas have been missed and it will be impossible to work out areas of overlap. b) Correct flight path. No areas are missed and overlap can be worked out (after Norton Griffins 1978).

c accuracy of the count by comparing their totals. This will allow herd by herd comparisons to be made, from which the number of groups or individual elephants missed by each crew can be estimated. In the case of the Tsavo 1994 elephant count, the average bias towards undercounting was 15%.

Finally, if there is a long series of sample counts made in the same area, a comparison can be made of the sample and total count elephant estimates. The sample count which scans and counts a much narrower strip usually returns a higher elephant density and hence a larger estimate which may give an indication of the order of the bias in the total count. However, this will not work if the sample count has high confidence limits, which is usually the case.

4.9 POST-FLIGHT PROCEDURES

4.9.1 Ground support activities

Flying, spotting, counting and recording on an elephant count are arduous activities and take a toll on the flight crew, especially if the pace is maintained day after day. It is advisable, therefore, to have an efficient ground crew to take care of routine activities such as refueling, transport to and from the airstrip, accommodation and meals. All should be arranged to ensure the minimum extra burden on flight crews so that they can concentrate their energies on the job in hand.

The ground crew should also download GPS data on to computers; make print-outs of flight lines and waypoint records of observations; collect data-sheets, fair copy maps and used films, checking that none is missing; and sort and compile data by crew, day and block.

Clear and legible recording is not always possible while flying. Therefore, after each day's flying the FSO should set aside an hour or so for finalising the day's data collection. The original data sheets and flight maps must be tidied up so that they are legible by anyone attempting to read them.

After verifying the original flight data, the FSO should take a clean map and plot onto it each group by species and number of individuals (or estimated number of individuals). Ideally, this map should be printed out from the GPS data with the flight path and numbered waypoints clearly displayed. The FSO then only needs to attach the species data to each waypoint.

A simple code or colour highlighting can be used to distinguish species. For example, in the Tsavo counts the convention used is a number enclosed in a circle for elephants, a square for buffalo, a cross for a dead elephant and a cross within a circle for a recently dead elephant.

It is vital that these debriefing activities should be performed the same day the data is collected while the mind is still fresh with the day's images.

After printing out the location of elephant groups block by block, it is necessary to go through the records very carefully to eliminate double counts. With the GPS this becomes very easy. Even without computers and GPS systems the data can be summarised by hand, as in all the early counts in Tsavo and in Kruger, where records go back for decades.

For those observations where a waypoint was recorded for elephants, offset by a distance from the observers that has been recorded on the datasheet. a computer correction can be made based on a simple algorithm. This correction can then transpose the waypoint to its proper position.

4.9.2 Analysis

If the data have been compiled using the above instructions, they will form a permanent record for future workers. Check sheets need to be copied to spreadsheets, and data on each species can be compiled block by block. With the advent of Geographical Information System (GIS), the GPS waypoint data can be combined with the species data on spreadsheets to form a GIS database of observations.

This system greatly enhances the scope for geographical analysis in relation to other features digitised into the database. For example, elephant numbers and densities could be plotted out and summarized on grid squares of any size by counting block or any other area unit. Elephant distributions could also be related to features such as protected status, habitat, land-use, human population density, or proximity from features such as roads or rivers. The usual practice is to summarise results by counting blocks, which reveals any large change in distribution, or trends from year to year.

Corrections to the data can be calculated from the experimental blocks. The degree of undercount can be assessed from three separate sources:

i) Repeat total counts of the same blocks at different scanning intensities: the difference between the block scanned at normal intensity and that scanned at high intensity gives the undercount.

ii) Serial total counts made by several aircraft in the same block: the difference between the number counted by all crews gives the undercount.

iii) Comparisons of total count and sample count data, if made over a long period: the sample count scanned at a higher intensity will return a higher figure and the difference again gives the undercount.

Dead elephants may be used as an indicator of relative mortality, both over the previous 12 months and for longer periods. It is thought that only between one in three and one in five dead elephants are actually seen, so actual mortality rates cannot be calculated in relation to the elephant estimate. However, the number of "recent dead" is a sensitive indicator of annual mortality which will vary in any given area from year to year. The "carcass ratio" is also a useful indicator of mortality over time or between areas. It is calculated as all dead divided by dead plus live. This has been found to vary greatly between areas and has been used as an index of the relative effect of poaching or other causes of mortality (Dublin & Douglas-Hamilton 1987; Douglas-Hamilton & Burrill 1991).

4.9.3 Scanning intensity

Scanning intensity can conveniently be measured as km^2 searched per hour, or minutes taken to scan 10km^2. The average for many counts is 250km^2 per hour (Norton-Griffiths 1978). Work in progress relates spotting and counting success to scanning intensity. These results can be used to apply correction factors to old counts where the scanning intensity or flight path was recorded. Therefore, it is an important parameter to record and present so that results can be compared with later counts.

4.9.4 Report Writing

The report should present the results in a way that is of maximum use to park planners or future researchers who may want to use them as base line data.

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CHAPTER 5

ESTIMATING FOREST ELEPHANT ABUNDANCE BY DUNG COUNTS

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5.1 INTRODUCTION

Dung counts are the most common type of indirect census method for counting elephants. Since the early 1980s, as interest quickened in the status of elephants in the forests of west and central Africa, more and more dung counts have been conducted. In the late 1980s researchers in India and then in south-east Asia turned to dung counts for estimating the numbers of Asian elephants, *Elephas maximus.* The proliferation of forest elephant surveys on both continents has stimulated the rapid evolution of dung survey techniques. In this chapter general methods of censusing elephants by dung counts will be described. These methods have been described previously by Barnes and Jensen (1987), Dawson and Dekker (1992), and Barnes (1993). You should read Norton-Griffiths (1978) as a general introduction to animal census work. You are also strongly urged to consult Burnham *et al.* (1980) and Buckland *et al.* (1993) for the details of the line transect technique.

Many of the concepts involved in dung counts are similar to those already described in the preceding chapters on aerial surveys, i.e. one goes through the same stages of stratification, arranging the layout of transects within each stratum, collecting the data on the transects, and then analysing the data. However, with dung counts one then has the further problem of converting estimates of dung-pile numbers into estimates of elephant numbers.

A major difference between direct counts of elephants and dung counts is that the methods for direct counts have been worked out and standardised, and the improvements now consist of fine-tuning. On the other hand, the general methods of dung counts are still evolving. This presents you, the practitioner, with a challenge: you may have the opportunity to improve dung-counting methods yourself.

5.2 PRELIMINARY COMMENTS

A dung survey can be used in two ways. First, one may use dung as an index of elephant abundance or relative distribution. This can provide a considerable amount of valuable information about the biology of elephants in your study area (e.g. Barnes *et al.* 1991). For many purposes you do not need an estimate of the actual number of elephants; an estimate of the number of dung-piles, the relative distribution of dung-piles, or changes in the number of dung-piles over a period of years will give you all the information you need to manage your study area.

The second option is to translate the dung data into numbers of elephants. To do this will require considerably more time and effort.

To obtain an estimate of elephant numbers you will have to go through four stages:

i) Estimate the numbers of dung-piles, or the density of dung-piles per km^2.

ii) Estimate the defaecation rate of elephants.

iii) Estimate the mean rate of dung decay.

iv) Combine the above three estimates to give you an estimate of elephant numbers or the density of elephants per km^2.

Few wildlife officers possess the range of skills required to conduct a dung count from beginning to end. If you are competent in the field but lack experience of statistics and computers, then it may be wise to find a statistician/ data analyst to collaborate with you. You may find such a person at the nearest university, or possibly at a research institute. Agricultural stations often have statisticians who may be interested in your problems. Failing that, you can write to the Assistant Director for African Programs, NYZS, The Wildlife Conservation Society, Bronx Zoo, New York 10460, U.S.A. or the Chair of the African Elephant Specialist Group, P.O. Box 62440, Nairobi, Kenya. These people will be able to put you in contact with a collaborator who can help.

5.3 RECONNAISSANCE

Having decided to conduct a survey, there is a great temptation to leap in and begin collecting data at once. However, it is essential to make a reconnaissance or preliminary investigation first, and then plan the survey carefully. The reconnaissance will show you how elephants are distributed within your study area, and therefore how it should be stratified. It will also reveal the logistical and practical problems you are likely to face. During the reconnaissance you should visit each of the major vegetation types in the census zone. You should also examine the major geographical features (rivers, valleys, roads, villages, mountains, etc.) as these will all affect your planning of the census. All your reconnaissance work will, of course, be conducted on foot. Use a pedometer to give an approximate measure of distance walked. To obtain a rough index of dung-pile density in each area, record all the droppings you see in a one-metre band on either side of you. This will enable you to gauge the relative abundance of elephants in different parts of your census zone.

The importance of a reconnaissance before you plan the census cannot be over-emphasised. A reconnaissance can save you an immense amount of wasted effort later. If you are new to a forest, then as a rule of thumb, you should spend not less than 10% of the time allocated for the whole census in conducting the reconnaissance.

The reconnaissance should be followed by several days at your desk when you plan the stratification, layout of transects, and the organisation of personnel, equipment and logistics. Then, having satisfied yourself that these plans fit within the limits of your budget, you can set off to cut the first transect.

5.4 STRATIFICATION

It is rare for elephants to be evenly distributed across a study area. One usually finds that dung-piles are more abundant in a particular vegetation type (e.g. secondary forest) and sparsely distributed elsewhere, and the reconnaissance will give you an idea of this. These variations in density across the study area will result in a large variance and therefore wide confidence limits for your final estimate. The variance can be reduced considerably by dividing the study area into strata. Each stratum is a sub-division of the study area m which the dung-pile density is more or less homogeneous. Thus one might divide a forest into three strata: one where dung-pile densities are low because of human disturbance, then a medium density stratum, and finally a stratum of mixed primary and secondary forest with no human activity and a high dung-pile density.

Human activities are often more important than vegetation in determining elephant distribution, even m fairly small or sparsely inhabited forests (e.g. Butynski 1986; Barnes *et al.* 1991). Every forest is different, and the most appropriate form of stratification will depend upon the size and shape of the forest, the original vegetation, the history of human activity, and the present relationship between humans and elephants. This is why it is so important to get to know your forest before planning the census.

5.5 ESTIMATING THE DENSITY OF DUNG-PILES

5.5.1 Distribution of transects

The distribution of transects, both between strata and within strata, can have a marked effect upon the accuracy of your estimate and the width of its confidence limits.

How should the transects be arranged? Norton-Griffiths (1978) gives a good discussion on the layout of transects. Transects may be laid out randomly or in a regular pattern. For example, in each stratum you draw a base-line running along the longest axis of the stratum. Then the transects are placed at random intervals along the base-line (use a random number table which is a published list of randomly selected numbers to decide where each transect should go), lying perpendicular to the base-line. Another option is to have the transects at regular intervals along the base-line. In that case the starting point of the first transect should be determined with a random number table.

From the point of view of statistical efficiency, it is preferable to have many short transects rather than a few long ones (Norton-Griffiths 1978). Thus, if you have enough money to cut 100km of transect, it would be better to have 20 transects of 5km rather than 10 transects of 10km. But, in forest one is often constrained by logistical considerations. Moving from the end of one transect to the beginning of the next can be expensive, especially when the transects are distributed across a huge area. One needs to minimise the ratio of "dead time" when travelling between transects and not collecting data, to working time when one is collecting data on transects (Barnes & Jensen 1987). Logistics may, therefore, demand that you have a few long transects. An alternative is to place transects end to end in a zig-zag pattern (Fig. 5.1). Then each leg of the zig-zag is considered to be a separate transect. The starting point of the first leg should be determined using a random number table.

Fig. 5.1: The zig-zag pattern for laying out transects. Each leg of the zig-zag is treated as a separate transect.

How many transects should there be in each stratum? The number of transects should be proportional to the variance to be expected in each stratum. If you have not previously conducted a survey in that area you cannot know the expected variance. But variance is usually proportional to density. Thus you can allocate transects in proportion to the approximate density revealed by the reconnaissance. For example, imagine that you have enough money for 50 transects and that you have divided your study area into three strata. The reconnaissance showed that the ratio of dung-pile densities was 1:2:4 in the low, medium, and high density strata respectively. Therefore the ratio of transects should be 7:14:28 in the three strata.

How long should each transect be? Simulations using data from north-east. Gabon showed that the optimum transect length was 5km for that stratum (Barnes *et al.* 1988). Until you have some data from your own study area, you can use this figure as a rule of thumb.

Having worked out the number of transects in each stratum, and the length of each transect, you should use the results from the reconnaissance to calculate approximately how many dung-piles you are likely to record in each stratum. A minimum of 60 to 80 dung-piles in each stratum is recommended (Buckland *et al.* 1993). You might have to adjust the numbers or lengths of transects to ensure that you achieve at least the minimum number of dung-piles in the medium and high density strata. My experience is that you are never likely to find 60 dung-piles in a low density stratum.

5.5.2 Permanent versus temporary transects

The earliest dung-counters used permanent transects to which they returned at regular intervals to record the disappearance of old dung piles and the deposition of new ones (Wing & Buss 1970; Jachmann & Bell 1979 & 1984; Short 1983; Merz 1986). This lays one open to the criticism that elephants like to walk down paths, such as permanent transects, leaving a higher dung-pile density on transects than in the surrounding forest. In order to overcome this problem, and also because it is not feasible to revisit transects in the vast equatorial forests, Barnes and Jensen (1987) adopted a different approach. One assumes that the forest is in a steady state. That is, no elephants move in or out of the study area, and the rates of dung deposition and decay have remained constant for a long period before the census and also while the census is taking place. This means of course that you should do your dung counts either in the wet season or the dry, but not both, nor during the transition period between seasons (Barnes & Jensen 1987). Then, one need pass only once down the transect ("one-off" transects). We found that in the central African forests it was most practical for the observers to follow immediately behind the labourers cutting the transect. Then there is no possibility of bias caused by elephants defaecating on the transect between the passage of the cutters and the observers.

If you are unhappy with the steady state assumption, then Hiby and Lovell (1991) provide an alternative method. Their mathematical model was designed specifically to avoid making this assumption.

5.5.3 Cutting the transect

Draw the base-line and transects onto a map in pencil. Then use the north-point of the map to calculate the bearing of each transect. Remember to take into account magnetic deviation, which is the difference between grid north (north shown on your map) and magnetic north (shown by your compass). This can sometimes be about eight degrees. It is usually iven on the map's margin. Then set your compass to show the bearing.

You will need to employ labourers to cut the transect for you. They should carry sighting poles (paint them white or red so they stand out in the forest gloom) to ensure that they cut a straight transect. The man wielding the panga/cutlass should be replaced every hour, otherwise he will tire and the transect will proceed slowly.

Do not cut a wide swathe through the forest. All you need is a straight path just wide enough for you to pass down. As you walk down the transect you scan the undergrowth on each side for elephant droppings.

5.5.4 Line transects

Strip transects are transects with a pre-determined fixed width, such as the type used in aerial surveys (see Chapter 3). Strip transects are not usually appropriate for dung counts in forest. This is because visibility (i.e. the probability of seeing a dung-pile) declines very rapidly with distance from the observer. Thus, in many forests the undergrowth is so thick that 50% of all dung-piles at a distance of two metres are missed by an observer (Fig. 5.2). Clearly, if you used transects that were, say, five metres wide you would miss a high proportion of the dung-piles lying within the transect. You could make the transect very narrow, perhaps one metre on either side of the observer, but that brings the disadvantage that only a small number of droppings would fall within the limits of your transect. Then your census would produce an estimate with wide confidence limits.

Under these conditions the most appropriate method is the line transect technique. This technique is based upon the fact that the probability of detection by an observer declines with the object's distance from the observer. With an adequate sample of measurements of the distance between the detected objects and the centre-line, mathematical techniques can be used to model the detection function and then estimate the density of objects.

Comparisons made by Burnham *et al.* (1985) between line and strip transects showed that line transects produced estimates that were both more accurate and had lower standard errors (i.e., narrower confidence limits) than strip transects. During the last two decades a considerable amount of effort has gone into perfecting the line transect method of censusing. A seminal work was the monograph by Burnham *et al.* (1980) which formed the basis for much of the field work

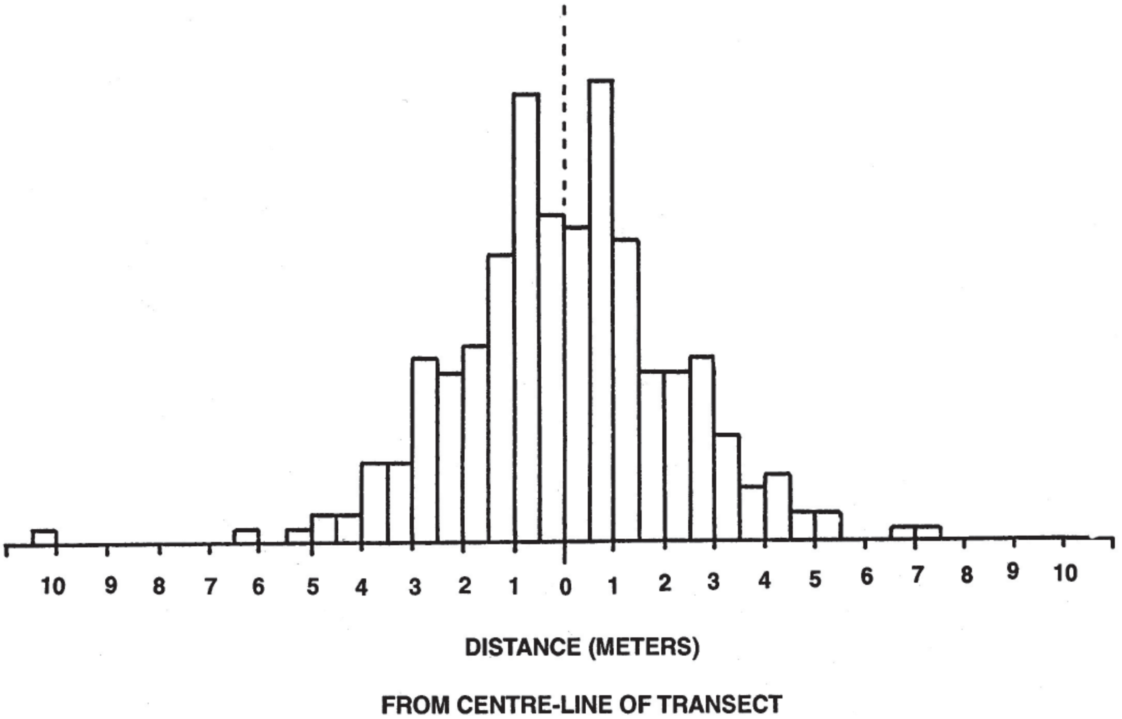
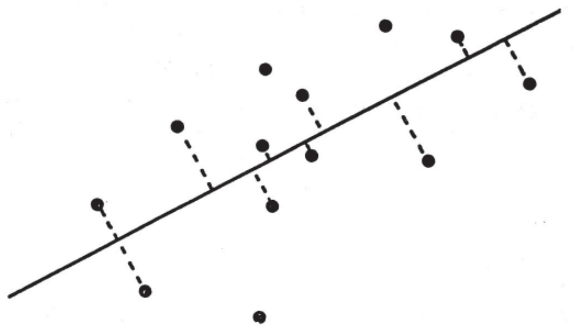


Fig. 5.2: An illustration of the numbers of dung-piles seen on either side by an observer as he or she proceeds down the centre-line of the transect. The horizontal axis represents the distance to the left or right of the centre-line of the transect. The vertical axis represents the number of dung-piles found in each distance class (0.00-0.49 metres, 0.50-0.99 metres, 1.00-1.49 metres, etc) to the left or right of the centre-line. Data from N.E. Gabon.

done on forest elephants in the 1980s. This has now been superseded by the volume by Buckland *et al.* (1993) which describes the recent developments in the science of line transect surveying and in which you will find references to all the relevant literature. A concise summary of line transects is provided by Krebs (1989.)

When doing a line transect census for dung-piles, the observer walks slowly down the centre-line of the transect. The perpendicular distance (x) of each dung-pile from the centre-line is measured with a good quality measuring tape (Fig. 5.3). You will find that you will record all droppings that fall on the transect centre-line or very close to it. But the further the droppings from the centre-line, the lower the likelihood of their being seen (Fig. 5.2).

Very great care must be taken in measuring the perpendicular distances. Sometimes droppings lying close to the centre-line are recorded as on the centre line (x = 0), when in fact x = 10cm or x = 20cm. This can bias the final estimate (Buckland *et al.* 1993). Care must be taken in ensuring that the centre-line of the transect is straight and is clearly marked.



F ig. 5.3: Diagrammatic representation of a line transect. The observer walks along the centre-line of the transect ***(—).*** Whenever he spots a dung- pile (.),he records the perpendicular distance ***(——).*** Some dung-piles, especially those further from the centre-line, are not seen at all.

Fig. 5.2 shows that more dung-piles at a distance 0.5-0.99m from the centre-line were recorded than in the band 0.0-0.49m. Scrutiny of the raw data suggests that the observers had a tendency to record any value of x greater than 0.45m as "0.5m". This phenomenon, when measurements are unconsciously rounded to certain figures like 0.5,5, and 10, is called "heaping" and is common in line transect surveys (Buckland *et al.* 1993). To avoid it, the observers must take care in their measurements.

Another practical problem is the tendency for the cutters to shift a metre or two to the side to go round a shrub instead of going straight through it. This usually happens towards the end of the day when everybody is tired. Elephants are more likely to leave dung-piles around a bush than in the middle of it, so by bending the transect you will get a shorter measurement of x than if the transect had gone straight through the bush. This will give a biased estimate of dung density.

The length of the transect can be measured with a surveyor's chain or with a topofil (called a "hip chain" in the USA), which is more practical but Less accurate.

During the process of decay a dung-pile gradually diminishes in size, changes colour, and becomes partially covered by leaves. There comes a time when it becomes less visible to someone running a transect. If you do not take this into account then the results of the census may be biased. Thus Barnes & Jensen (1987) classified dung-piles by their shape, i.e., by their probability of being spotted (Table 5.1). Categories A to D were likely to be seen, while category E was defined as the stage at which a dung-pile was unlikely to be seen by an observer at a distance of two metres or more. Note that Barnes *et al.* (1988) found no difference in visibility when they compared stages A to C with stage D.

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

Tabel 5.1: Dung-piles can be classified according to their shape, i.e. the probability of being seen from the centre-line of a transect (after Barnes & Jensen, 1987). Only dung-iles in categories A to D are used to estimate dung-pile density.

Thus the morphological stage of each dung-pile should be recorded. Stage E dung-piles will be ignored in the analysis, but it is still useful to record them. Sometimes in areas of low elephant density you may find only stage E dung-piles and they may then give you some index of elephant abundance.

All data should be recorded systematically on check-sheets. See Fig 5.4.

km	A,D	Xi	Elephant sign	GeneraNotes	Vegetation Type
0.00				Start from road	Secondary forest. canopy > 5m
0.27					
0.65					Secondary canopy < 5m (recently abandoned plantation)
0.93					Secondary canopy > 5m
1.34					Marsh
2.00				Alarm call of grey checked mangabey	Primary forest with dense under-storey
3.62				Ravine	
3.73				Footprints signs of feeding	
3.94	D	1.7	Dropping		
4.17					
4.21	C2	0.6	Dropping		Abandoned village, Secondary canopy > 5m
5.22	D	2.4	Dropping		
5.23				Gorilla nest (group of 5)	
5.24					
5.27				Stream	Marsh
5.28					
5.29				Hunter’s camp	Primary forest with dense understorey

Fig. 5.4: Example of a check-sheet to use in line-transect survey.

5.5.5 Analysis

The mathematics of line transect surveys are complicated and consequently a computer is essential. You will need a programme to analyse the data. Several are already available. For example, TRANSECT was written by Burnham *et al.* (1980). A user-friendly programme called ELEPHANT, based on Burnham *et al.* (1980) and employing the Fourier series model, has been written by Dekker and Dawson (1992) to accompany their booklet on counting Asian elephants (Dawson & Dekker 1992). It is designed for use by wildlife officers. Although it is a simple programme to use, you still need to understand the rudiments of using a computer, such as creating data files.

While the Fourier series model is robust and flexible (Burnham *et al.* 1980), and will provide a good fit to most dung-pile data, it is not necessarily the best. The hazard rate model is being used increasingly for animal census work. For example, White (1992) used it to analyse elephant dung-pile densities in the Lope Game Reserve in Gabon. A new programme, DISTANCE, which allows you to select different models, and also a range of different options, has been prepared by Laake *et a!.* (1993). This is designed to be used in conjunction with the manual by Buckland *et al.* (1993). This programme will enable you to get the most out of your hard-won data, but most wildlife officers will find the technicalities baffling. If you are setting out to do line transects for the first time, you would be well advised to use Dekker and Dawson’s (1992) programme. Then, as you gain experience and confidence, you can consider graduating to the more sophisticated analyses promoted by Laake *et al.* (1993).

Whichever programme you select, you will have to create a data-file containing the data on perpendicular distances. The programme will read this file and use the perpendicular distances to calculate f(0) This is an estimate of the reciprocal of the effective strip width (ESW). This is defined as the perpendicular distance for which the number of dung-piles missed between the line and the ESW is equal to the number of dung-piles beyond the ESW that are detected. See Burnham *et al.* (1980) and Buckland *et al.* (1993) for details.

The density of dung-piles, D, is then:

$$D = \frac{n.f(0)}{2L}$$

where **n** is the number of droppings and **L** is the total length of the transects in which they were recorded. The methods for estimating the variance of **D** and the confidence limits are given by Bumham *et al.* (1980) and Buckland *et a!.* (1993). The calculations are done automatically by the programmes ELEPHANT and DISTANCE.

The data should be analysed separately for each stratum, and then combined to give an overall estimate for the whole study area (Norton-Griffiths 1978).

5.6 DEFAECATION RATES

5.6.1 Data collection

The defaecation rate is the average number of dung-piles produced per elephant per day. Defaecation rates have been estimated for forest elephants by Wing and Buss (1970), Merz (1986), and Tchamba (1992). You should estimate defaecation rates in your own study area, because there are likely to be variations from one place to another. However, this is not always possible, in which case you should use the estimate from the site which is most similar to yours in terms of rainfall and vegetation.

One way to obtain data on defaecation rates is to follow elephants, as Tchamba (1992) did: follow a group's tracks, record all droppings, camping at night and then following up the tracks the next day. If you know the number of individuals in the group and the length of time represented by the tracks you followed, then you can calculate the total number of elephant-hours (the number of elephants multiplied by the number of hours). Assuming you did not miss any droppings and no animals left or joined the group, then you can calculate the number of dung-piles per elephant per day. A modification of this method is being employed in Cameroon by the WCS research team (J. Powell pers. comm.): a radio-collared elephant is located in the early morning and a peg left as a marker. The next morning the animal is again located. Then one walks back along the group's tracks, recording all dung-piles, until the peg is found.

You must ensure that your observation periods are reasonably long (a minimum of five or six hours but preferably twelve), that you obtain an adequate number of observation periods, and that they are evenly distributed throughout the 24-hours because of diurnal variations in defaecation rate (Dawson 1990).

A word of warning. Elephants become very cunning when they suspect they are being followed in thick vegetation. Do not underestimate them.

It may seem easier and safer to watch elephants from a hide and record their defaecations. However, when such a hide is at a drinking place, you may get a biased estimate because elephants have a habit of defaecating when they approach water.

5.6.2 Analysis

For each observation period, the defaecation rate per hour is the total number of defaecations divided by the total number of observation hours. Multiply this by 24 to give a daily rate, and then calculate the mean, variance and confidence limits by the usual means.

BOX 5.1: VARIANCE AND ASSOCIATED TERMS

One must understand the distinction between the true population size and the estimated population size. The true population size is the actual number of elephants in the study area. Usually we do not know the value of this figure. The estimated population size is what we calculate the population to be using the data collected in a survey. We hope that this estimate will be close to the true population size. In that case it is an accurate estimate. Often however, there is something causing a consistent error in the estimate, so that it either over-estimates or under-estimates the population size. The difference between the true population size and an estimate is called bias. In aerial surveys the most important source of bias is observer efficiency, the failure of observers to see all the animals in their sample units (Caughley & Goddard 1972). This is a much larger source of error than you might realize. Another source of bias in aerial surveys may be faulty altimeter leading to an error in the estimate of strip width (Norton-Griffiths 1978). However, computer simulations suggest that observer efficiency is not a source of bias in dung surveys which use the line transect method (Barnes *et al.* 1988).

A second type of error is sample error. This is the random variation one always finds in biological studies. If you conduct repeat surveys of the same area, each estimate will be slightly different from the others because of this random variation. If you look at the results from one survey you will find the randomly-selected transects contain different numbers of animals or droppings from the transects in the other surveys of the same area. Animals or droppings are never evenly distributed. Some transects will contain many droppings, while others will contain few, and you may have some transects with none at all.

For each survey, the estimates from the individual transects will tend to cluster about the mean value. This is the simple average (the sum of the estimates from the **n** transects divided by **n**). If the estimates from the individual transects are tightly clustered around the mean (Fig. 5.5), it means there is little variation between transects. This variation is measured by the variance. In this case the variance is low. If the estimates from the transects are widely spread (Fig. 5.5b), then the variance will be high.

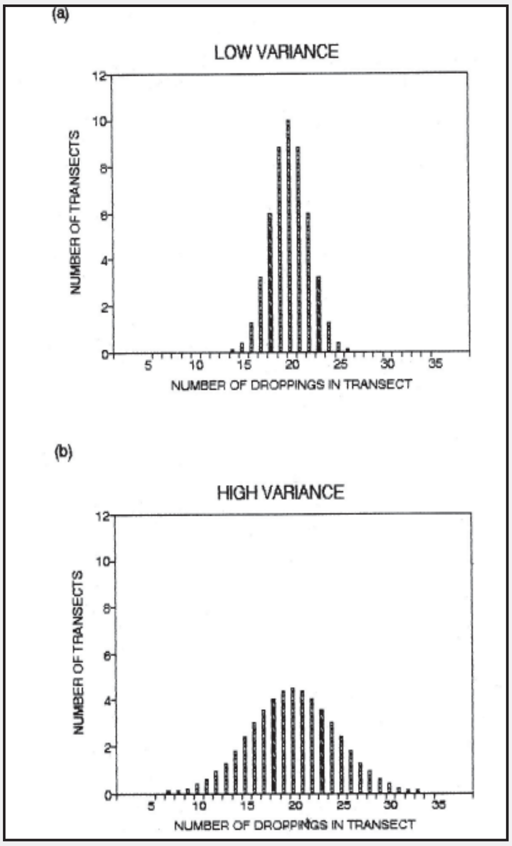


Fig. 5.5: An illustration of variance. In each of the graphs above, the mean number of droppings per transect is estimated to be 20. In graph a) the variance is low and the estimates from the different transects are clustered tightly above the mean. In graph b) the variance is high and there is greater spread of estimates above the mean.

The standard error is the square root of the variance. The 95% confidence limits are found by multiplying the standard error by a fact t**.** For large samples t = 1.96 for 95% confidence limits. In wildlife surveys one usually calculates the 95% confidence limits, but there may be situations when you want to calculate 90% or 99% confidence limits.

The confidence limits are usually expressed as a range above and below the estimate. For example, an estimate of 100 droppings with confidence limits of +20 is usually written as 100±20. The confidence limits mean that if you were to re-sample the population repeatedly and calculate the population estimate, 95% of your estimates would fall between 80 and 120. They can also be interpreted to mean that there is a 95% certainty that the true population size lies between 80 and 120.

An estimate with a small variance and narrow confidence limits is termed a precise estimate. An estimate can be inaccurate but precise. That means the estimate differs by a large amount from the true population size, but it has narrow confidence limits. Of course, we hope that all our estimates will be both accurate and precise.

This topic is discussed in greater detail in Norton-Griffiths (1978).

5.7 DUNG DECAY RATES

5.7.1 Data collection

Estimating the rate of dung decay is very time-consuming. It needs to be done at the same time as the line transect is being conducted. This means that you will need two teams, one to do the line transect census and the other for dung decay observations. Or you could use the same team to do the line-transects in the first year and the dung decay observations at the same season in the following year.

your study area) for several weeks. However, Barnes and Barnes (1992) showed that if you used the Goodman method of analysis, then the estimate of decay rate is insensitive to truncation. That is, if all except two droppings have decayed then you can stop the observations and start analysing the data. Ignoring the last two droppings will have no effect upon the estimate of dung decay rate. But this only holds if you use the Goodman method.

The aim is to estimate the mean daily rate of dung decay by measuring the time that each dung-pile in a sample takes to pass from deposition to stage E. Data collected in the Kakum National Park in Ghana indicates that 50 dung-piles is the optimum number for obtaining a good estimate of decay rate in any one season. It is worth aiming for 55 or 60 in case some are disturbed by poachers or lost in other ways.

Searching for fresh dung-piles may take longer than you anticipate because you must be sure of the date of deposition of the dung-pile. It is usually difficult to estimate the age of droppings that are more than 48 hours old; distrust anybody who claims they can do so unless you have tested them with known-age droppings. It is best to search for droppings that have been deposited within the preceding 24 hours. Each dung-pile should be marked and mapped so that you can return at weekly intervals. You should return to each dung-pile until it reaches stage E. Note that there is a degree of subjectivity in the definition of stage E. This subjectivity is an important potential source of error. However, we have found in Ghana that with practice different observers can be trained to be remarkably consistent in deciding on the transition point between stages D and E. The important thing is to be consistent in the definition you use, and to use the same definition in both your line-transect survey and in your decay observations. Before starting a dung census you should spend several days walking through the study area to decide upon your definition of the D/E transition.

Dung-piles do not age uniformly. Some pass from deposition to stage E in ten days. Others take a hundred days (Barnes & Barnes 1992). The fact that all your dung-piles except two have decayed can be an extreme nuisance. You may spend a lot of money to monitor just two lone dung-piles (they invariably seem to be at opposite ends of your study area) for several weeks. However, Barnes and Barnes (1992) showed that if you used the Goodman method of analysis, then the estimate of decay rate is insensitive to truncation. That is, if all except two droppings have decayed then you can stop the observations and start analysing the data. Ignoring the last two droppings will have no effect upon the estimate of dung decay rate. But this only holds if you use the Goodman method.

5.7.2 Analysis

The analysis of dung decay rates is complicated by the non-uniform process of decay. At first the process of decay was thought to be exponential (Short 1983; McClanahan 1986; Barnes & Jensen 1987). But Dawson (1990) showed that this was not the case, and her conclusion has been confirmed since then by a number of large samples of decaying dung-piles (Grimshaw & Foley 1990; Reuling 1991; L. White pers. comm.). The methods of analysing these data are still evolving. One method has been described by Dawson (1990); another, based on Goodman s (1984) model of mammalian survival rates, is given by Barnes and Barnes (1992). Others are being developed (R. Sukumar pers. comm.).

5.8 CALCULATING THE NUMBER OF ELEPHANTS

The number of elephants (E) is calculated from the dung-pile density (Y), the defaecation rate (D), and the decay rate (r) by the equation (McClanahan 1986; Barnes & Jensen 1987):

$$E = \frac{Y.r}{D}$$

The individual variances of Y, r, and D each contribute to the variance of E. This variance can be calculated in three different ways. all described by Barnes (1993). Another method has been worked out by Dr. R. Sukumar (pers. comm.) and will be published shortly.

If you want to avoid the steady state assumption, then Hiby & Lovell (1991) have prepared a programme that will give an estimate for E. But this still requires observations of dung decay and it also requires an estimate of defaecation rate.

5.9 MISCELLANEOUS TIPS

A potential source of error is an elephant's habit of walking while defaecating. This means that some boli may fall in one pile and the rest in another, and sometimes the boli may fall in three separate piles. If you pass along later when the boli have reached stage D (an amorphous mass), you will not be able to tell whether it was two separate defaecations or one defaecation falling in different piles. I have found that even experienced trackers may think they know but cannot tell.

When faced with this problem, one should note clearly on the check-sheet that the dung-piles may be either from the same or different defaecations. Then when analysing the data, do two separate analyses. In the first assume these dung-piles all belonged to the same defaecation (i.e. use the mean of their perpendicular distances). In the second, assume that they are separate defaecations. There may be a large difference between the two estimates, but since you cannot tell which is the true figure (or since some may have come from two defaecations and some from only one, the true figure may lie somewhere between the two) you must simply present the two estimates.

Savanna elephants show seasonal variations in defaecation rate (Barnes 1982), and Wing & Buss' (1970) results indicated this was also true of elephants in the Budongo Forest in Uganda. But Tchamba's (1992) study in Cameroon showed no seasonal variations. There are, however, marked seasonal variations in decay rate. In some habitats there will also be seasonal variations in the visibility of dung-piles. These seasonal changes mean that you should complete a dung count within one season. If you are surveying a very large area, then you might have to survey one stratum in the wet season, go and do some other type of work in the dry season, and then survey the next stratum in the wet season of the next year.

Make copies of your field data as soon as possible after you have collected it. Place a sheet of carbon paper under your checksheet so that you make a carbon copy as you record the data. Or copy the check-sheet out in the evening. If you have only one copy then you risk losing the results of all your hard work when a canoe overturns, the camp burns down, or your haversack is stolen.

Do make a list of every item you will need in the field, and take spares. When you are six days' walk from the nearest village there is nothing more galling than realising that the pencil you dropped in the rapids was your last.

5.10 CONCLUSION

While it may be true that "counting elephants will not save them" (Boshe 1990), most elephant conservation efforts are preceded or even triggered by a census of one sort or another. For example, the large forest conservation project now underway in the Nouabale area of northern Congo was stimulated by the results of the forest elephant surveys conducted by Wildlife Conservation International (Fay 1991; Fay & Agnagna 1991; Barnes *et al.* 1993). It is often difficult to stimulate politicians or senior officials to do anything until you have some numbers. Numbers give substance to your arguments.

You must have a thick skin if you are going to count elephants. If the goal of your work is to provide data to be used in making management decisions (e.g. culling, ivory trade), then you will be attacked simultaneously by those who claim your estimates are inflated and those who believe them to be too low. You must be completely objective. Avoid setting out to prove there are too many elephants and so they should be culled, or that there are too few. Your prejudices might unconsciously cause you to bias your results. Ideally, you should collect and analyse the data in a professional and objective manner; then the management decisions based on your results should be taken by a higher authority.

Dung counts can, if done properly, give estimates that are accurate (i.e., close to the true population size) and precise (i.e., with narrow confidence limits), as shown in a series of experiments conducted by Jachmann (1991) in Burkina Faso. In fact, Jachmann (1991) showed that in both respects sample counts of dung were superior to sample counts of the elephants themselves.

5.11 ADDRESSES TO OBTAIN COMPUTER PROG RAMMES

l. The programme ELEPHANT can be obtained from:
The Director, Wildlife Institute of India,
Post Bag 18,
Dehra Dun - 248001,
India.

2. The programme DISTANCE can be obtained from:

The Colorado Cooperative Fish &
Wildlife Research Unit,
201 Wagar Building,
Colorado State University,
Fort Collins,
Colorado 80523, USA.

Both programmes are distributed free of charge.

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CHAPTER 6

DIRECT COUNTS OF ELEPHANTS FROM THE GROUND

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6.1 INTRODUCTION

The most direct way to estimate the abundance of an elephant population is to Count all individuals in a defined area. An estimate of population density is obtained simply by dividing the number counted by the size of the area censused, and the density figure obtained in this way can then be applied to surrounding areas with similar characteristics, such as soil types and vegetation. Census methods based on this approach are usually called quadrat, plot or strip-sampling methods. Defining an area or establishing a plot and then counting all the elephants within it on foot or from a vehicle can be very time consuming and impractical, and certainly impossible if the target elephant population is mobile or if individuals are widely scattered. As an alternative, transect and line-transect methods have been devised to estimate animal abundance. Both can be carried out on foot or from a vehicle, and the principles that apply are very similar to those used in estimating elephant abundance using dung counts (see Chapter 5).

This chapter begins with a brief description of transect counts on the ground, and then goes on to discuss line-transect methodology. You are strongly advised to read Norton-Griffiths (1978) for an introduction to survey work, and Burnham *et al*. (1980) and Buckland *et* al. (1993) for a thorough statistical background on line-transect sampling.

6.2 TRANSECT COUNTS

The simplest form of estimation of numbers from observation data uses linear extrapolation. That is, having surveyed a defined area within a region, such as a transect with a fixed width, and assuming that all the animals within that area have been seen, applying the calculated density to the whole region. This method produces the best results in open country where there is no visibility problem. In all other cases the method will be inadequate in at least two ways that result in error in the estimate of animal abundance:

i) it is difficult to define accurately the area that has been surveyed; and

ii) one assumes that all individuals have been seen in the surveyed area. This assumption, however, is not realistic when using a transect of fixed width in woodland habitats, for instance. In this case the population estimates will be negatively biased, that is, one will estimate fewer elephants than there actually are in an area.

These problems can be overcome by using variable fixed-width transects, whereby the width of the transect is adjusted according to the vegetation density. In open country, the width of the transect may be as much as 500m; while in areas of dense vegetation, the fixed width may be reduced to l00m. This technique, however, has the same sources of error as the fixed-width method described above. King’s method was the first technique to use this variable visibility profile, taking the average sighting distance as half the effective strip width or half the width of the strip censused. Although the method is weak and usually produces overestimates of density (Norton-Griffiths 1978), it does not require much training to carry Out the field procedure and the data analysis.

Another approach is Kelker’s method (unpublished dissertation), where the distance of each group of elephants from the transect line is measured. The number of groups observed are tallied by distance from the transect line, i.e. all groups falling between

0-10m, l0-20m, etc. The number of elephants in each distance category or belt is then plotted against the sighting distance from the transect (Fig. 6.1). The resulting curve will drop off steeply for a particular distance away from the transect. This point is taken as one half of the effective strip width. The precision of the estimate will improve with a declining belt size, e.g. belt intervals of 25 metres will provide considerably better estimates than belt intervals of 100 metres. Small belt sizes are only practical, however, when the elephants are used to the presence of people and vehicles, otherwise no observations will be made in the first few belts.

Although Kelker's method is somewhat better than the ones described previously, it usually leads to overestimates of density (Norton-Griffiths 1978. The method will only work if the observations drop off in a fairly abrupt manner.

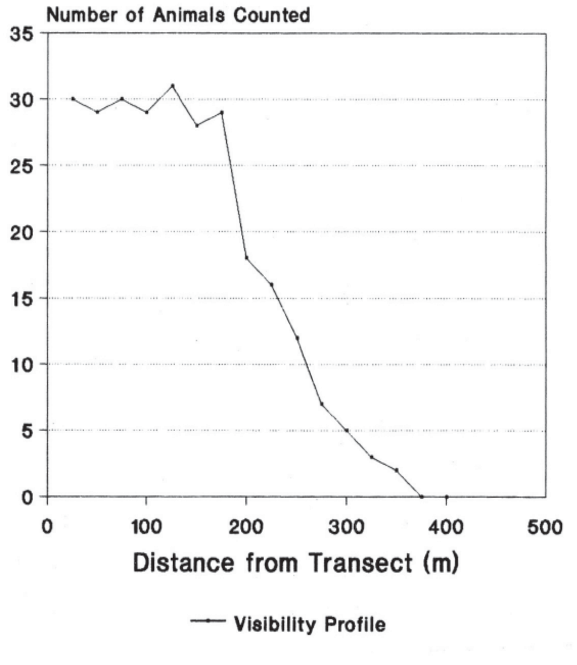

Fig. 6.1: An adaptation of Kelker‘s method: number of animals counted in 25m belts (abscis) of increasing distance from the transect line (ordinate). The point at which the numbers drop off is taken as half the effective strip width, which is 175m in this hypothetical case.

The precision of the method is limited when the observations drop off gradually or shows a sine or s-shaped pattern.

Essentially, the only approach which reduces considerably is the line-transect method discussed below.

6.3 LINE-TRANSECT SAMPLING

6.3.1 Line-transect sampling theory

In line-transect sampling the observer *progresses* through the area following a straight line of known length (transect). He or she records each animal, notes the distance of the animal from the observer when spotted and using a compass, its bearing, which is then converted to a sighting angle relative to the transect (Fig. 6.2). As a result, the observer is able to calculate the perpendicular distance of each animal *from* the transect. The width of the transect is not fixed and changes constantly according to the visibility or density of the vegetation along that particular segment of the transect. The width of the transect also differs for each species of animal when multi-species counts are conducted.

The data from a line-transect survey are a set of distances and angles and the resultant sample size itself (i.e., number of groups seen and number of transects walked). The Set of distances and angles are transfomed to a set of perpendicular distances of the elephants from the transect line. These perpendicular distances are then used in a statistical model to calculate the elephant density for the area. The basic idea underlying such a model is that the probability of detecting an elephant decreases as its distance from the transect line increases. Mathematically, this idea is represented by a function or curve called the

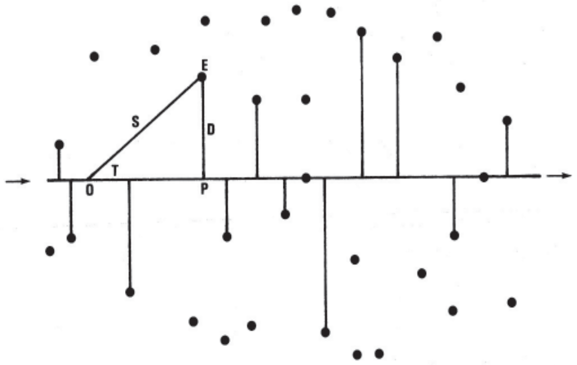

Fig. 6.2 Diagrammatic representation of a line-transect sample and the data that should be collected for a detected elephant Elephants detected show the perpendicular distance to the transect line. Those on the line ***are*** always detected, while those further away have a lower probability of being detected. The observer is at position 0, the elephant detected at position E and P is the point perpendicular to the elephant. The sighting distance is S, the sighting angle is T and the perpendicular distance is D.

detection function g(x), where x is the perpendicular distance (Fig. 6.3). This is the conditional probability of observing an elephant, given that the animal is at perpendicular distance from the transect line. There are numerous factors that affect the probability of detecting animals: for example, alertness, interest and training of observers, habitat conditions, time of year, time of day and elephant group size, etc. If line-transect sampling depended upon the detection probability being a simple function of x or the perpendicular distance from the transect of all sighted animals over the entire study period, it would be of little value, because such a condition does not exist in reality. Fortunately, analytical methods exist that are not affected by variations in detection probability for each sighting or over the course of the study. Mathematically, the detection function is allowed to be a mixture of many simple functions: $g(x) = g_1(x) + \quad + g(x)$, where each $g_1(x)$ applies to a set of detection c conditions (Burnham *et* al. 1980). Although the detection function is related to many factors, the spatial distribution of elephants is one factor to which it is not related.

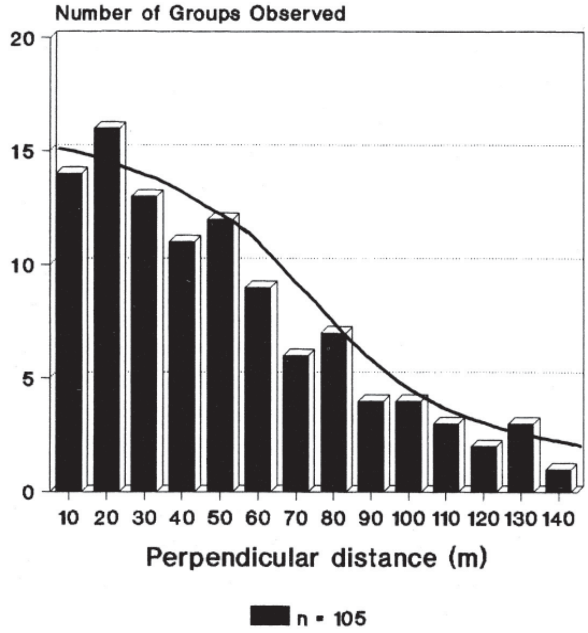

Fig. 6.3: Hypothetical example of a frequency diagram of perpendicular distance data for groups of animals observed. The detection function (g(x)) is indicated, but is not to scale.

6.3.2 Density estimation

In Chapter 5 on dung counts it was stated that the mathematics of line-transect techniques are complicated and the use of a computer is essential. This is also the case with direct counts, and you are advised to seek the help of someone well versed in computers and statistics to help you analyse your data and explain the assumptions of the different methods for doing so.

The conceptual background of all line-transect estimation is as follows. The estimator of the density (D) of (n) observations over a transect with length (L) can be expressed as:

$$D = \frac{n}{2.L.a}$$

The unknown parameter (a) can be referred to as one-half the effective strip width of the transect, where the relationship between (a) and the detection function is the integral of the detection curve:

$$a = \int_{0}^{w} g\,(x)\,d\,(x)$$

6.3.3 Field procedure

The major advantage of the line-transect sampling technique is the relative ease of its implementation in the field. The placement of transect lines may be either temporary or permanent. Permanent transect lines, delineated by markers, should be considered if the transects are to be surveyed periodically. Use of permanent transects enables pairing of the data for the analysis of differences in density over time and thereby increases the power of such analyses. When the survey areas have been selected, the layout of transects must be determined. That layout will depend on statistical design requirements, but as the field examples at the end of this chapter will show, considerations of logistics supplies and access will in practice often determine the final survey design.

As with dung counts (see Chapter 5), the following factors are of the utmost importance:

i) defining a straight line of travel;

ii) obtaining accurate measurements of distances and angles; and

iii) ensuring that all elephants on, and very near, the transect line are detected with certainly

Although the field procedure is relatively simple (see Section **6.3.1)** some understanding of the theory is essential for obtaining good estimates of density. The entire procedure of line-transect sampling is based on being able to follow a straight transect line or series of straight line segments. This is almost always compromised to some degree in the field because of physical obstacles such as trees, rivers and rock formations, and the difficulty of trying to maintain a straight line and searching for elephants simultaneously. However, unless the line of travel is defined in some manner, accurate measurements of perpendicular distances cannot be obtained. If the observer tends to walk towards the elephants when they are sighted, the perpendicular distance and sighting angle will be negatively biased and the density estimate positively biased.

It is important to consider the statistical design or the determination of the desired level of sampling effort and its allocation over both the study area and the duration of the study. Factors that affect the level of effort include the number of transect lines, the length of each line, the frequency With which each line is surveyed, and the number of observers or teams of observers that conduct the study. The placement of transect lines within the study area is critical. Transects can be placed systematically, randomly, or in a stratified design. The lines should not be too close together, nor should they overlap. Stratifying the study area by some feature such as habitat type is often done and may be useful under certain circumstances. However, a stratified design presents a potential pitfall. If each stratum contains a sufficient length of lines to provide a sample large enough to enable analysis of the data by stratum, no problems arise. However, if the effort per stratum is insufficient to analyse the distance data separately by stratum, the data will have to be pooled over several strata before analysis. Such pooling will lead to a biased estimator of average density, unless the total line length allocated to the strata is in proportion to the area of each stratum (Burnham et al. 1980).

The timing sequence must be considered in conducting a survey, including such major considerations as the time of the year for the survey and the assignment of observers to the replicate lines or repeats of transects. It also includes lesser considerations such as the starting and stopping time of observation during a single day and even the direction of travel. The main objective in these considerations is to avoid confounding any changes in density that may occur over time with the sequence in which the lines are surveyed.

6.3.4 Data analyses

The raw data collected in the field consists of sighting distances, sighting angles, group sizes, the number of groups of elephants and the number of transects walked. The field bearings should be converted to angles relative to the bearing of the transect. Because a group of elephants is treated as a single observation and the overall data analyses deal in terms of densities, the mean group size should be calculated. Then the data can be analysed using an appropriate computer programme such as TRANSECT (Burnham *et al* 1980), allowing the Fourier Series, Modified Hayne, Generalized Hayne and Hayne estimators to be used. There are several other computer programmes available for the analysis of line-transect data. However, to my knowledge, TRANSECT is the most user-friendly programme and it allows the use of these four different estimators.

As was stated earlier, if you have more than 40 observations of elephant groups you should use the Fourier Series estimator. With fewer observations, each of the remaining three estimators can be determined. A statistician will help you to establish which of the models generated by each of the estimators best fits your data (explains the most variance), and thus which model to use for your elephant density estimation.

6.3.5 Level of precision

In line-transect sampling, the sample size or the number of sightings of groups or individual animals determines the precision of the population density estimate, independent of the type of estimator used for the analysis (Jachmann 1992). The relationship between the number of sightings (S) and the coefficient of variance (CV) follows an orthogenal hyperbolic curve (Fig. 6.4) (see Chapter 5 - Box 5.1 for an explanation of

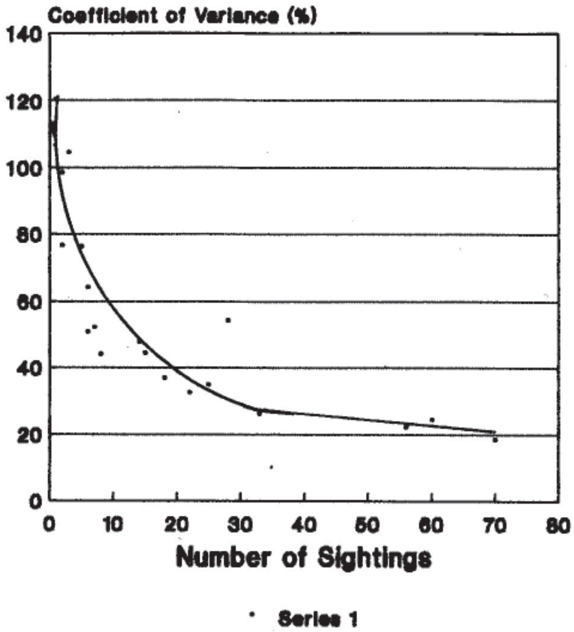

Fig. 6.4 The relationship between the number of sightings of groups and individuals of a species and the precision of the density estimate, (co-efficient of variance). The relationship is significant at P<0.001, and is independent of the type of estimator used for the analysis.

variance). The linear relationship is described by logCV = 2.08 - 0.40 logS and is significant at P < 0.001, (Fig. 6.5). With an increasing number of sightings, there is a quick initial drop in the coefficient of variance, up to about 30 sightings (Fig. 6.5). A further increase in the number of sightings results in only minor improvements in the level of precision (Fig. 6.5). Table 6.1 shows the number of sightings required for a certain level of precision.

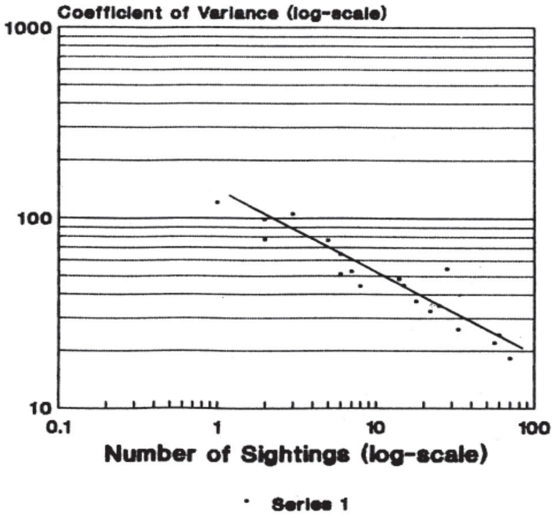

Fig. 6.5: The relationship between the number of sightings of groups and individuals of a species and the precision of the density estimate, (co-efficient of variance) on a log scale. The relationship is significant at P< 0.001, and is independent of the type of estimator used for the analysis.

Unless the elephant population is at an extremely high density, or the survey design allows a high percent coverage of the area, a coefficient of variance of less than 15% is very unlikely to be found in practice.

Co-efficient of Variance	Number of Sightings
0%	158,489
5%	2,818
10%	501
15%	178
20%	89
25%	50
30%	32
35%	22
40%	16
45%	12

Table 6.1: The desired level of precision of the density estimate and the required number of sightings of elephant groups during a line-transect survey (Jachmann, 1992).

6.4 GROUND COUNTS BY VEHICLE

The various techniques available for ground counts on foot, from the simple fixed-width belt method to the more elaborate line-transect method, can all be applied during a road count done using a vehicle.

There are two types of vehicle surveys. The first one is used in wide open country, where a series of straight lines can be travelled without being restricted to the existing infrastructure. This type of vehicle survey is essentially the same as transect counts on foot. The second type of vehicle survey uses the road network and may be open to considerable bias, because the road system is unlikely to be representative of an area. Roads tend to be constructed in scenic areas, along contours and rivers. Depending upon the season, elephants often tend to concentrate along rivers, and consequently road counts may produce over estimates. In some areas with a high level of human activity, elephants tend to be shy, avoiding the roads, which results in a low estimate. A good example of this, is the road count carried out in

March 1988 on the Nazinga Game Ranch in Burkina Faso (Jachmann 1988a, 1991). In Nazinga human disturbance meant that the elephants were shy and thus avoided the roads (Jachmann 1988b, 1989). The survey took approximately six days to complete and covered 267km of roads. Sighting angles and sighting distances were used to calculate the perpendicular distances. Twice the mean perpendicular distance was used as the transect width, and the 95% confidence limits were calculated by counting the same stretch of road a number of times and using the variance of the estimates as an approximation of the sample error (Burnham et al. 1980). The road count gave a population estimate of 293, about 20% lower than the aerial total count for that year (Table 6.2), which was considered a conservative estimate (Jachmann 1991).

While population estimates obtained through road counts may be biased, road counts may be the only practical method of censusing an area when the available survey budget is limited. A cost-benefit analysis showed that at the Nazinga Game Ranch, a single line-transect survey on foot was four to eight times more expensive than a road survey (Jachmann 1988a, 1991).

6.5 FIELD EXAMPLES

6.5.1 General

Two field examples of transect counts are presented: one from the Lupande Game Management Area in the central Luangwa Valley in Zambia (Jachmann 1992), and one from the Nazinga Game Ranch in Burkina Faso (Jachmann 1991). In both cases, multi-species counts were carried out using line-transect methodology to estimate animal densities and to determine the annual hunting quotas for selected species. However in these examples the results and discussion will be restricted to elephant population estimates.

6.5.2 The Lupande Game Management Area (GMA), Zambia

6.5.2.1 Layout of transects
In the survey block of the Lupande GMA (3,728km^2), a total of 41 transects were placed at 5km intervals, with a total length of 317.5km (four transects with a length of 10km and 37 transects with a length of 7.5km). The transects were covered twice in 1992, the first time in late July and the second time in late October (late dry season).

The layout of transects was more or less determined by the limited number of roads in the survey area. After finishing a transect, the team of observers had to cover the same distance back to the road. Transects were laid out in such a way as to allow a team of observers to be able to finish each transect within one morning. In spite of the above constraints, the number of transects, as well as the total length of transects, was chosen to give a more or less even distribution of transects over the survey area, with approximately 1km of transect for each 12km^2 of survey block. With the exception of a few transects in the north, all transects ran east-west or had a magnetic bearing of 900 or 2700. All transects were marked with a starter tag, showing a number that corresponded to the length and magnetic bearing of the transect.

6.5.2.2 Walking transects
The transects were surveyed by six teams, usually of three people each, consisting of a teamleader, a wildlife scout and a village scout. All transects were walked from 7.OOa.m. to 10.00a.m. Prior to the first survey, in July, all teams attended a three-day seminar to get acquainted with line-transect theory, distance estimation and the use of a compass, pedometer and range-finder. A compass was used to follow a straight line by sighting of landmarks on the line of travel as

Method of Surveying	Year	Population Estimate	95% C.I.	Estimator
Aerial Census	1989	366		Total Count
Foot Survey	1987	487	210-774	Fourier Series
Foot Survey	1988	306	0-952	Mod. Hayne
Vehicle Survey	1988	293	0-728	Perp. Distance

Table 6.2: Elephant population estimates in the Nazinga Game ranch, Burkina Faso (Jachmann 1991).

well as taking bearings to the object(s) relative to the transect line. In order to estimate the distance covered on the transect StepSets 400 pedometers were used. This equipment was calibrated every other day, over a 400m distance, automatically indicating personal step-length. It indicates the distance walked with a 25m precision, while a series of replicate lines showed an error of 5-10% for each of the pedometers used during the survey. On slopes, however, a rangefinder was used to determine the profile distance covered on the transect.

In relation to the straight line of the transect, the following information was recorded each time an animal/group was spotted:

- the species;
- the number of animals in the group;
- the distance to the animal from the observer; and
- the compass bearing of the animal, ensuring that all readings had been taken on the line of the transect.

6.5.2.3 Results

During the two foot surveys only 14 elephant groups were sighted, totaling 62 individuals, and giving a mean group size of 4.43. The population was estimated at 403±185(95% Confidence limits 22-783), using the Generalized Hayne estimator. An aerial sample survey, covering 6% of the Lupande area, gave a population estimate of 666 ± 258 (95% Confidence limits 160-1172), which is not significantly different from the estimate obtained through line-transect sampling.

6.5.3 The Nazinga Game Ranch, Burkina Faso

6.5.3.1 Layout of transects

On the Nazinga Game Ranch (1,000km^2), 30 transects with a total length of 562.1km were traversed. The transects ran from the south boundary to the north boundary of the ranch (a magnetic bearing of 1800). Each team was dropped off at the start of a transect and picked up at the end of it. This survey design could be used because of the extensive road network that provided easy access to the entire region. In 1987, three foot surveys were carried out during the first weeks of February. April and May (late dry season). In 1988, only one foot survey was carried out in April. All transects were marked with a starter tag as well as a tag at the end of each transect. Walking the transects was done in essentially the same way as in the Lupande area in Zambia.

6.5.3.2 Results

The data collected on the three foot surveys carried out in 1987 were combined to give an elephant population estimate of 487±277 (n=35), using the Fourier Series estimator to determine the population density (Table 6.2). The single foot survey carried out in 1988 gave a population estimate of 306±646 (n=7), using the Modified Hayne estimator (Table 6.2). The combined estimate for 1987 is 33% higher than the result of the aerial census (100% coverage) carried out in 1989 (Table 6.2). The single foot survey, carried out in 1988, gave an estimate that was 16% lower than the result of the 1989 aerial census. The larger sample size of the combined surveys gave a higher degree of precision compared to the single foot survey, but the estimate from the single foot survey was more accurate (Table 6.2).

6.5.4 Discussion and conclusions

Both the survey designs in Nazinga and Lupande used permanent transects that were covered three times and two times a year respectively, to increase the number of sightings and thus the precision of the final estimates (this does not include the single foot survey carried out in Nazinga in 1988). There were, however, two major differences between the two survey designs: first, in Nazinga, the percent coverage was roughly six times higher than in the Lupande GMA and second, the infrastructure in Nazinga allowed the length of each transect to be determined exactly, whereas the use of pedometers in the Lupande area introduced an error of at least 5-10% in the estimate of the length of each transect. In addition, elephant densities in Nazinga were roughly three times higher than those in the Lupande area. Consequently, one would expect the population estimate obtained at Nazinga to be more precise (or have a narrower confidence interval) than that obtained in the Lupande GMA. This, however, was not the case! The population estimate from Nazinga gave a standard error of 57% with 35 elephant groups detected, whereas the population estimate from Lupande gave a standard error of 46% with only 14 elephant groups detected. The explanation is that at Nazinga, during most of the dry season, the entire elephant population is compressed into an area of less than 400km^2 (Jachmann 1989). In practice this means that during the foot surveys elephants were observed in only a few of the 30 transects covered, resulting in a population estimate with wide confidence intervals (low level of precision). What did we learn from this? If the survey in Nazinga was designed exclusively to count elephants, the appropriate thing to do was to stratify or divide the area into areas of high elephant density and low elephant density, using the detailed information available on seasonal elephant distribution (Jachmann 1988b, 1989). The placing of transects in the resulting two strata should have been proportional to the elephant density (i.e., more transects in the high density area), considerably reducing the variance and therefore the confidence limits of the final estimate. In the Lupande area, however, elephants were more or less evenly distributed over the entire survey block and, if the aim of the survey had been to count elephants only, it would have been needless to stratify the area.

When determining the statistical design of a line-transect study, (e.g. the desired level of sampling effort and its allocation over the study area as well as the duration of the study), in theory, we should carefully establish the number of transects required, the length of each transect, the placement of transects, and the frequency with which they should be surveyed. In practice, however, the available survey budget appears to be the single most important factor determining the survey design. In the Lupande GMA for instance, a coefficient of variance of 25% is realisable for some of the more common species, but not for the estimation of elephant densities. Elephants occur at such low densities that a survey designed to obtain a coefficient of variance of 25% would require at least 50 observations. This would be very labour intensive and, above all, extremely expensive. For the Lupande GMA, the cost of a single survey is approximately US$2,500. The elephant population estimates were derived from the data collected during two surveys, with a total cost of approximately US$5,000. If we set the acceptable level of precision at 25% (CV), we would need roughly four times the coverage of our previous two surveys, at a total expense of about US$20,000. Hence, the principle is to maintain a balance between the precision required for management purposes and the amount of labour, time and total costs involved to complete the exercise.

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SECTION 3

STUDYING POPULATIONS

CHAPTER 7

GETTING TO KNOW A POPULATION

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7.1 INTRODUCTION

For anyone starting out to study an elephant population an essential question has to be asked first: what is the topic of study, or in other words, what does the researcher want to find out about these particular elephants? The answer will determine how well one has to *know* the population. If the goal is to find out how many elephants there are in a given area, or to find out how many and what their range is, or to find out the numbers, range, and what habitats they use within that range, or even the numbers, range, habitat use and feeding preferences, then the researcher might set out to study the elephants with methods involving aerial counts, radio tracking, ground transects and direct observation of feeding elephants. If, however, in addition to, or instead of, the above objectives, the researcher wants to describe the social structure, behaviour and demography of the study animals then he or she would have to get to know the members of the population on an individual basis.

Individual recognition can be an important tool in any elephant study, and in this chapter I will cover the methods used to identify and catalogue individuals. But there are additional ways of knowing elephants and I will also discuss the techniques I have used for collecting a variety of data on individuals and groups of elephants.

7.2 FIRST STEPS IN KNOWING A POPULATION

7.2.1 How to find elephants

Wherever your study area is, the best place to begin is with the local people, that is either with the people living in the area or, if it is a national park or reserve, with the wardens and rangers. Find out where elephants have been sighted, what trails they use, what drinking spots are favoured. Also ask people where they have seen elephant dung. Try to get an idea of the elephants' daily movement patterns so that you will know where to expect to find them in the morning, midday and evening.

If there have been any aerial counts carried out of your study animals, try to get copies of the maps with the sightings and numbers indicated. These data will tell you for each count where elephants were seen on one day in one year under particular environmental conditions. But don't expect the elephants to be in the same places when you set out. It is important to realise that elephants are very flexible in their behaviour; it is virtually impossible to say, "the elephants always come to such and such place at a particular time". However, elephants are water-dependent, which in their case means that they have to drink, at the very least, every third day, but much more commonly, they drink every day. This water dependence can be a great aid to researchers, especially if water is restricted to only a few places in the study area. Find out where the water holes, springs, rivers, swamps, bore holes, wells, etc. are. If there are signs (dung, footprints) that elephants have used particular water sources, then start looking for your elephants in these areas.

7.2.2 How to approach elephants

Once you begin to get an idea of where the elephants can be found, the next step is approaching and observing them. This stage of the study is going to differ widely depending on the history of the elephants in the area and the habitat. The range of situations in Africa is extreme: from highly habituated elephants living in open, accessible terrain to very wary elephants living in thick forest.

In the case of forest elephants, it will most likely be impossible to approach and observe them in the forest itself. Rather, it is better to let them approach you. To do this a hide or blind can be set up in a clearing that elephants are known to frequent, say one where they obtain salt. For savanna elephants the logistics are usually less difficult and there are more choices.

Depending on the status of the study area, there will be various ways to try to get near elephants living in non-forest habitats. If the research is being conducted in a national park with tourists present, you will probably be more or less restricted to a vehicle. On private land or communal land, research could be carried out on foot, but being on the ground is not necessarily an advantage. It can be dangerous, and you don't have the benefit of height. An alternative could be to carry out some of the study from camel or horseback.

Whatever form of transport you use, there are certain rules of approach which apply under almost all conditions. Elephants have mediocre eyesight, but good hearing and an excellent sense of smell. In most cases wind direction will be an important element. Except with the most habituated elephants in national parks, it will be best to approach the elephants with the wind coming from the elephants to you, that is downwind from them. If you are using a vehicle in an area where elephants run away at the sound of an engine, you will probably have to leave the vehicle some distance from the elephants and proceed on foot. In this case, you should have an experienced tracker or guide with you. Remember, elephants can move very fast; and if you are working in an area where they have been hunted, poached, or harassed they are more likely to charge.

Let us assume for the moment that the elephants under study live in some sort of protected area and are partially habituated to vehicles. One of your aims is to have them get more and more used to you as your research progresses so that eventually you will be able to observe undisturbed elephants. The first months of your study will be important in establishing your relationship with your study animals. The key is to be as non-threatening as possible. Try to follow these important rules:

i) Always approach elephants very slowly.

ii) Do not try to get too close; as soon as the elephants start to turn or move away, stop and turn off your engine.

iii) Do not approach elephants from behind their movement or behind their direction of orientation.

iv) Whenever possible, make a large detour around a group and approach the elephants from an angle or head on or, better yet, stop and let them come to you.

If you consistently approach elephants in this way they will gradually get accustomed to having you around and will soon realise that it is not worth the effort of moving away.

In areas where elephants are prone to charging vehicles rather than running away, it is still important to use the above guidelines. In most cases I would suggest holding your ground when an elephant charges, especially if the elephant has displayed indecision by shuffling backwards or forwards or vocalising before it actually charges. The exception is with a bull in musth (see Chapter 1) who might go through a whole set of demonstrations before charging. He may or may not follow through, but it is definitely best not to wait and find out. In a serious charge, an elephant simply puts its head down and attacks with no hesitation and often with no vocalisation. If the elephant is coming at you at full speed in what appears to be a serious charge, one technique to try to stop it is to reach your hand out the window and bang the side of the door, making as loud and sharp a sound as you can. This is a method taught to me by lain Douglas-Hamilton who has had a great deal of experience with charging elephants. For me it has worked every time. However, "discretion is the better part of valour" until you are very familiar with the elephants you are studying.

Once again, depending on the goals of your study, at the beginning it is worth weighing the pros and cons of using intrusive, disturbing methods to collect data, such as darting and immobilising members of family groups for radio-collaring or taking blood samples. If you are not trying to habituate your study animals then there is no problem with using these methods, but if you are trying to gain the confidence of the elephants, you might find yourself erasing all the patient work you have carried out by suddenly changing your behaviour in attempting to dart them. Elephants definitely have very long memories and one bad experience can make them wary of vehicles or even of individual researchers for years after.

7.3 COLLECTING INFORMATION

7.3.1 Baseline data

From the very first day of your study you can start collecting data on the elephants, even those that are running away from you. In order to conform with other studies which are being carried out, I recommend collecting certain baseline data on every group or single individual that you encounter. In this way, the same information can be compared and contrasted for elephants across Africa.

The baseline data are:

i) Date, Time
ii) Place
iii) Habitat type
iv) Activity
v) Number in the group
vi) Type of group (bull, cow/calf, mixed)

The date and time need no explanation. For place you will have to decide how refined you want the sighting record. In Amboseli we use grid squares of 1km^2. The habitat type will depend on the study area, but there are broad guidelines for Africa (see Pratt *et* al. 1966). As soon as a group is sighted, note the activity that the majority of elephants in the group are exhibiting. In Amboseli we distinguish eight activities: moving while feeding, feeding, resting, comfort behaviour (dusting, scratching, mudwallowing, etc.), interacting, drinking, walking, standing, if there is no majority activity we code for that. These activities are used for general sightings. In behavioural studies more categories would be used and the above eight would be broken down (See Chapter 10).

The final two categories of baseline data, number in the group and type of group may sound straightforward but there are actually some problems and pitfalls in obtaining accurate information.

7.3.2 Counting elephants

Elephants are surprisingly difficult to count from the ground, even in open areas with good visibility. One would think that such large animals would be easy to count but it is their very size that causes the problem. The big ones block the observer's view of the small and middle-sized ones. When elephants are moving in a clump it is virtually impossible to get an accurate count. Even after 26 years of experience if I try to count a clumped group of over 10 elephants I will get three different totals if I count the group three times in a row.

Of course, you can get an approximation of how many are in the group by counting several times, but in order to get an exact count you will have to wait until the group is spread out. The easiest group to count is one that is moving in single file. The next easiest is a group that is feeding. A resting group is difficult to count because small calves get lost in the middle.

Whenever possible, watching elephants from a slight rise or better yet from a hill is a great help. One other aid is to wait for a group to cross a road and then count each individual as it crosses. However, if the group is moving fast and two or three are crossing at once, it will be difficult to get an exact count. When collecting data on group numbers it is best to have a qualifying code which indicates how accurate the count is. (In Amboseli we use: 0 = no count; 1 = poor or partial; 2 = good estimate; 3 = exact.) In this way when you come to analyse your data you will be able to take the quality of the count into consideration.

One further problem which may arise in counting groups of elephants is trying to decide what a group is, in other words where the group begins and ends. This question may arise when there is a loose aggregation of elephants spread over an area. It may be difficult to decide if there is one large group present or two or three smaller groups. The definition of group that I use is: "any number of elephants moving together with no individual farther away than the distance that is equal to the diameter of the co-ordinated body of the group at its greatest point" (Moss 1983).

7.3.3 Group Type and Composition

Elephants are basically found in three types of groups: 1) all male groups, 2) cow/calf groups, and 3) mixed groups (which are cow/calf groups with adult males present). Despite the fact that there is discernible sexual dimorphism in adult elephants, many people find it difficult to distinguish males from females.

Before you even try to look at the elephant's physical characteristics, there are some clues which will help you. Females are only very, very rarely found on their own. Therefore, if you come upon a single animal it is very likely to be a male. Second, cow/calf groups are made up of animals of different sizes from tiny calves standing only 85cm at the shoulder to large adult females standing up to 270cm. If you encounter a group that is fairly uniform in size with no small animals, it is probably all-male. Needless to say, you will have to confirm the sex and age composition before you record the type of group.

7.4 DETERMINING SEX AND AGE

7.4.1 Sexing elephants

Adult elephants are strikingly sexually dimorphic in body size. Both male and female elephants grow throughout their lifetime but female growth levels off at around 25 years of age while male growth continues steadily (Laws & Parker 1968). By age 50 a male might be 330cm to 360cm at the shoulder and weigh six or seven tons. Females rarely reach more than 270cm at the shoulder and may weigh approximately three tons at the same age. This difference in body size can be a useful aid in determining sex for the older adults.

In addition, male tusk shape and weight is different from females. Males have much thicker and more tapering tusks than females whose tusks tend to be uniform in circumference until the tip. But more obvious is the size of male tusks compared to that of females. The largest male tusks ever recorded were 100.8kg each; the largest females tusks were only 29.7kg each.

A further difference in appearance between males and females is in head shape. Males have rounded heads which are broader between the eyes. Females tend to have pointed heads and the area between the eyes is narrower (Fig 7.1a). These characteristics are distinguishable even in calves.

Just as in any other mammal, the final arbiter of determining sex is the external reproductive organs. The problem with elephants is that the genitals are not easily visible under most

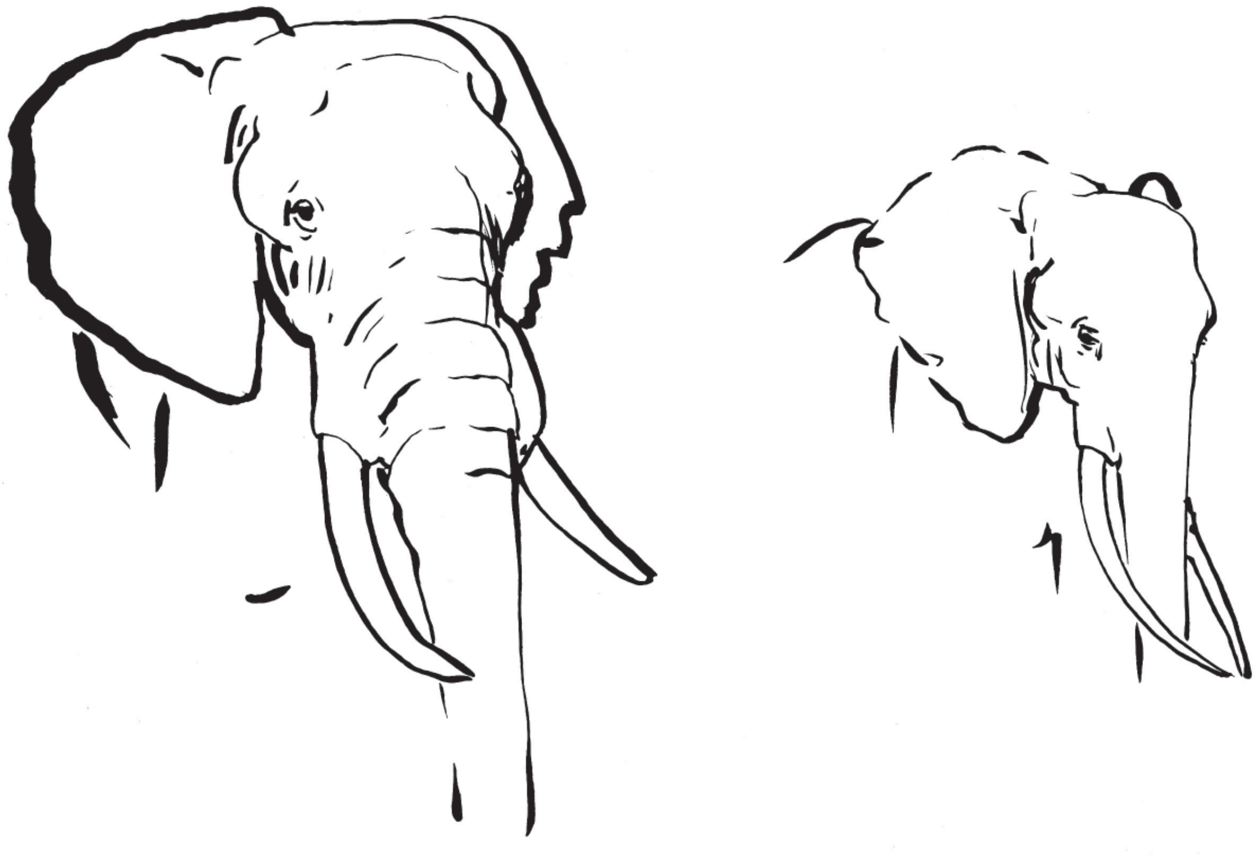


Fig. 7.1a: Male (left) and female (right) head shape differences: male is broader between the eyes and forehead slopes; female is narrow between the eyes and tusks, and forehead forms a sharper angle.

circumstances and in most habitats. A male elephant has no external testicles and the penis is enclosed in a sheath (Fig 7.Ib). The female elephant's vulva hangs low between the hind legs with the opening facing the ground unlike most ungulates whose vulva is just below the anus.

Even when elephants are in short grass and their whole bodies are visible, it is not always easy to view the genitals because they are hidden by the legs for much of the time. The best way to see the genitals clearly is from behind. The male has a ridge which runs down from the anus and in between the hind legs, emerging as the end of the sheath just in front of the hind legs. The female has folds which end in the squared off opening of the vulva (Fig. 7.2). When an elephant urinates it is usually obvious which sex it is, but sometimes the clitoris of a female calf can be mistaken for a penis.

Adult females can also be distinguished by their mammary glands or breasts which are located between their front legs. An elephant has two

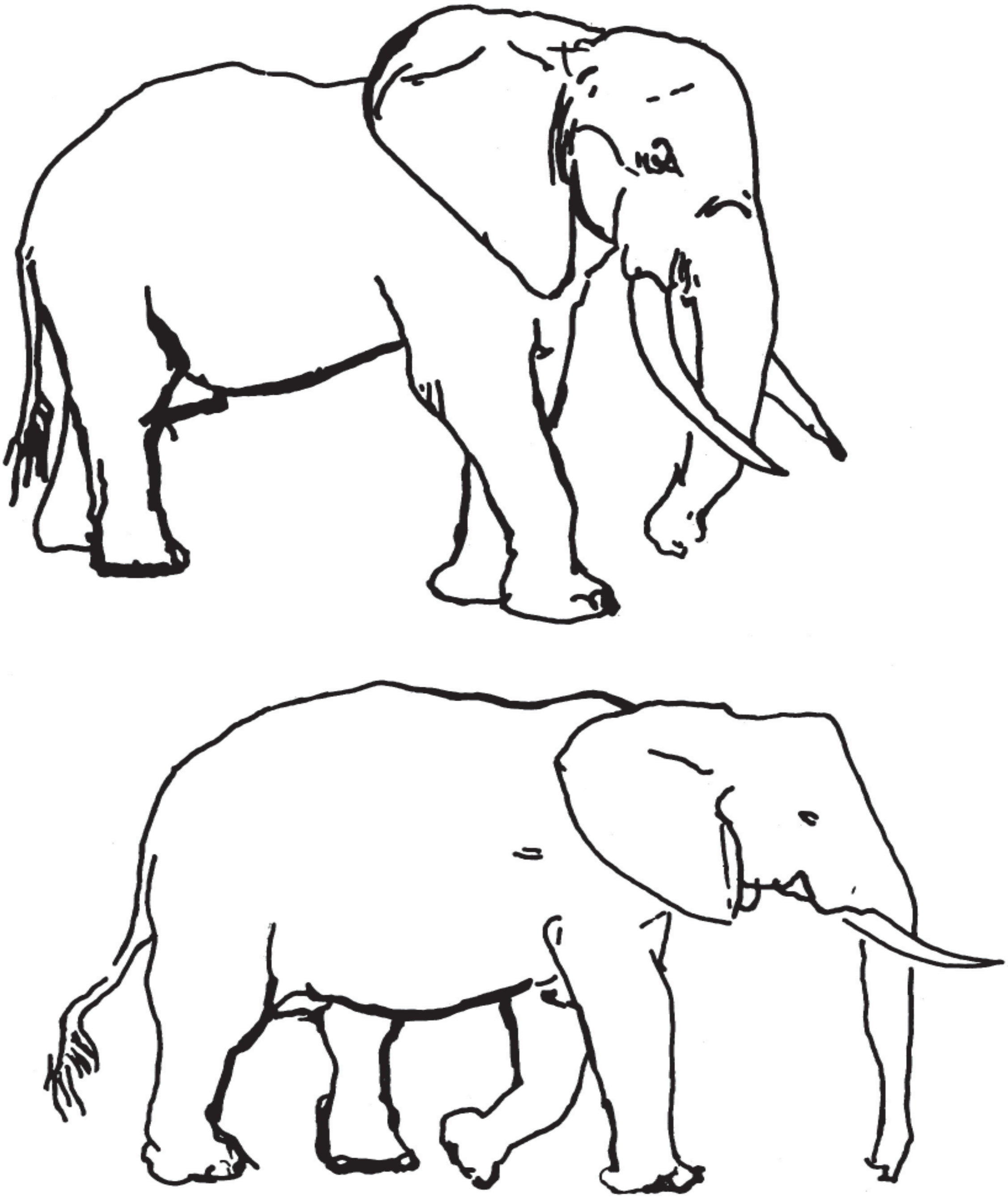


Fig. 7.1b Male (above) and female (below) body shape differences: male underside slopes up towards front legs, penis sheath visible; female underside more parallel to ground, breasts on adults visible.

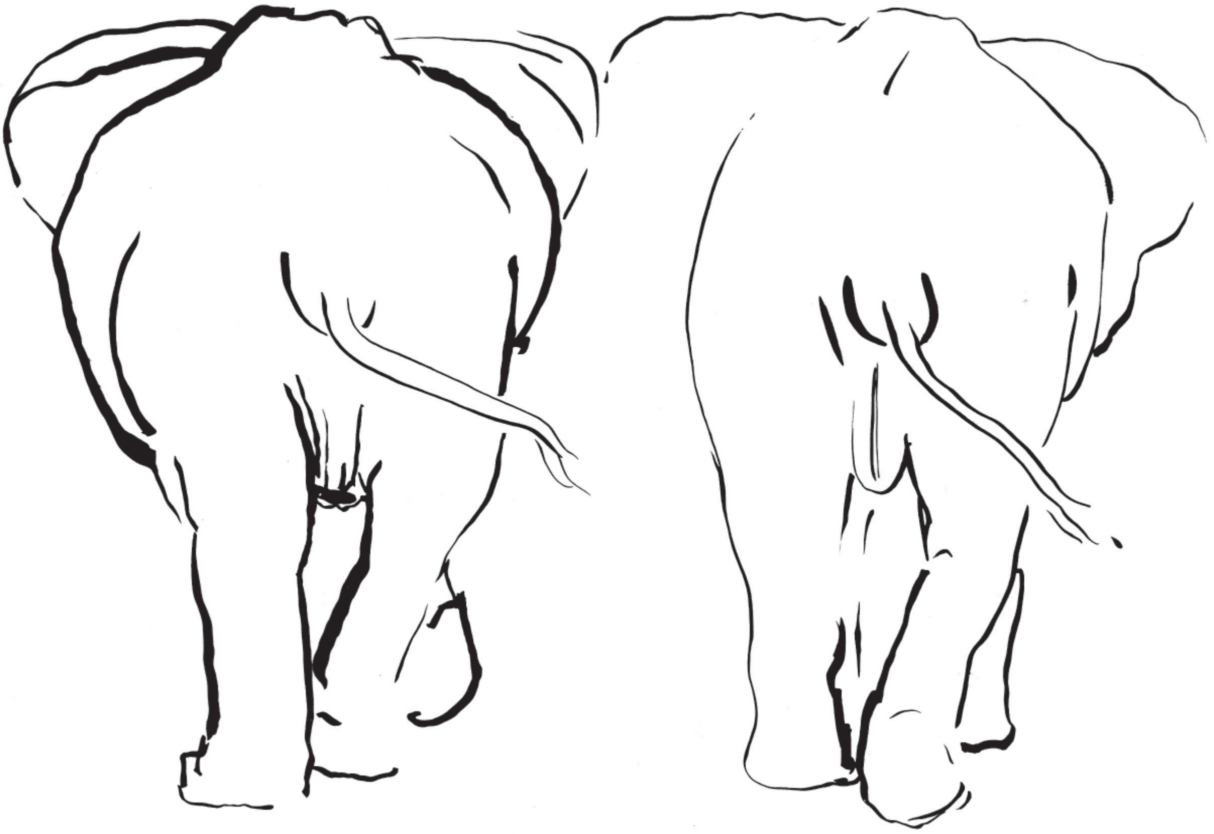


Fig. 7.2: Female (left) and male (right) from behind: female vulva squared off with opening facing ground, folds of skin from tail down to opening male has ridge that extends from below tail down in between the legs and forms sheath with opening facing forward. Note also that female body shape is more rounded and sides often extend beyond pelvis while male has a narrower shape.

breasts, each with one nipple. Male and female breasts look the same until a female becomes pregnant for the first time. Then the breasts begin to swell and grow and once a female has had a calf she will always have some breast development even when she is not suckling a calf.

7.4.2 Ageing free-ranging elephants

There are several methods for ageing elephants, ranging from recording the births of individuals and thus absolutely knowing their age to rough estimates based on general appearance. Once again the type of study that is being planned will determine what methods will be used. For example, the Amboseli Elephant Research Project was always intended to be a long-term project with the goal of following the life history of each animal. By the beginning of 1994 there were over 537 known-aged elephants in a population of 832, ranging from newborn calves to animals 22 years old.

Birth registration along with individual recognition is the most accurate method of collecting demography data, but it will usually be important to estimate the age structure of the population in a time span of less than 30 or 40 years! Luckily for elephant researchers there are other methods available.

Because elephants grow throughout their lifetime, the larger an elephant is, the older it is. Age estimates can be made based on shoulder height (Laws *et al.* 1975; Lee & Moss 1995), back length (Laws 1969; Croze 1972) and footprint length (Western et al. 1983; Lee & Moss 1986; Lee &Moss 1995). Methods of measuring these parameters on live elephants can be found in the papers cited. Dead or immobilised elephants, of course, can be measured on the ground (see Chapter 18).

Another method of ageing a dead elephant is by its teeth. During an elephant's lifetime it acquires six sets of molars, each of which comes in at a certain age and wears down at a certain rate (See

BOX 7.1: ESTIMATING THE AGE OF ELEPHANTS USING MOLAR EVALUATION TECHNIQUES

The age of an elephant can be determined by observing the stage of molar progression. Elephants develop six molars in each quadrant of their jaws during their lifetime. Each erupts at a certain age and wears at a particular rate. Two techniques have been developed for using molars to age elephants. Laws (1966) had used tooth eruption and wear to establish thrity age classes, while Sikes (1968) has used the number of lamellae or ridges on the tooth that disappear in the process of wear.

Discrepancies in both methods have been pointed out by Jachmann (1988), who highlights the problems of the use of these molar evaluation techniques for ageing adolescent and mid-adult age classes, as well as the problem of variation between populations. Jachmann (1988) goes on to make some adjustments to Laws' age classes, and stresses that the measurements of the length and width of a molar is sufficient to identify the correct molar number.

The method presented here is adapted from Laws' method of ageing elephants using molars, and incorporates the adjustments made by Jachmann (1988).

On finding the jaw of a dead elephant or in an immobilisation operation one should determine the number of molars that are present in the lower jaw of the elephant. One should then measure the length and width of the molar closest to the front of the mouth using calipers (see Fig. 7.3). Compare the measurement of the tooth to those in Table 7.1 to identify the tooth as either M1, M2, M3, M4, M5 or M6.

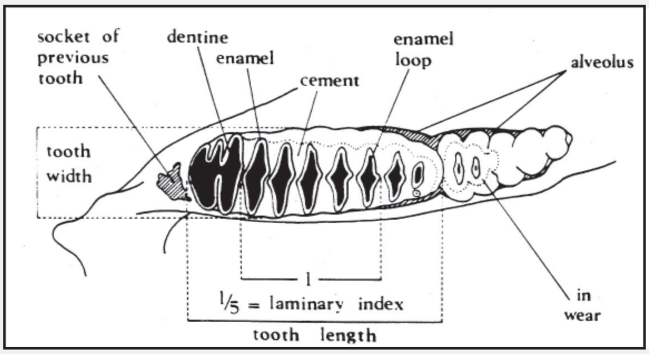


Fig. 7.3: Diagram illustrating tooth measurements and terms (Source: Laws 1966).

Molar number	Molar length (cm.)	Molar width (cm.)
M1	1.0 - 4.0	1.3 - 2.0
M2	5,0 - 7.0	2.5 - 4.0
M3	9.5 - 14.0	3.9 - 5.2
M4	13.0 - 17.5	5.0 - 6.8
M5	17.5 - 22.5	5.9 - 8.5
M6	22.0 - 31.0	6.4 - 9.4

- If the molar length you measure falls into two molar number classes, (for example between M3 and M4 or between M5 and M6) then the molar width should be used to identify the correct molar number.
- If the molar width you measure falls between two molar number classes, then the molar length should be usedtoidentify the correct molar number.
- If both molar width and molar length fall between two molar classes, then the molar should belong to the molar class whose maximum width or length dimensions are closest to the measured dimensions.

Having assigned the molar to one of these molar numbers, the identified molar should be examined for the extent of eruption and degree of wear. One should determine whether there were any previous teeth lost by looking for empty socket of the previous tooth. Using the group classes describes in Table 7.2 one can then determine the age of the elephant.

Table 7.1: Molar length and width for molar numbers one through six (Manspeizer & Delelegn 1992).

Group Class	Mean Age	Description
Group I	0	No teeth worn, M1 protruding above bone; M2 lamellae fused; M3 forming.
Group II	0.5	Slight wear, M1 and M3 protruding above bone; M3 forming.
Group	1	M1 well worn showing lozenges (anterior root eroded); M2 moderate wear showing III lozenges; M3 above bone, may be showing slight wear.
Group IV	2+0.5	M1 lost, and no socket showing; M2 well worn, first two enamel loops may be confluent; M3 Worn to enamel of first two lamellae.
Group V	3+0.5	M2 well worn, anterior few lamellae lost; M3 well into wear, 5-6 enamel loops showing; M4 Still within alveolus (see Fig 7.3).
Group VI	4+1	M2 well worn, only 1-3 enamel loops remaining; M3 all except last lamella in wear: M4 well Formed lamellae visible in alveolus, but unfused.
Group VII	6+1	M2 Lost; M3 all lamellae in wear; M4 lamellae fused, first 4-5 lamellae in wear showing above bone, first 1-2 at gum level (stained), none in wear.
Group VIII	8+1	M3 first 2-3 lamellae loops confluent, anterior edge of tooth eroding; M4 alveolus not open.
Group IX	10+1	5 enamel loops of M4 showing. Socket of previous tooth in the anterior part of the M4 tooth visible.Second from last enamel loop on lamellae just starting to open. Alveoli of M5 visible behind M4.
Group X	12+1	M4 well worn in the anterior parts with the exception of lost lamellae beginning to wear. M5 formed but fused without any wear.
Group XI	14+1	M4 well worn on all the lamellae. M5 lamella just starting to open with little wear on first two enamel loops. First four lamellae visible and fused on M5.
Group XII	16+1	Anterior edge of M4 eroded. Anterior 2-3 enamel loops confluent. M5 anterior lamellae fused and 5-6 visible. First 1-3 lamellae at gun level or just in wear.
Group XIII	18+1	M4 eroded and anterior few lamellae confluent. Enamel loops confluent. M5 anterior lamellae visible (6-7). First 3-4 in wear and showing enamel loops.
Group XIV	20+1	M4 highly eroded and only two loops showing. The first enamel loop is confluent with the second. M5 with 4-5 enamel loops visible. Last lamellae barely starting to wear.
Group XV	22+1	M4 not visible; only socket seen. M5 first two enamel loops confluent. Five enamel loops visible on M5. Last lamellae barely showing wear.
Group XVI	24+2	M5 anterior part highly eroded. Third enamel loop beginning to form confluence with second loop. Six fully developed enamel loops visible. Last amellae showing wear. M6 alveolus visible.
Group XVII	26+2	M5 last 7 enamel loops fully developed and visible. Enamel loops 4-6 confluent. M6 lamellae fused and visible. M6 lamellae not in wear. Alveoli of M6 present.

Group XVIII	30+2	M5 last 6 enamel loops eroded. Anterior part highly eroded and confluent. M6 a nterior 1-2 lamellae showing signs of wear. Rest of lamellae fused. Alveoli of M6 present but being closed out by M6 lamellae.
Group XIX	32+2	M5 erosion of anterior border, a few anterior lamellae are confluent and project as a shelf or have broken off; M6 first 2-3 lamellae in wear, one or more enamel loops showing.
Group XX	34+2	M5 nearly th same as in Group XIX; M6 has 3-4 enamel loops complete.
Group XXI	36+2	M5 only 5-6 enamel loops left; erosion of posterior border may have commenced; M6 had 5-6 enamel loops complete.
Group XXII	39+2	M5 socket only for 2-3 enamel loops remain; M6 has 8-9 enamel loops complete; no erosion of anterior border. This and subsequent groups show no further development of alveoli.
Group XXIII	43+2	M5 only socket remains; M6 last 2-3 lamellae not in wear, erosion of anterior border has begun.
Group XXIV	45+2	M5 usually vestige of socket; M6 all except last lamellae in wear.
Group XXV	47+2	M6 erosion of anterior border, first 3-4 enamel loops confluent.
Group XXVI	49+2	M6 erosion of anterior border, first 3-4 enamel loops remain.
Group XVII	53+2	M6 anterior third of tooth missing, 6 complete enamel loops remain.
Group XVIII	55+4	M6 has only 4 complete enamel loops remaining.
Group XXIX	57+ 4	M6 has 6 or less enamel loops remaining, all but 1 or 2 are confluent.
Group XXX	60+4	M6 less than about 15 cm of tooth remains rooted; remainder broken off or projecting as a shell; all remaining enamel loops are confluent.

Adapted from Laws (1966) and Jachmann (1988) by Manspeizer & Delellegn (1992).

Table 7.2: Age group classes of the African elephant as defined by molar wear

Box 7.1 and Laws 1966). By examining the lower jaw for tooth eruption and wear, an age can be assigned to the elephant at death. Sometimes an immobilised elephant's teeth can be examined but this would not be a feasible method of getting an overall age structure for a population.

For those Situations in which measurements cannot be taken, elephants can be assigned ages by visual assessment. With experience it is possible to estimate the ages of elephants by using a combination of characteristics such as size, physical development, eruption of tusks, the length and circumference of tusks, and body shape and proportions (See Box 7.2 for guidelines). Calves up to 10 years old are easy to age to ± one year, and elephants 10-20 years old can usually be assigned an age to ± two years. Individuals 20 years and older are more difficult to age by eye, particularly females. Since males continue to grow in shoulder height and weight throughout their lifetime it is not difficult with experience to distinguish a 25-year-old from a 35-year-old, or a

BOX 7.2: GUIDE TO AGEING

ZERO TO 10 YEARS OLD (MALES AND FEMALES)

The calf sizes given below are relative to an adult female between 25 and 45 years old with a should height of about 250cm. Allowances have to be made for claves with younger or older mothers.

AGE	SHOULDER HEIGHT	DEVELOPMENT
Newborn	Top of shoulder reaches lower Wrinkles below mother'selbow'; can easily walk beneath her back.	Thin, stiff-legged; sometimes part of umbilical cord attached; whites of eyes often red; backs of ears bright pink; often hairy on head and
2-3 weeks	Same as above.	Walking well' more filled out in body' backs of ears no longer pink; trunk is short and slender but exploring, picking up sticks.
3-4 months	Reaches to below point of mother's elbow.	More rounded, fatter, begins trying to feed on grass; spends time away from mother, plays with other calves.
8-9 months	Reaches elbow; can still pass under mother but probably scraping.	Feeding adeptly and continuously for long stretches; capable of drinking with trunk.
1 year	Shoulder taller than breast level of mother, reaching to wrinkles above elbow.	Head and ears look in proportion to each other and body.
1-2 years	Top of shoulder midway between elbow and junction of leg withtorso, the "armpit".	Trunk looks more in proportion; tusks of male calves may show beyond the lip from 18 months on (depending on region of (Africa).
2-3 years	Reaches mother's armpit.	Tusks of most male calves and many female calves will show; mother may show signs of trying to wean calf.
3-4 years	Top of shoulder above mother's armpit; backalmost level with anal flap and reacheslower quarter of mother's ear.	Almost all calves will show at least 5-7 cm of tusks; most calves still suckling, but some may be weaned.
4-5 years	Reaches mother's anal flap or above.	Tusks are 15-18cm long; has probably Stopped suckling and may have a younger sibling.
5-6 years	Appears to be about one-quarter the size of an adult female' back almost level with middle of mother's ear.	Tusks area bout 20-23cm long; has probably male and female behaviour become more pronounced: female calves allomother younger calves; male calves seek out other males for sparring.
6-7 years	Shoulder and back height above base of mother's tail and above middle of ear.	Tusks begin to splay out in both males and females; sexual differences discernable: males have thicker tusks and heavier bodies.
7-8 years	Back level with adult female's eye and well above base of tail.	Tusks are usually splayed by now; no longer Look calf-like, but more like a small adult.
8-9 years	Overall size in height and length over half an adult female.	Tusks are about 25-30cm.
9-10 years	Overall size almost three quarters of an adult female.	Males are larger than females of same age And spend more time on periphery of family; females are more integrated in family.

10 AND ABOVE – SUGGESTED AGE CLASSES FOR FEMALES.

10-15 years	Thin tusks, probably still splayed rather than convergent; more square in body shape than older females who are rectangular.
15-20 years	Tusks begin to take on their adult configuration, that is convergent, straight, or asymmetrical with one higher than the other.
20-35 years	Circumference of tusks at base distinctly bigger than teenaged females.
35-50 years	Tusks marginally thicker; back has lengthened so that animal appears long in body.
Over 50 years	Hollow above the eyes, ears held lower, longer back length, sometimes long tusks.

10 AND ABOVE – SUGGESTED AGE CLASSES FOR MALES

10-15 years	Male head shape (sloping rather than angular) more noticeable; tusk circumference and should height greater than females of same age.
15-20 years	At about 17 years old males reach same height as largest adult females over 40.
20-25 years	Taller than all adult females; but most still slender and narrow in the head compared to older males.
25-40 years	At about 25 years old male head shape has changed to an hour glass shape, that is wide at eyes and wide at base of tusks; the head gets broader as it moves through this age class; shoulder height increases steadily.
Over 40 years	Very big, tower over largest females by three feet or more at shoulder; neck thick; overall body heavy set; tusk circumference at lip strikingly greater than younger males and all females.

35-year-old from a 50-year-old. In addition, not only does a bull continue to grow in shoulder height and in tusk circumference but his head gets larger across the forehead and at the base of the tusks, giving the head a more hour-glass appearance from a front view as he gets older (Poole 1989). Other characteristics such as the size of the head in relation to the body and the thickness of the neck and trunk can also be used as indicators of age in males.

Females continue to grow slightly in shoulder height throughout their life but this is barely perceptible. (Laws & Parker 1968). However,females' back length increases with age and this dimension has been used as a guide in estimating age (Laws 1969; Croze 1972). In addition, tusk circumference and length increase as females get older. Overall appearance is also an aid. Older females get bonier around the shoulders and head, and the tops of their ears fold down more and appear to be positioned lower in relation to the head and shoulders than those of younger females (Moss 1988).

In Amboseli we have assigned each animal a known or estimated year of birth. For purposes of analysis we have used the following age classes:

0A	0-4.9 years
0B	5-9.9
1A	10-14.9
1B	15-19.9
2	20-24.9
3	25-34.9
4	35-49.9
5	50+

For surveys in other areas and for workers trying to attain an age structure for shorter term studies, I suggest using five-year age classes up to 20 and above that age using 15-year classes. Thus Class 2 would become 20-34.9, Class 3,35-49.9 and Class 4,50+.

7.5 INDIVIDUAL RECOGNITION

7.5.1 Why use individual recognition?

There are many aspects of elephant ecology and behaviour that would be difficult or simply impossible to study without knowing individuals. Let’s take some examples. *Say* you wanted to understand the distribution and association patterns of elephants over a given range. You could go out on your first day and start recording numbers and locations of elephants at various places and times. The first group you sighted might consist of 12 animals feeding in quadrat A-5. The second day you might to see a group of 12 in A-5 again, but you could not say if they were the same 12 animals, or whether five were the same and seven were different. Without knowing individuals, you could not begin to collect data which would show either consistency or fluidity in group composition, nor could you say anything about the ranging patterns of individuals or groups.

Now say you are studying social behaviour. What could you record about the behaviour of those 12 animals in the group you saw on Day l other than that they were in a group of a certain size and that they exhibited certain behaviours which you observed. In order to say something about who was affiliated with whom or who was dominant to whom, you would have to know them as individuals. Then you could carry out the kinds of studies described in Chapter 10.

If the purpose of your study is to track the population’s demography over time, there is no better way to get a complete and accurate picture than collecting data on birth rates, mortalities, interbirth intervals, age at sexual maturity, etc. for known individuals.

7.5.2 When is it appropriate to use individual recognition as a technique?

It is all well and good to explain why knowing individuals is important, but it is not always practical to attempt to do so. If the study population is very large, say over 2,000, then it would be very difficult to try to get to know every individual. In some cases it might be better to learn to identify just the adults or maybe just one or two adults from each family unit and maybe only the large adult bulls. Then too, if the habitat is a difficult one in which to observe elephants, such as forest or thick bush, it might not be worthwhile to try to use the recognition method.

When designing your study questions and topics, it will be important to be realistic about what you can and cannot do under the particular conditions in your study site. If individual recognition is feasible and it will help you answer some of your questions then it is definitely worthwhile.

7.5.3 What makes an elephant identifiable?

No two elephants are alike, and once a researcher starts watching elephants and trying to distinguish one from another, he or she will begin to see the variety of individual characteristics: size and shape of the body and tusks, posture and way of moving, relative proportions (i.e. long legs, big head, small ears, etc.). Eventually one can recognise an elephant in the same way that one recognises a friend walking away on the other side of a Street. However, an absolutely positive means of identification is necessary as well as this more generalized “gestalt” recognition.

lain Douglas-Hamilton (1972) pioneered a reliable method of recognising individual elephants by their ears, and this method is now widely used in elephant studies throughout Africa. The patterns on the ears make each elephant unique and actually very easy to recognise. Elephants usually have holes, nicks, and tears on the edges of the ears. In addition, the veins in the ears are often prominent and the pattern they form is unique, as precise a means of identification as human fingerprints, and a lot easier to see. A combination of nicks and holes and vein patterns guarantees accurate identification, once a good photograph has been taken.

7.5.4 Where to start

As described earlier, elephants can be found in three kinds of groups. The best place to start is with these groups, taking into account what type they are.

a) Single bull or all-bull group
In this case, an attempt should be made to identify all the individuals. Note the number in the group and

the relative ages. Then look for striking individual characteristics such as:

i) Tusklessness
ii) One-tuskedness
iii) Broken tusks
iv) Large holes or tears in ears
v) Broken ears
vi) Scar tissue on body
vii) Deformities and injuries, e.g. missing trunk tip, no tail

Try to make a note and possibly a drawing for each individual. For example your note might read: “large bull, class 3 or 4, with broken right tusk and V-shaped nick out of lower left ear”. The next step is to start taking photographs, which is covered in more detail below.

b) Cow/calf groups
This type of group can initially be treated in a different way from an all-bull group. Rather than trying to identify every individual, your immediate goal should be to try to distinguish only the adult females. You can work on the calves later if they are a necessary part of your study.

Once again the notes that you take will be very important. Start by noting how many animals there are in the group and then break it down into ages: how many adults, how many calves and roughly of what ages. Find the adult females and note down any outstanding characteristics in the same way as with the bulls, such as tusklessness, big holes or nicks in the ears, etc. Then start taking photographs.

7.5.5 Photographing elephants

l recommend photographs over drawings because drawings cannot show the finer details of the vein patterns on the ears. l also recommend black and white film over colour film because l have found that there is much sharper detail in the prints. l use either Kodak Tri-X 400 ASA or Fuji 400 ASA. These are fast films which can be used even in fading light.

A good 35mm camera with a zoom lens in the range of 80-200mm or l00-300mm is essential. If individual recognition is going to be attempted in areas where it is difficult to get close to elephants, then a lens of up to 600mm may be required. However, in using a long lens it will be necessary to use a tripod, monopod, or at the very least, a bean bag rested on a vehicle door to ensure sharp prints. Even with a shorter, lighter lens l recommend steadying the camera with one of the above methods or by resting it against the door or window frame if you are in a vehicle. The sharper the photograph the better.

Taking good black and white photographs is actually more difficult than working in colour. Light is extremely important. The best conditions for getting optimal contrast for highlighting the holes, nicks, bumps and vein patterns is in slight crosslighting, that is when the sun is to one side but shining on the ear. However, l hasten to add that usually you will be having a hard enough time just getting the elephant in frame, so the refinement of the lighting is something of a luxury. Nevertheless, there is no point in taking a photograph in poor light, such as when the elephant is backlit, that is when the elephant is between you and the sun.

The goal is to get the head, ears and tusks in the picture. When photographing an elephant that is side-on to you, wait until the ear is flat against the neck and shoulder and be sure you can see the holes and nicks through the viewfinder. Your own eye will tell you what the best angle and light is. If you have time take more than one frame of each ear. If you are photographing with the elephant against the sky l recommend opening up half a stop, that is overexposing slightly. The light meter will be balancing the bright sky with the dark elephant, but you may have to override what it registers, to be sure that the elephant is not underexposed. Most cameras can be set to over- or under expose automatically by however many stops you require.

Ideally, for each individual you will want three photographs: one of the left ear and tusk, one of the right ear and tusk, and one head-on showing the tusk configuration. If you are close enough, focus in on the head and tusks only, but if you are farther away just take the whole elephant. Later on, in the printing you can blow up the head and tusks. If the elephant has scar tissue, lumps, deformities or oddities in body shape then you might want to photograph the whole body.

Probably the most important aspect of taking ID photos is the note-taking. There is little point in taking dozens of photographs of a group and then later trying to sort out which left ear goes with which right one. It is far better to make a note for every frame taken. The following is an example of the method l use:

(Before photographing you would have recorded all the basic sighting data and then the group size and composition and any striking characteristics of individuals, perhaps even making one or two drawings of ear patterns.) Let us assume that this family had four adult females. Until they are registered they will simply be called F (for female) l through 4:

	Film #26
2 pics right ear of largest female—Fl, right tusk higher, lump on right shoulder	1-2
l pic left of - 15 yr. old—F2, with large V nick in right ear	3
2 pics left of F3—-20-2Syr old, even convergent tusks with first-year calf	4.5
l head-on of F4—35-44) yr old, left one-tusk	6

This might be all you can get on this occasion, but you would be doing very well to have photographed all four of the adult females. On the next encounter you would try to get the other ears and head-on photographs of the individuals to complete the IDs.

7.5.6 Setting up recognition files

In Amboseli each elephant above the age of about eight years old has an identity card with its photographs pasted on it. The photograph number (roll number, plus frame number.) and the date the photograph was taken are marked under each photo. This system of indexing ensures that duplicates can be readily produced from the negatives and provides a means of matching each photo with the field notes recorded at the time. Additional information on the card should include the animal's name or number, its estimated or known birth date, its mother if known, its family if known, the area it tends to be found in; and, in the case of an adult female, her offspring and their years of birth. It might also be helpful to include information on where and when the animal was first seen. If you will be dealing with a large population and do not expect to resight individuals often, you could include each sighting of the individual on the back of the card.

Because cows and calves and bulls are found in different social contexts, it is useful to have different filing systems for them. Since adult, independent bulls live in loose, fluid groupings and are often found on their own, and also might travel widely, a bull simply has to be recognised by his own characteristics. We have found that filing them by size, and therefore age class, is the most helpful system.

Females and their calves live in more or less stable family groups, which is a great aid to identification. There are many clues that the family can give you before you even identify the first individual. First the number and composition of the group might help, then the area the group is found in may add another piece to the puzzle; and even the behaviour of the members, whether they run away or are tolerant, might be suggestive of who they are. But of course, ultimately you will have to look at their ears and tusks and body characteristics to identify the individuals. If you can recognise one adult female, the chances of identifying the others are much improved. For this reason it is generally best to file the recognition cards by family rather than by age or ear characteristics. Thus once you find the card for the known individual and then look through the cards for the other family members, you should be able to identify the other adults fairly quickly. Needless to say, you cannot assume that the others are present or that there are no new ones there.

7.6 SETTING UP LONG-TERM

The final step in setting out to study an elephant population is a carefully thought-out plan for how to keep the records. The types and topic of your study will determine how you will design the data base. You will save youeself much tedious work and dissapointment if the record-keeping is efficient and flexible. A computer is probably essential in most cases, but where one is not available good check sheets (see Chapter 10) and other t kinds of record sheets on which tabulations can easily be made are invaluable.

BOX 7.3: MEASURING ELEPHANTS AND ASSESSING GROWTH

Studies of elephants frequently depend on assessments of size to reconstruct the age structure of the population, but the determination of size is a considerable problem. A variety of direct measures of stature and weight, as well as a number of techniques for non-invasive assessment, have been attempted.

Stature measures show considerable differences between populations (Table 7.3). A number of studies have measured shoulder height in wild African elephants, using a variety of photographic techniques (Douglas-Hamilton 1972; Croze 1972; Jachmann 1988; Lee & Moss 1995). These techniques rely on using either a reference height during photographing, or measuring the distance to the elephant for a known lens focal length. One rather complex method is to use stereo-photos (e.g. Douglas-Hamilton 1972) and another more simple one is to take a picture of an animal from a specific site, wait until it has moved on, then place a measuring pole in the front foot impression and take a second identical picture of the pole. The elephant as measured on the photograph can then be compared with the pole measures on the second photograph (Western *et al*. 1983). Jachmann (1985) measured from the camera to the elephant's position, with a known focal length. Another similar technique is to use a lens with a fixed digital caliper to accurately measure lens extension (invented for whales, Jacobsen 1991) to photograph the elephant. The extensions are calibrated against known pole heights and a simple linear formula then can be derived for relating the extension recorded in the field when photographing the elephants to the distance measured on the print. Photographic techniques are quick and relatively accurate, although expensive in terms of film. Another statural measure that gives reliable information about size and age is that of backlength. This can be recorded in the same way as shoulder height, and such measures can also be made from an aeroplane traveling at a specific height (Croze 1972). Again, some calibration against a known measure must be made for each flight and height. The differences between measures of total head to anal flap backlength and scapula to anal flap backlength appear to be relatively unimportant (Lindeque & van Jaarsveld 1993), and both give reliable indices of overall size.

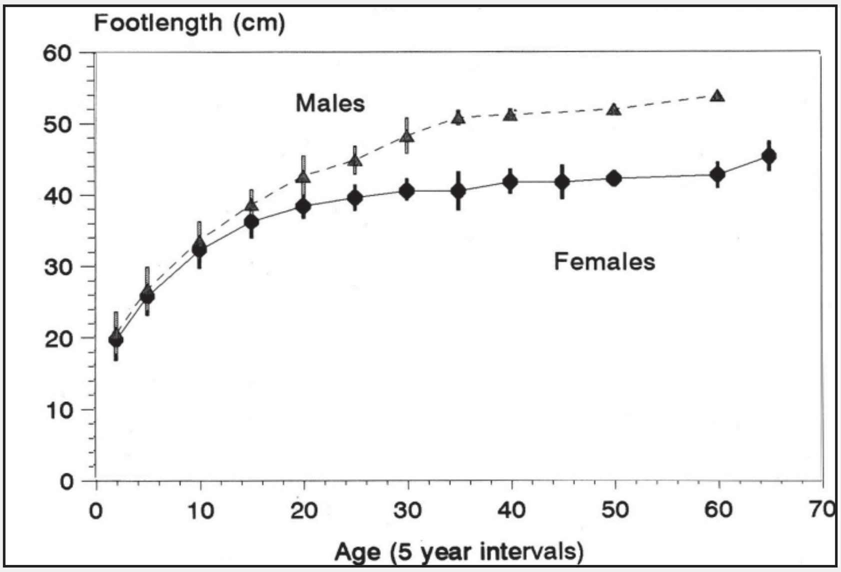
	MALES		FEMALES
AFRICA			
Uganda			
Murchison	317	274	Laws 1966, Laws et al. 1975
Murchison South	307	252	“
Queen Elizabeth	298	252	“
Kenya			
Tsavo	nd	272	Laws 1966
Amboseli	304	232	Lee & Moss 1995
Malawi			
Kasungu	295	252	Jachmann, in Lindeque & Jarrsveld 1993
Zambia			
Luangwa	375	250	Hanks 1972
Zimbabwe			
Hwange	350	300	Haynes 1991
Namibia			
Etosha	345	262	Lindeque & van Jaarsveld 1993
ASIA			
Tamil Nadu/Madras			
Captive	258	231	
Wild Born	273	240	Sukumar, Joshi & Krishnamurthy 1988

Table 7.3: Measures of asymptotic or maximum shoulder height among adult elephants in different populations.

It is also possible to estimate stature indirectly, especially in populations living in areas where a good impression of the hind footprint length can be obtained. Hind footprint length is known to relate to shoulder height and age in African elephants and thus can be used to assess age distributions in a population as well as overall size of the animals (Western et al. 1983). This measure can be reliably determined, and is easily replicated across observers. The length from the hell of the foot through to the arch (rather than the tip) of the toe is made on footprints which are clearly visible and not in deep soil, mud or sand. One easy means to check for the effect of the substrate is to measure the observer's footprint over a number of paces. These can be compared with the length of the shoe and some idea of error introduced by substrate and walking can be assessed. It is then necessary to ensure that measures of elephant footprints are only made in substrates that do not distort the measurement. Several footprints from the same animal should be measured to ensure reliability.

The relationship between footprints and age have only been determined for one population of known aged African elephants (Lee & Moss 1986, Poole 1989). Since there could be inter-population variation, these measures may only be a rough guide. As a general rule, animals with foot prints of less than 25 cm are under five years old, while those over 50 cm are large bulls of 30+ years (figure 7.4). Bulls have a larger footprint length than do females at all ages over five, and their inclusion will distort any population age profiles, unless the sex of the animal is known when the measurement is taken.

The relations between shoulder height and footprint appear to follow a linear relationship (Western *et al.* 1983; Lee & Moss 1995). The shoulder height increases at roughly six times footprint length. Thus footprint



Figures 7.4: The mean footprint length for age, with standard deviations, for 1668 male and 204 female African elephants in Amboseli National Park, Kenya. Data from P.C. Lee & C.J. Moss 1995.

Length can be used to estimate both size and age. For Asian elephants, the standard measure has been to use the circumference of the front foot, which predicts should height as 2.03 multiplied by the foot circumference (Sukumar *et al.* 1988). However, this measure can only reliably be determined from tame or captive animals, and thus is of limited use in field studies.

Comparable measures of size can be taken from dead or immobilized animals, with the understanding that shoulder height may be larger than standing height due to compression while upright, and that foot sizes may be hard to accurately determine when the foot is not placed flat against the ground.

Determination of age is essential when attempting to assess growth. Most studies rely on a large cross-sectional sample, since longitudinal growth is typically difficult to assess. Longitudinal growth measures are, however, currently available from African elephants only in one study of five wild animals who were immobilized to fit radio-collars (Lindeque and van Jarsveld 19930, and some other data are available from a small sample of captive animals (Laws 1966; Hanks 1972; lang 1980). For Asian elephants, both longitudinal and cross-sectional growth have been assessed of the different growth curves available, and their results suggest that the use of the three standard curves, Von Bertalanffy, Gompertz and logistic, provide similar results in assessing rates of growth, especially for the post-weaning ages (five years onwards). They note that using non-linear curve fitting techniques produce more accurate growth curves than do methods of linearisation.

The three most frequently used equations for sigmoidal curves are presented below. A further curve without a sigmoidal function, an asymptotic exponential curve, can also be used. These curves assume that growth over the separate measurement intervals is linear, but there are few other options for describing curves.

Con Bertalanffy: $L_t = L_{as}\ [1 - e^{-k(t - t_0)}]$ (size)
$W_t = W_{as}\ [1 - e^{-k(t - t_0)}]^3$ (mass)
Gompertz: $L_t = L_{as} .\ b^{rt}$
Logistic: $L_t = L_{as} / 1 + b\ r^t$
Asymptotic: $L_t = L_{as} - b\ (e^{-kt})$

L_t = length at time (t); L_{as} = asymptotic length, K = rate constant, b = an empirically derived constant, r = rate function for time (t). Full details can be found in Zullinger *et al.* (1984) and Lindeque & van Jaarsveld (1993).

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l highly recommend at the outset consulting with researchers working on elephants and other mammals in Africa so that at least part of the data base that you create will conform to an Africa-wide model. Ideally we should aim for a network of information on elephant populations that can easily be compared and contrasted.

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CHAPTER 8

STUDYING ELEPHANT MOVEMENTS

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8.1 INTRODUCTION

The movements of elephants and related species like mammoths must have been pondered upon almost since primitive man first began to hunt them. Ivory hunters such as William Bell (1923), returned to hunting grounds that had been productive in earlier safaris only to find that their quarry was no longer there. Today an understanding of the movements of elephants is important as wild areas have diminished and the survival of elephants has become dependent upon the establishment of relatively small conservation areas which will have to be adequate for elephant conservation for many hundreds of years into the future.

8.2 WHY STUDY ELEPHANT MOVEMENTS?

A knowledge of elephant movements can answer a wide range of questions relevant to their general ecology and thereby to their long-term conservation and management. Some of the areas one could look at are:

a) Home range
In many respects, the size of an elephant’s home range is an indication of the availability of essential resources, restrictions imposed by the size of the respective conservation area (where applicable), and the degree of disturbance (perhaps man-induced) to which the animal is exposed. Where water and food are abundant and disturbance is minimal, it can be expected that home ranges will be small. For example, in the Kruger National Park home ranges have been shown to be relatively small at a calculated mean of 909km^2(Whyte 1993) while in a more arid environment in Namibia, they tend to be much larger at a calculated mean of between 5,860km^2 and 8,693km^2 (Lindeque & Lindeque 1991), presumably as elephants in this environment need to be more mobile and opportunistic, due to limited availability of food and water. This basic information can give important clues to the avenues future research should take.

In some instances, conservation areas (or the ranges of elephants) extend across international boundaries, and an understanding of the movements is important to the relevant conservation authorities in order to synchronise census work, co-ordinate management plans, etc. An example of this is the contiguous elephant range which extends from southern Angola and northern Namibia through south-western Zambia and northern Botswana into western Zimbabwe (Douglas-Hamilton *et al.* 1992). The movements of the elephants herein are not well understood and, as a result, the size of the total population is not accurately known. An understanding of the movements across these international boundaries would contribute greatly to the development of a conservation plan for the population as a whole.

b) Seasonal or periodic long distance movements
This is an aspect which falls within the realms of a normal home-range study, but also movements of this nature indicate areas which may be of vital importance to the long-term conservation of that population, and which may (in some cases) lie outside of conservation areas. Moss (1988) and Lindeque and Lindeque (1991) describe areas of this sort outside the Amboseli and Etosha National Parks respectively.

c) Dynamic relationships between darts, herds and individuals
This is an aspect which may not be of direct management importance but is of importance in understanding elephants and their ecology The relationships that have so painstakingly been

unravelled through classic studies like those of Moss (1988) would be far less meaningful if the movement patterns had not been so well understood. These studies were possible through direct observation in Amboseli, due to the small sizes of both the reserve and the elephant population. In a larger area containing a larger population, other methods such as the use of radio telemetry would have been essential.

d) Foraging behaviour and spatial use of resources
One of the fundamental aspects of understanding the ecology of elephants in any particular area is knowing how the animals use the resources at their disposal. The study of foraging behaviour is dependant not only on knowing what food and other resources are available and how they are distributed, but also on an understanding of the movements of the animals in and around the plant communities and waterpoints.

e) Specific management questions (e.g. which herds frequent which areas)
From a management point of view, it may be important to understand which elephant clans or groups have home ranges that allow access to vulnerable plants (or plant communities) or perhaps which elephants may be. potential problem animals, such as "crop raiders" outside established conservation areas. The knowledge helps a manager having to conduct culling operations, allowing him to identify which groups he should concentrate upon. Also, knowing which elephants are where is useful if selective trophy hunting is practised.

It is known from studies in the Kruger National Park (Whyte 1993), that a culling operation may induce a certain degree of movement among other elephants in the area. If it is important to cull animals from a particular area only, it is essential to know where the animals concerned have gone in response to such a cull so that attention is then not diverted to non-target groups.

8.3 AVAILABLE TECHNIQUES FOR STUDYING MOVEMENTS

8.3.1 Techniques not involving radio-tracking

The success of techniques not using radio-tracking is dependent on the type of information required and on the terrain. There are two basic methods, both of which require fairly tractable study animals that do not flee when approached. The first is a long-term study in which all the localities of particular animals seen are recorded, and slowly a picture of the home-range emerges. The method relies on being able to identify specific animals either by particular physical features (such as ear nicks and tears, tusk shape and size, etc.) or having fitted them with colour coded collars. As such animals cannot always be located when required, the data are acquired mainly from *ad hoc* resightings. Much of Moss' study (1988) was conducted in this manner but she was able to identify nearly all of the approximately 750 elephants in the Amboseli population'- a remarkable achievement.

The second is a technique in which identifiable study animals are followed for continuous periods and all movements/activities are recorded. This is an extremely time-consuming method which would usually be used for the collection of data other than that pertaining strictly to movement, such as feeding or behavioural studies. Movement data can, of course, be acquired as a spin-off to these other priorities. These two methods can of course be combined and specific identifiable animals can be tracked or followed for continuous periods at regular intervals.

A limitation of both these techniques is that certain inaccessible localities which the animals may visit either occasionally or regularly may never be recorded, giving a bias of unknown magnitude to the result.

8.3.2 Conventional radio-tracking

8.3.2.1 General

Before a radio-tracking study is initiated by someone who has little or no experience in this field, a substantial review of techniques and problems concerned with radio-tracking should be conducted. Amlaner & Macdonald (1980) and Cheeseman & Mitson (1982) are useful references. A comprehensive review article was also published by Harris *et al.* (1990).

Radio-tracking involves puffing a small radio transmitter attached to a collar or harness on an elephant. The transmitter emits a pulsing signal on a predetermined frequency which can be detected on a radio receiver set to the same frequency. The signal is detected through a directional (Yagi) antenna attached to the receiver set to the same frequency. The signal is detected through a directional (Yagi) antenna attached to the receiver which in turn emits an audio signal through a speaker or headphones. The strongest signal will be received when the antenna is directed straight at the transmitter.

The great advantage of using radio telemetry is that the study animal(s) can nearly always be located when required. This means that little time is wasted looking for the animal, and study periods can be planned to allow for the most meaningful subsequent analysis of the data. It does happen from time to time that the terrain will prevent the signal from being received -usually when the animal is low down in a valley - as the reception of high frequency radio signals is dependent on "line of sight" conditions. The range of radio transmitters (the distance at which a signal can be received) is very variable under field conditions. In poor terrain the range may be very small, but when both the receiver and the study animal are located on high points, the range can be as much as 40-50km.

There are a few different methods of determining or "fixing" the position of the collared animal, depending on the kind of study being conducted and the type of data required. The different methods can be separated into two basic group - those in which only the position of the animal is determined and those in which the animal is approached after radio contact has been made and until visual contact is achieved. This first is achieved through "remote" sensing either by triangulation or from the more recent development of satellite tracking (see Chapter 12). Usually, the only data that can be obtained by these "remote" methods are estimates of the animal's position (on a map) and/or the point's grid reference. However, if the position of the animal can be estimated to a satisfactory degree of accuracy, this can be coupled to a vegetation! habitat map or a Geographic Information System (GIS) if one has been developed for the particular study area concerned (GIS is a computerised database containing geographic information such as soil type, vegetation, rivers, roads, topography, etc.). Such information can then be used'to infer relationships between the study animals and their physical and/or biological environment.

The second type of data in which the animal is approached and visual contact is achieved, after radio contact with it has been made, allows the accurate plotting of the animal's position and the collection of other data pertaining to habitat, social grouping, as well as behaviour.

8.3.2.2 Potential sources of error using "remote" radio-tracking

Remote radio tracking is prone to three types of error (Macdonald & Amlaner 1980):

a) System error

i) Inaccuracies in the directionality of the antenna

Due to the nature of such work, antennae seldom survive undamaged for long. Buckling of the antenna may lead to inaccuracies and equipment should be tested occasionally (particularly after having sustained damage) by"ground truthing" - testing the equipment on a transmitter located at a known locality.

ii) Inaccuracies imposed by the geometry of triangulation

If it is only necessary to ascertain the animal's position (remote radio tracking), this can be done by the observer pinpointing his own position on a map (either a base station or the position he finds himself in once a signal has been obtained) and then determining the compass bearing of the source of the signal. A line can then be drawn on the map from the observer's position (Fig. 8.1: "Base station 1") through the source of the signal (Point A). By doing this from two (from Base station 2 through Point B) or more points in quick succession, an estimate of the position or a "fix" of the study animal can then be made. This will be where the lines on the map converge (Point AB). The method is known as "triangulation". The true direction of the animal can always be expected to be a few degrees either to the left or right of the bearing taken, and although the plotted position will be at the point of intersection of these two bearings (Point AB), the animal may be anywhere in the shaded area X. Triangulation is most accurate when the bearings from the two receivers intersect at about 90 (area X on Fig. 8.1). As the angle of intersection either increases (Area Z) or decreases (Area Y) from the ideal 90, the potential for error will increase. In other words, as the study animal approaches the line between the two receivers (Point DE), accuracy diminishes. Also, the farther the animal is from the base stations (Point AC), the smaller will be the angle between the bearings from the two receivers, which also reduces precision. The difficulties and limitations of the method are discussed in more detail by Heezen and Tester (1967), Taylor and Lloyd (1978), Macdonald (1978) and Macdonald and Amlaner (1980). This method was used with success on elephants by Fairall (1980).

iii) Other inaccuracies

Errors can result from misreading bearings, due to taking the reading from a magnetic compass

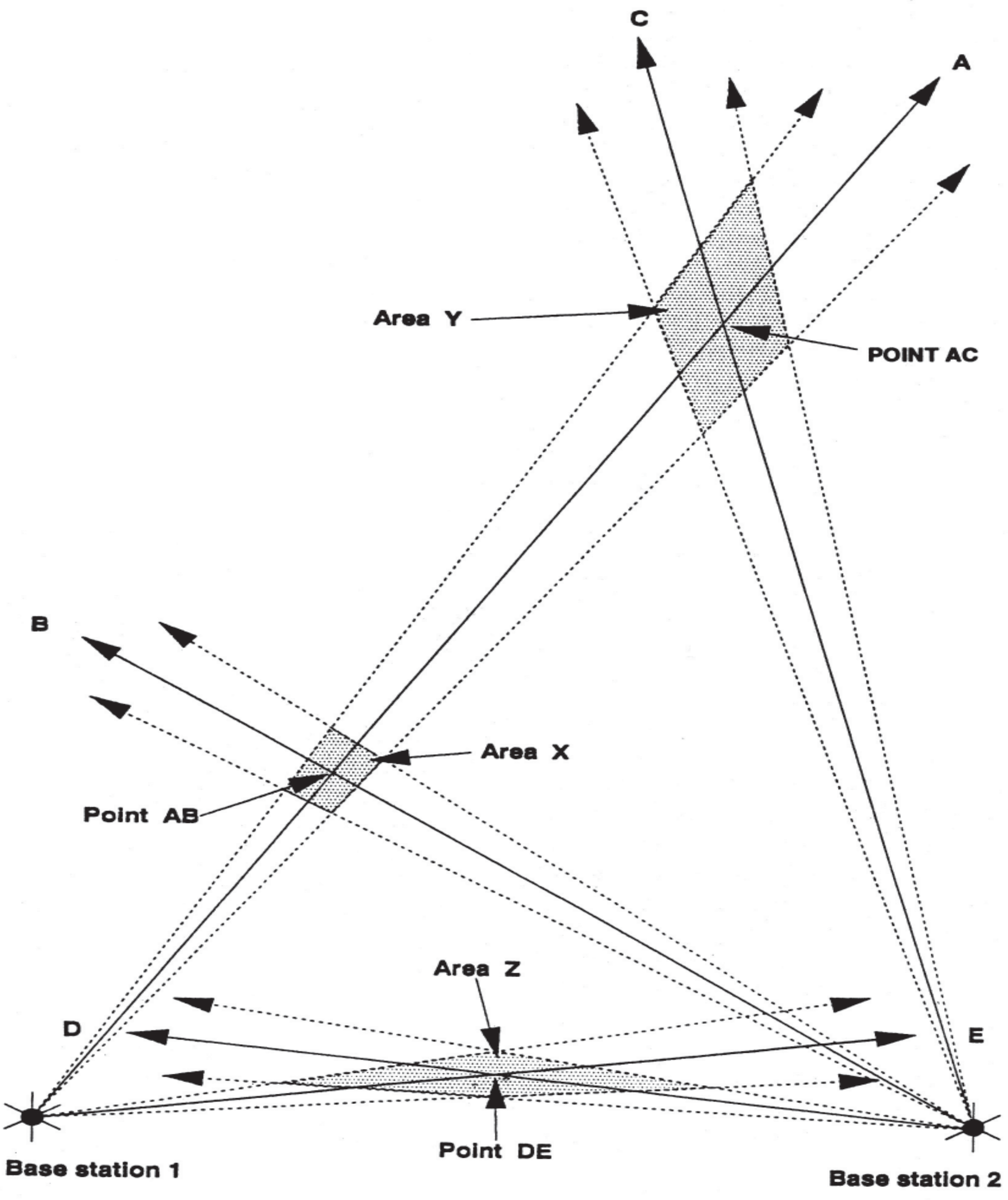

Fig. 8.1: Potential errors in the geometry of triangulation

too close to the vehicle. Error can also be the result of the antenna being mounted too low - it should be at least one wavelength above the vehicle's roof.

b) Movement error

A delay between the taking of bearings to pinpoint the animal's position will result in error. The magnitude of the error will be determined by the speed at which the animal is moving, the time lag between taking the bearings and the animal's position relative to the localities where the bearings were taken (geometric error).

c) Topographical error

High frequency radio waves are attenuated by vegetation and tend to reflect off topographical features, the higher the frequency, the greater is this tendency. Inaccuracies due to topography are variable and need to be learned for the particular study area concerned.

All the mthods discussed below also have certain nherrent advantages and disadvantages in terms of cost effectiveness and labour intensiveness. These should also be borne in mind when planning a study.

8.3.2.3 Radio-tracking from the ground

Radio-tracking elephants from the ground is usually conducted from a vehicle. Apart from the fact that elephants are dangerous animals, they have relatively large home ranges and to find the collared animal in a home range which may be as large as 1,000km^2 or more often means wasting much time in covering the ground between high points while searching for the initial "contact".

Depending on the requirements of the study, it may only be necessary to ascertain the animal's position by triangulation (remote tracking). This method was used to track elephants by Fairall (1980). The main drawback of this method is that it does not allow the collection of any other (often very useful) additional data, and that the method is prone to movement error, topographical error and geometric inaccuracies.

If visual contact of the study animal and its family group must be made (in order to determine the sex and age structure of the group, to undertake feeding studies or to determine habitat condition, etc.), the animal can then be approached once the initial radio contact has been made by moving toward the signal either by vehicle or on foot. The advantage of approaching elephants on foot is that little disturbance occurs if due attention is given to noise and wind direction, but this must be conducted with extreme caution. Approaching elephants by vehicle usually requires off road work which is invariably noisy and results in observations on disturbed rather than relaxed study animals. An additional advantage of gaining visual contact with the study animal is that it eliminates the errors associated with remote sensing as its position can be accurately plotted on a map, particularly with modem'"Global Positioning Systems" (GPS) technology. (These small hand-held instruments can indicate positions by precise latitudinal and longitudinal co-ordinates of the operator to an accuracy of within ±50m anywhere on the earth's surface from signals received from orbiting satellites. See also the section on GPS in Chapter 12).

Radio tracking from the ground is reasonably cheap, requiring only the running costs of the vehicle and the usual overhead costs such as salary, etc. It is labour-intensive in that many hours are often spent travelling through a large home-range trying to make initial contact with the required study animal.

Bertram (1980) gives some very useful advice to those who may be about to embark on a study making use of radio telemetry:

i) Routinely time the signal rate of each transmitter fitted to obtain advance warning of impending battery failure.

ii) Carry at least one spare radio collar with you at ail times so that collars giving such warning of battery failure can be replaced before contact with the animal (and perhaps the collar itself) is irretrievably lost. Also, a spare collar allows checking the receiving equipment should a problem be suspected.

iii) Fit a collar to more than one animal in a social group so that the group can still be found in spite of the failure of one. The frustration of losing contact is extreme!

iv) Habituate animals by dealing with them as quietly and gently as possible so that they can be observed without disturbance. This also facilitates the easy fitting and recovery of collars.

8.3.2.4 Radio-tracking by triangulation from base stations

This method requires the establishment of two or more base stations, each equipped with a receiver and a tall, sensitive antenna. These stations should be located on the highest ground available in the study area which would offer the best possibility of receiving signals from the animals' collars. The positions of these base stations are then plotted on the map and manned during the time that the animals are to be tracked. Compass bearings of the direction of the study animal is determined from all base stations simultaneously at predetermined times. The localities of the animal can be determined later by triangulation, as described above.

This method is very useful for activity studies as regular plots of each animal (hourly, half hourly or at whatever interval is required) will allow the determination of the path that the animal follows by connecting the respective "fixes". Distances moved can then be calculated. The drawback of the method is that it does not allow for the collection of other data (see Section"8.5.3). The method is also prone to topographical error and geometric inaccuracies. These can be minimised if the local topography is well understood.

The method will only be useful in a study area offering suitable high ground (such as a high escarpment overlooking a low lying home-range) on which base stations can be established. The large home-ranges of elephants will often make contact with the animals impossible from fixed base stations if suitable high ground is not available. Given these prerequisites, the method is fairly cheap once the initial outlay of establishing and equipping the base stations has been achieved. Travel is minimal and many fixes can thereafter be obtained for a minimal expense.

8.3.2.5 Radio-tracking from the air

Radio-tracking from the air has proved to be an extremely useful method, particularly when, as in the case of elephants, the study animals often live in open savanna environments, and in these habitats they are easily visible from the air. In inaccessible areas aircraft are also particularly useful. Another great advantage of using aircraft is to save time. From altitudes of up to 5,OOOft above ground level, radio signals can be picked up from distances of upto 60 or70km! This means that a study animal can be found quickly whenever required.

The method involved will be dependent on the type of aircraft that is available, but small fixed≠-wing aircraft, helicopters and micro-light aircraft have been used with success. Helicopters can provide high quality data as the ability to hover allows assessment of the age and sex structure of the group. Habitat data can also be accurately acquired. Tracking can be accomplished by holding the antenna out of the window; no special fittings to the aircraft are needed. However, the extremely high running costs of a helicopter and their unavailability in distant rural areas usually preclude its use.

Small fixed-wing aircraft can also provide high≠ quality data on both habitat variables and group composition. An additional advantage is that they can travel fast, so many different study animals or groups can be located over a wide area in a relatively short time. They are far less expensive than helicopters and are more generally available, but running costs are still high enough to make this a severe drawback, and tracking flights need to be carefully planned to realise their full potential as they can usually not be carried out regularly. These aircraft require the mounting of an external antenna or two - usually one on each wing. Both antennae are connected to the receiver inside the aircraft by way of a two-way switch box. Through this, either the left, right or both antennae can be selected. The initial signal is obtained by listening on both antennae, and then selecting left or right to determine which side of the aircraft the animal is on. The aircraft is then turned towards the animal until the signal strength from both antennae is the same. By constantly switching between the left and right antennae the aircraft's direction is adjusted to maintain equal signal strength. The signal strength increases as the animal is approached, and if the terrain and vegetation are suitable, the study animal is easily located.

Micro-light aircraft have the distinct advantage over the other two in that they are relatively cheap to acquire and maintain, and to learn to fly (which eliminates the additional expense of hiring a pilot). They can be easily operated from bush strips and are relatively quiet, which limits disturbance. Their disadvantages in comparison to other aircraft are that they are sensitive to bad weather and have limited speed and range.

Data recording in the form of written notes is difficult in an aircraft as the time available while the study animals are within visual range is limited. If the researcher is also the pilot, the problem is even more difficult (as flying the aircraft is clearly the priority!). A small hand-held dictaphone or tape recorder is very useful under these conditions, and the data can be transcribed later.

The position of the animal can be plotted very precisely if the pilot/observers know the area well and if accurate maps of the area are available. This necessity is obviated if the aircraft is fitted with a GPS.

Another great advantage of tracking from the air is that it eliminates all of the errors and inaccuracies associated with remote tracking listed above (see Section 8.3.2.2) as the position of the study animal can be plotted exactly.

8.3.2.6 Radio-tracking using satellites

Satellite radio tracking is a relatively new technology which improves the logistics of data acquisition by circumventing many of the deficiencies encountered with conventional remote telemetry techniques. Factors such as hazardous weather conditions, darkness, international boundaries, remoteness and extensive animal movements do not hinder the systematic collection of data (Fancy *et al.* 1987). See Chapter 12 for more information on satellite-tracking and new methods of studying movements such as GPS.

8.4. WHAT SORT OF DATA ARE REQUIRED?

8.4.1 General

Data gathered regularly at predetermined times will allow better analysis of the results. Areas used or distances moved can be satisfactorily compared if they were measured over the same time spans.

An animal's movements and home-range will usually not be entirely stable but will change with time. An animal's requirements are more easily met at certain times of year than others, thus reducing the space needed to meet these requirements. Seasonal environmental changes may even require that long-distance movements be undertaken, resulting in very large home-ranges. Such movements may take the form of regular migrations or irregular vagrant movements to optimise locally favourable conditions. Ideally, studies should be made over more than two full annual cycles.

The kinds of data required depends on what sort of questions need to be answered. If it is only necessary to know what sort of areas elephant clans utilise, then remote plots of animals in neighbouring clans taken as regularly as possible will probably suffice. But if other questions also need answering (such as how many individuals make up the various clans? Do all clan members use the same range? Do habitat types influence movement? How does rainfall affect movement? etc.), then other types of data will be required, but it is beyond the scope of this chapter to look into all of these as they include other techniques such as habitat analyses, botanical surveys, etc.

8.4.2 Home-range

For many kinds of animals, a home-range is one of the keys to their ability to survive and reproduce, and a knowledge of the home-range requirements of the species is essential to the understanding of its general ecology. But studies of home-ranges have been somewhat vague. This is because the techniques used do not allow for the monitoring of the exact position of the animal at all times. Data almost invariably are of the form of sporadic fixes of the animal's position, taken either at regular or irregular time intervals, when the whereabouts of the animal during the intervening time is not known. The data therefore can only present a vague image of the actual nature of the study animal's home-range, but the more intensively the study is conducted, the clearer the image becomes.

The intensity with which any such study is conducted is often limited by budgetary constraints or else time constraints due to other responsibilities of the researcher, but any data that can be gathered over a sufficient period of time will give some indication of the area that any particular animal uses as its home-range.

8.4.3 Grid systems

Any useful analysis of plotted positions of the study animal is dependent on a grid system. Such a grid can follow one of the recognised geographical co-ordinate systems such as latitude/longitude (i.e., either decimal degrees or degrees/minutes/seconds), a projection system such as the Universal Transverse Mercator (UTM), or a Cartesian system in which a grid is drawn over a map of the study area at a scale which suits the requirements of the study. Any one of the geographical co-ordinate systems is useful as these are usually compatible with GIS programs but most such studies rely on a Cartesian system as their grid references can usually be rendered GIS-compatible through a simple conversion program. Both the vertical and horizontal grid lines should be given numeric values (not alphabetic or alphanumeric) as positions anywhere on the grid are thus assigned an arithmetic character which subsequently allows for certain mathematical procedures to be carried out.

The size of the Cartesian grid cells should be chosen to reflect the inherent error in calculating each fix. In other words, if the calculated position is expected to be within one kilometre of the elephant's actual position, grid cells should ideally be 1km x 1km. Although grids need not be square or be of any specific size, to use grids of 100m x l00m or 1km x 1km can simplify the

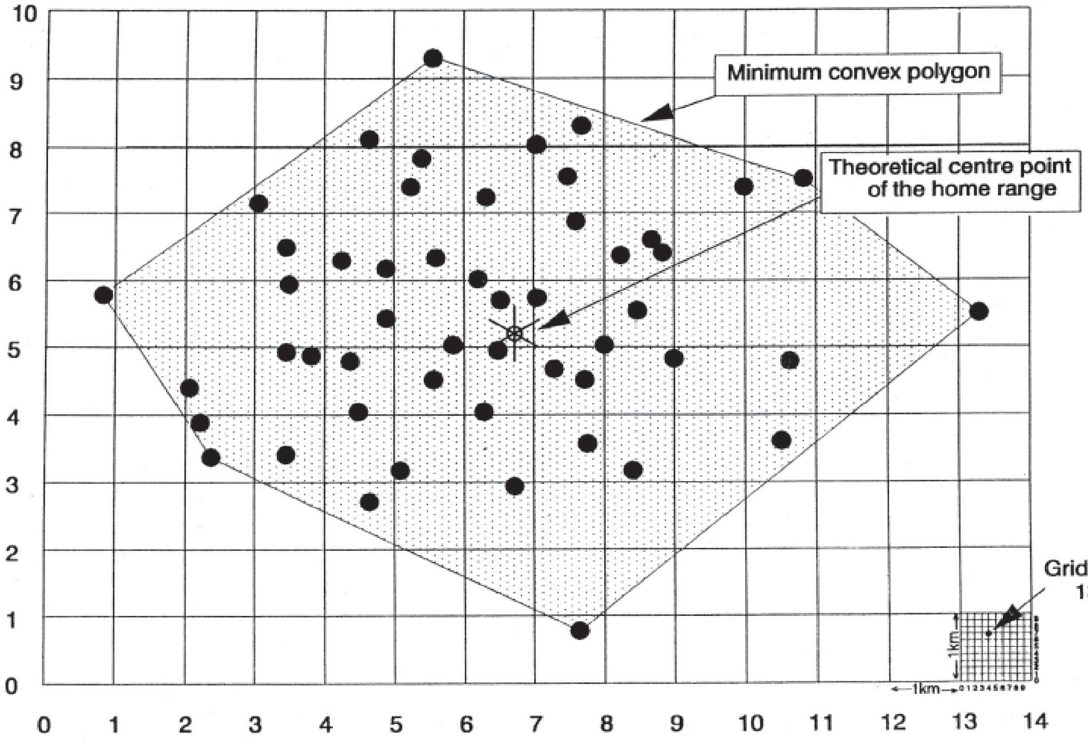

Fig. 8.2: A Cartesian grid overlaying the fixes representing a hypothetical home-range.

later analysis of the data. Fig. 8.2 illustrates such a grid of 1km x 1km which has been further subdivided (bottom right hand corner) into 100m x l00m blocks. To illustrate this, point A in the bottom right hand block would have a grid reference of 134.007 (longitudinal (Y) are given before the (X) latitudinal values). Each of the plots on this hypothetical figure can be assigned a six-numbered reference point which implies that it lies in a particular block which has an area of 100m x 100m The calculation of the mean X and Y values of all points indicates the theoretical centre point (or “centre of activity”) of the home range.

8.4.4 Seasonal or periodic long distance movements

Elephants may leave conservation areas either seasonally or periodically. As such movements may cover long distances, their whereabouts may not be known during these times, and the only realistic way of finding out which elephants go where is to monitor their movements through radio tracking. A problem like this was described by Lindeque and Lindeque (1991) in Namibia. Under these circumstances tracking from base stations or from the ground is unrealistic or impossible options so the tracking has to be conducted either from the air or by satellite. Satellite tracking can be satisfactory if accurate plots are obtained, but unless several animals in these groups have been fitted with Platform Transmitter Terminals or PTT’s (see Chapter 12), it will not be known how many animals are involved in these movements and which animals go where. Under these circumstances, tracking by aircraft is an ideal method as accurate plots of the position can be obtained (particularly if used in conjunction with a GPS) and detailed information can also be gained on group structure. Knowing where the animals have gone is useful but it would be of much greater interest to know why they went there and then other data on such aspects as habitat variables may also be obtained.

8.4.5 Dynamic relationships between clans, herds and individuals

This kind of study ideally requires the concurrent study of several elephants in the same and different clans. Adult cows collared many kilometres apart may be of the same clan and the subsequent definition of the sizes and shapes of their respective home ranges can help illustrate their relationships.

In the absence of computer back-up, the use of coloured pins (each collared animal having its own colour) is a useful, simple method of showing these relationships. Each time a study animal is located a pin of the relevant colour is stuck into a map at the appropriate grid reference and gradually there emerges a much clearer picture of the home ranges than can be given by convex polygons (see Section 8.5.2). The convex polygons of the home ranges of neighbouring elephant clans in the Kruger National Park (Whyte 1993) indicate a large degree of overlap, but the use of a "coloured pin" technique would have shown the clear core areas which are not usually used by the clan's neighbours.

Grid references are again key data types for use in subsequent analyses.

8.4.6 Foraging behaviour and spatial use of resources

The study of foraging behaviour requires the study animal to be within sight of the observer so that details of what the animal is eating can be noted. This is not within the scope of an ordinary movement study and questions like "what plant species are being utilised?" must be answered by direct observation. Radio telemetry is a useful tool for this type of study as study animals can be easily located and relocated should visual contact be lost. Questions such as "are there favoured foraging areas? How far do elephants move from water to reach these areas? What times of day do elephants move to and away from water?" can all be answered through the study of movement.

It is clear that all of these types of study have two particular aspects in common. They require firstly that the position of the animal be accurately plotted. Secondly, an adequate grid system which can give any locality an accurate grid reference is vital for the subsequent analysis of the data. Initial observations in the field can be done by making a pencil mark on an accurate map"- grid references can be worked out later.

8.5 TECHNIQUES FOR DATA ANALYSIS

8.5.1 Simple analysis of movements

The measurement of movement is an analysis of the distance moved in relation to the time taken to cover the distance. To get the best possible measurement of an animal's movements it would be necessary to plot its exact position (and take the time) at every step it took. This is obviously ridiculous but to do so any less frequently than this will clearly introduce a degree of error into the measurement, as the path an animal would take between successive plots will never have been a perfectly straight line, and the less frequently a fix is obtained the greater will the error become. A movement study should therefore attempt to obtain accurate fixes as frequently as possible and the time that each fix is taken is as important a part of the data set as the radio fix itself. Depending on the time intervals between fixes, tracking can be considered to be either continuous or discontinuous.

For continuous tracking radio fixes should be taken at short intervals (< 15 minutes) to produce a series of fixes which would provide a rough approximation of the animal's travel route. This is useful for determining the intensity of home. range use, activity patterns, and interactions between individuals if more than one animal is radio-collared.

Discontinuous tracking involves locating the animal at either discrete or random time intervals. This technique is useful for determining home ranges. Time intervals should be selected to minimise the problems of auto-correlation which facilitates the analysis (see Harris *et al.* 1990). Another advantage is that the method allows the simultaneous study of a larger number of animals from separate social groups, discrete populations or sympatric species.

a) Patterns of movement

An animal will clearly never travel at consistent speeds for any length of time, and there will be differences in the amount of movement according to daily as well as seasonal cycles. Daily cycles will show variations depending on the time of day, due to rest periods (even sleep), special treks to water or to a particular food source, etc. To study these would ideally require continuous tracking over several 24-hour periods. These activities may show a seasonal variation and thus such 24-hour tracking periods should be conducted at all times of the year.

A second pattern of movement may be undertaken by a migratory species on a seasonal basis to another completely separate part of its range. Discontinuous tracking can provide adequate data as long as fixes are obtained regularly. It may conduct the study for more than one season to determine how fixed the migration pattern may be. These movements can be satisfactorily mapped (Fancy *et al.* 1987), but discontinuous tracking has limitations in showing just how the animal moved. Continuous tracking can better show mean distances moved over various time periods, and can therefore give an additional dimension to the data.

b) Mean distance travelled
In all of these studies the mean distance moved is of interest. This facilitates the meaningful comparison of different data sets. Mean hourly distance moved will vary if the animals are foraging, resting or migrating. The more intensively the pattern of movement of the animal is being studied, the more frequently will it be necessary to locate the animal. Mean short distance (daily) movements will require continuous tracking, while those of an animal on migration could be tracked discretely or even randomly. Of course, the more often radio fixes are taken, the higher the quality of the data.

8.5.2 Analysis of home range

As mentioned earlier, the study of a home range will present only an image of the actual nature of the study animal's home range, but the more intensively the study is conducted, the clearer the image becomes. To overcome this basic shortcoming, many different techniques have been devised to analyse and present home-range data. To go into these in any detail is way beyond the scope of this chapter, but they have been reviewed by Harris *et al.* (1990) and summarised here, with relevant references included for those who require further detail. The respective methods are illustrated in Fig. 8.3, using fictitious data. The 28 data points in all of the methods illustrated are identical, but no actual analysis has been conducted upon them - they are used only to show what the respective analyses can illustrate.

a) Sample size (Fig. 8.3a)
One of the fundamental aspects of a home range study is the collection of enough fixes to represent adequately the home range. This is fairly easily determined because as the number of fixes increases, so does the observed area of the home range. Initially the increase in the area is rapid but this tails off until eventually a point is reached where an increase in the number of fixes does not result in an increase in home-range area (see Whyte 1993). This point is known as the asymptote (Stickel 1954). After this point has been reached, further data collection is still useful for certain studies (intensity of home range use) but the boundaries of the home range will largely have been established. With elephants, however, this may not be quite so simple as they have large home ranges which may or may not be well utilised over a short period, and long-term studies may still reveal sudden unexpected increases. For example, in the Kruger National Park, one adult elephant cow increased the area of her known home range by 36% (from
1,200km^2 to 1,630km') due to one fix in an area where she had not previously been recorded over a period of 52 months subsequent to being collared (see Fig. 8.4).

b) Minimum convex polygon (Fig. 8.3b)
This technique is one of the simplest for home-range calculation and which is still one of those most frequently used. The great advantage is that it is the only technique that is strictly comparable between studies. It does not rely on complex statistical procedures; and for most management purposes, the polygon tells the manager what the probable range of the animal will be, even if there are unused areas within it. A disadvantage is that all data points are encompassed, including peripheral ones well beyond the main area of activity. It therefore includes some areas which are seldom or never visited. This method also gives no indication of intensity of range use, though the inclusion of the fixes in the polygon does give a useful visual impression (Fig. 8.3b). These disadvantages can be reduced by using concave polygons (Glutton-Brock et
al. 1982) or restricted polygons (Wolton 1985). This method is probably most useful when used in conjunction with one of the other techniques.

c) Grid cells (Fig. 8.3c)
Another non-statistical technique is the overlaying of grid cells. The method is useful for representing habitat usage (Lawrence & Wood≠-Gush, 1988). Voigt and Tinline (1980) used grid cell methods in which the cells adjacent to cells containing a fix were included in the analysis (influence cell method) and another (linked cell) in which cells between those containing successive fixes which were close enough in time but far enough apart for the animal to have been moving between them in a nearly straight line were also included. Home-range size is calculated by adding up the number of "active" cells.

The grid cell system is useful for calculating the

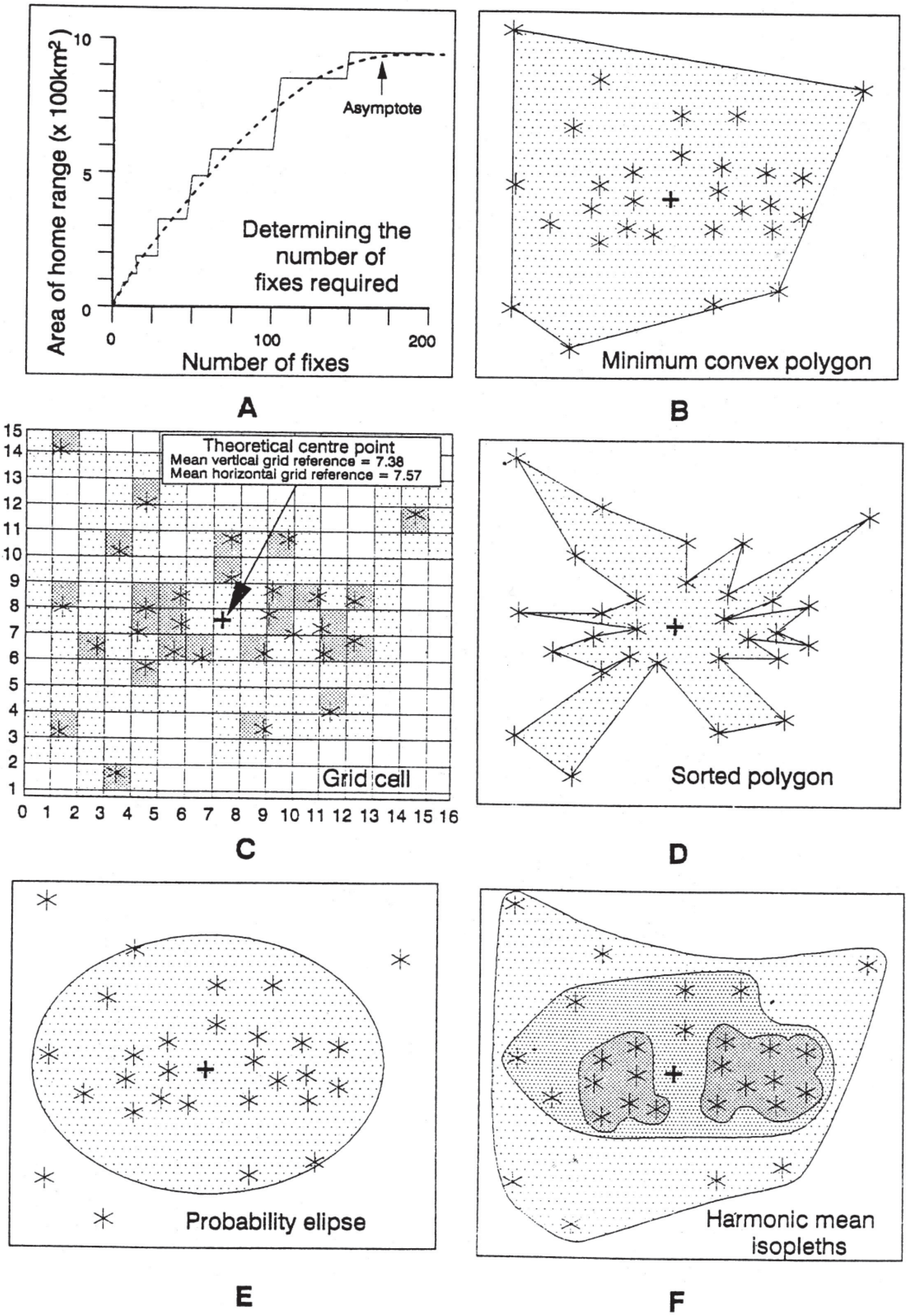

Fig. 8.3: Aspects of home-range data collection and methods of analysis.

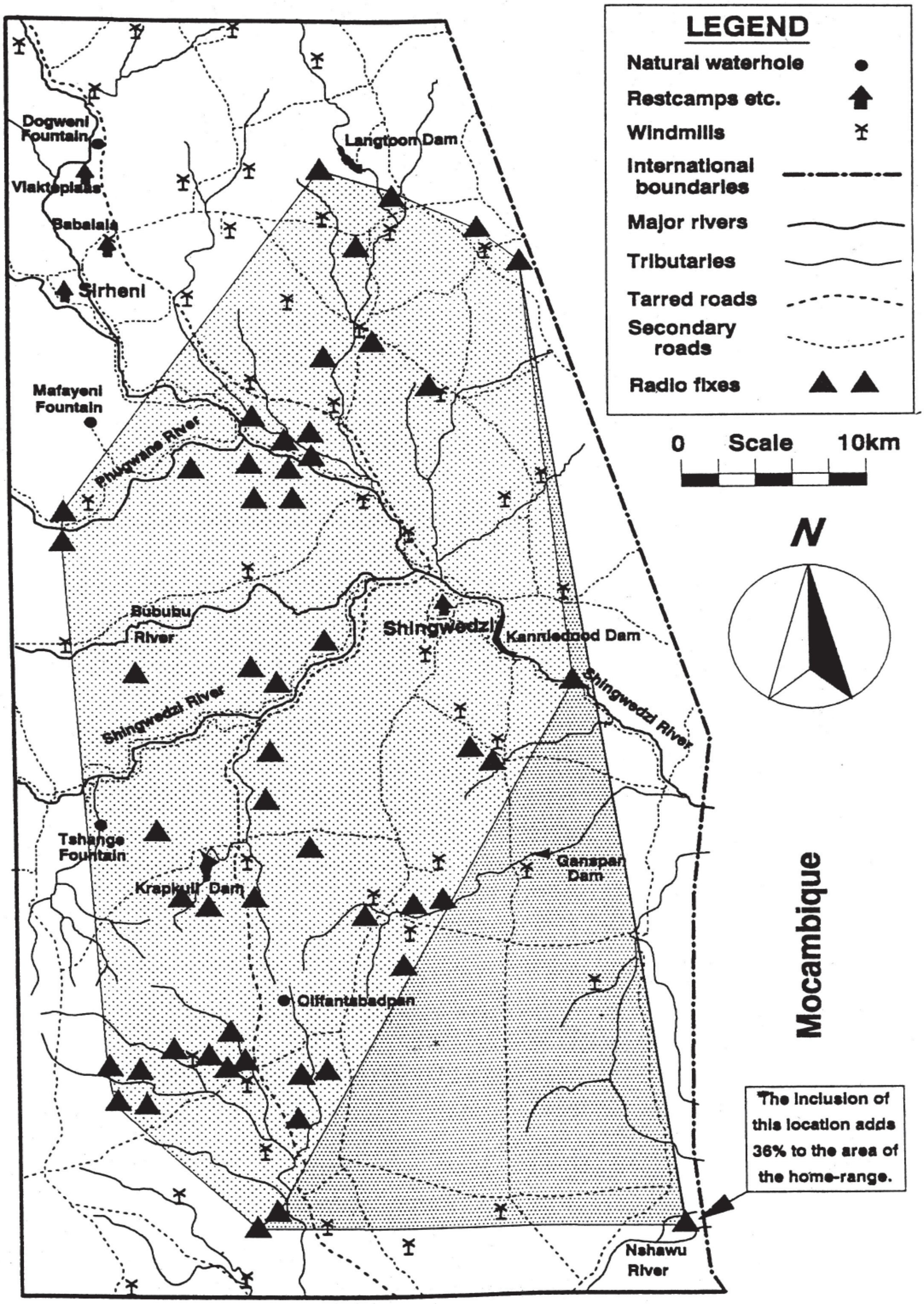

Fig. 8.4: Recorded home-range of an adult elephant cow in the Kruger National Park showing the influence of one “fix” on the area of the minimum convex polygon.

theoretical centre point or "centre of activity" from the point of intersection of the mean X and Y coordinates of all of the fixes. This point is used in some of the other analyses.

d) Sorted polygon (Fig. 8.3d)
This method was used by Voigt and Tinline (1980) in which the"centre of activity" is first determined. Each fix is numbered according to its direction from this centre of activity (i.e., from 0. through 360) and the points are then joined in numerical order resulting in a polygon looking something like a "star burst". This method yields a smaller polygon than the minimum convex but it removes much of the uncertain area between far-out adjacent fixes. The area of this polygon can then be calculated.

e) Probabilistic methods (Fig. 8.3e)
In these methods home-ranges are analysed as probabilistic circles or ellipses in which the ellipse boundary can be used to define home-range size. They suffer from certain statistical assumptions which will seldom hold true in nature and thus, though they are useful for academic analyses, they are less useful to managers requiring a more graphic image of home range.

f) Harmonic mean (Fig 8.3f)
This elegant technique was developed by Dixon and Chapman (1980) by which one or more centres of activity, home-range size and configuration can be determined. This is a mathematical procedure utilising a grid system in which values are calculated at each grid intersection to form a matrix on which isopleths are drawn like contour lines. The technique is particularly useful for highlighting core areas and those of relatively high and low usage within the home range.

8.5.3 Inferring use of habitat and behaviour from movement data

In many conservation areas much of the basic "spadework", such as the compilation of plant and animal species lists, the mapping of soils, geology, landscapes, vegetation types and/or plant communities has now been conducted. If such vegetation/habitat maps are available for the study area (either on a GIS system or on a map where the vegetation types are accurately drawn), a certain amount of information on foraging behaviour and spatial use of resources can be inferred. This is because an accurate grid reference of the location of the elephant can be cross-referenced to indicate in which habitat type the animal is located. The proportion of time spent in any particular habitat type will be indicative of its importance to the study animal or species which, in the case of an elephant study, could highlight plant species or communities at risk, thereby indicating avenues for future research. The more accurate the fix of the animal and the more accurate the vegetation map, the better will be the quality of the inferred information. Fig. 8.5 shows the same hypothetical home range as in Fig. 8.2 but this time with a vegetation map and Cartesian grid superimposed. Of the 50 fixes shown, eight (16%) were in the forest and 42 (84%) were in the savanna. Only three (6%) were recorded on the east bank of the river. Otherwise they apparently avoided the riverine types (unlike real elephants). If these were real data, such an analysis would tell us something about this animal's home range and its preferred habitat types.

Certain behaviours could also be inferred. For example, as these elephants apparently avoided the riverine areas, fixes on the river could indicate drinking and thus favourite drinking times. This could be corroborated by direct observations.

8.6 ADDRESSES OF SUPPLIERS

Satellite telemetry

1. Service Argos, Inc.,
   1801 McCormick
   Drive, Suite 10,
   Landover MD 20785, U.S.A.

2. Telonics Inc.,
   92 E. Impala Ave.,
   Carpinteria, CA 93013, U.S.A.

Conventional telemetry

1. Telonics Inc.,

2. Wood-Ivey Systems Corp. (WISCO),
   P O Box 4609,
   Winter Park, FL 32793, U.S.A.

Global Positioning Systems (GPS)

1. Trimble Navigation,
   P O Box 3642,
   Sunnyvale,
   CA 94088-3642, U.S.A.

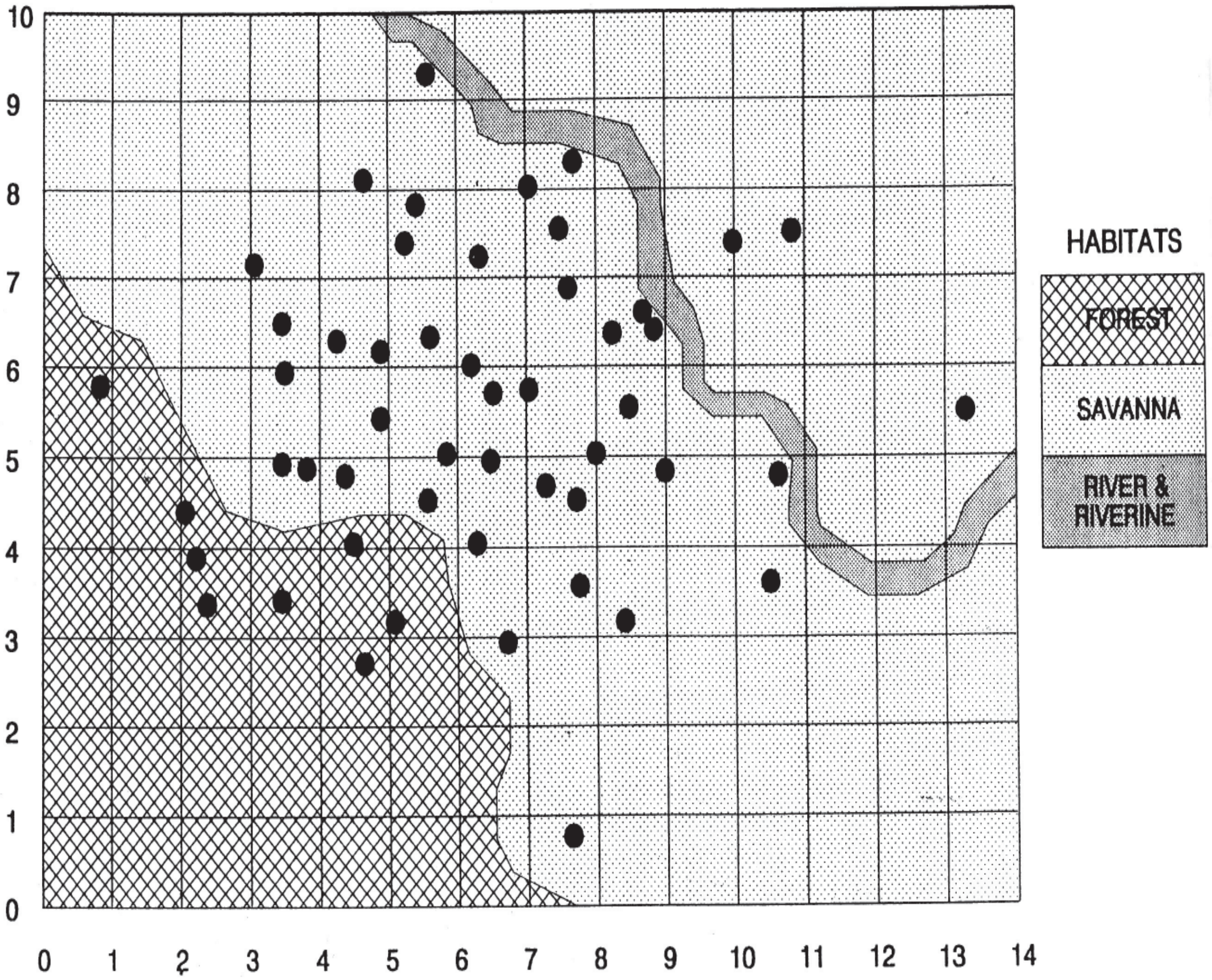

Fig. 8.5: A Cartesian grid overlaying a hypothetical vegetation map and fixes representing a home-range.

2. Garmin,
   9875 Widmer Road,
   References
   Lenexa, Kansas 66215, U.S.A.

3. Magellan Systems Corporation,
   960 Overland Ct.,
   San Dimas,
   CA 91773, U.S.A.

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CHAPTER 9

STUDYING ELEPHANT- HABITAT INTERACTIONS

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9.1 INTRODUCTION

The study of the interactions between elephants and their habitats is of interest both to ecological scientists and to wildlife managers (see Chapter 2). The management goals of a protected area authority can vary from the preservation of habitats in a chosen status quo (e.g. Martin & Conybeare 1992), to the maintenance of maximal biodiversity (Western 1989), to the conservation of ecological processes which allows latitude for habitat change (Sinclair 1983). The impact on habitats caused by elephants while feeding, particularly on woody plants, has been viewed with alarm or equanimity, depending on the observer's value system (Caughley 1983) and his management goals.

Generally, researchers are asked by managers to address a question which can be expressed simply as "are elephants causing the reduction of a woodland?" The decision to be made by managers is whether intervention is necessary to reduce or otherwise control the density of the elephant population, if the reduction of woodlands is seen as undesirable. It may be possible to provide an answer fairly readily to this simple question and to related questions about the rate of the change, but the management of wildlife areas might be improved if research can pose and answer more difficult questions about all the factors controlling woodland establishment and change.

The study of elephant-habitat interactions is very broad and includes not only the elephants' population dynamics, density, distribution and diet selection, but also the population dynamics and responses to environmental stresses of the plant communities. The interaction between elephants and trees involves the effects of elephants on plant survival and recruitment and the effects of changing food supplies on the elephants' survival. These are huge topics, with a long history of research and a vast literature in each area. It is also the case that tree populations are affected by environmental factors other than elephants. These factors include fire, climatic extremes such as drought, high rainfall and flooding or frost and high wind, browsing by other herbivores and the activities of man.

Elephant population dynamics are generally slow - they are long-lived, reproduce at a low rate, and have low mortality. Trees are also relatively slow-growing. Achieving a complete understanding of the interactive processes involved would require several centuries of observation, but a framework for understanding can be developed through building models of the hypothesised relationships between elephants and their habitats. A model can be simple or complex, from a diagram with boxes and arrows on a piece of paper to a detailed systems model on a computer. Any model developed should be seen as a tool for describing and understanding a system which operates on a scale which is larger than the human life span.

Since the most obvious feature of the interaction between elephants and habitats is the effect of elephants' feeding on plants, and since this is usually the question of most immediate concern to wildlife management authorities, this chapter will focus on the measurement of plant responses to elephant herbivory and describe some methods to study this in relative detail. It will discuss other aspects of elephant-habitat interactions in broad terms and provide information on the literature sources of these subjects.

9.2 METHODS FOR ASSESSING CHANGES IN TREE POPULATIONS

9.2.1 General

As discussed above, there are many possible levels of inquiry into elephant-habitat interactions. On a basic level, a simple description of the extent of elephant impact on trees will suffice. To gain a deeper understanding of the population dynamics of trees, it is necessary to look at the rate of loss of adult, canopy level trees, and the rates of establishment, growth and survival of smaller size classes through time. The degree to which these rates are affected by elephants as well as by other factors, such as fire and other herbivores, is also important.

9.2.2 Vegetation mapping

At the outset of any programme of elephant-habitat research, it is essential to have some form of map of the geographical distribution of the main vegetation communities. Such a map is useful for two reasons: a) to determine the relative area and location of specific vegetation communities of concern, such as riverine woodland or hilltop thickets, and b) to provide a basis for the stratification of sampling effort (see below).

Vegetation mapping in its most ideal form is done by reference to satellite images supported by numerous measurements of plant species composition on the ground. Computer-aided classification and multivariate statistical techniques (Jongman *et al.* 1987) allow the classification of site measurements of vegetation composition into habitat types or communities and refine the interpretation of satellite images. Mapping at a more modest level is accomplished by visual examination of aerial photos and delineation of apparent community types, again with checking and correction on the ground. However, even this level of technical sophistication is not always available. In the absence of a detailed vegetation map, even a rough estimate of the distribution of vegetation types would be preferable to none at all.

9.2.3 Historical accounts

Information on the trend through time in the structure of plant communities and elephant densities can come from historical accounts, whether written or verbal (Dublin 1991; Campbell 1991) Historical information is particularly useful if it is accompanied by photographs in which the localities can be identified and revisited for comparison (e.g. Lock 1993). More quantitative data on changes in tree cover can come from analysis of aerial photographs or satellite images (see Section 9.2.4).

9.2.4 Remote sensing

There are a number of sources which can provide data on the nature of habitat on a broad geographical scale. These include various forms of remote sensing, a broad term which includes both images obtained from satellites and from aircraft.

Satellite images are useful for mapping and assessing changes in ground cover over large areas at a relatively low cost. Images are produced from measurements of the reflectance of light at different wavelengths, some of which are specifically directed at vegetation cover. A variety of satellites have been launched, beginning with Landsat l in 1972 and followed by others in the Landsat series and the French SPOT system in 1986, with a steady improvement in the spatial and spectral resolution of the sensors.

Budd (1991) discusses the relative merits of different satellite products. An advantage of satellite data is that they can be analysed readily by computers, particularly with Geographic Information Systems (GIS). This can allow rapid classification of large areas of ground if the reflectance characteristics of vegetation can be identified. The reflectance data are well-suited for classifying vegetation which is fairly uniform over large areas, and less so when the pattern of spatial variation is complex. They can be used to great effect for mapping areas of bare ground or burned areas. However, there are a number of factors which can affect the reflectance of vegetation including the complexity of plant vertical or horizontal structure and variations in moisture content, soil type, atmospheric effects such as dust or water vapour and the angle of the sun at different times of year. As noted above in the discussion of vegetation mapping, sophisticated computer techniques can also be a drawback when these facilities are not available, and this can put satellite data out of the reach of many. There are a number of remote sensing centres located in Africa where images can be processed on request and a growing number of companies which specialise in these techniques. The application of satellite imagery to elephant -habitat interaction is still an early stage, but may ultimately prove to be a very useful technique (Nellis & Bussing 1990).

Quantitative information on habitat structure over large areas, and through time can be obtained from aerial photos. Generally the type of photographs which are available for this purpose are vertical photographs produced by

government departments responsible for mapping and are available at a scale of roughly l :50,000, which may also be in stereo pairs.
Photographs at a larger scale, such as l :4500, can be undertaken for the specific purpose of habitat monitoring (e.g. Viljoen 1990). Often these photographs are taken with “false colour” film which is sensitive to infra-red light which detects leafy vegetation more effectively. For this purpose, it is possible to purchase relatively high quality cameras, by manufacturers such as Hasselblad, which can be mounted in the body of a small fixed-wing aircraft.

The smaller scale photographs are generally useful only for examining changes in tree canopy, while larger scale photographs may be used for both shrubs and trees. It may also be possible to identify individual tree species on the larger scale photos, but rarely on those of the small scale.

Methods of analysis usually involve outlining identifiable vegetation patches or areas of bare ground as polygons with a marker pen and then overlaying these with a specially designed sheet consisting of a calibrated random distribution of dots. The number of dots counted, multiplied by a certain factor will give you the area of the defined polygon (e.g. Dublin 1991; KCS 1991). Tree densities within such delineated areas may be counted directly (Croze 1974). More sophisticated techniques. involving image analysis software in computer systems have also been developed (Viljoen 1990), and when such equipment is available, it can reduce the amount of time required for data analysis.

Another source of data on the spatial distribution of woodland change are low-level (300ft agl) systematic aerial surveys which are often undertaken by researchers for censusing large herbivore populations (See Chapters 3 and 4). During such surveys, an observer can estimate and map the relative extent of damaged or fallen trees (A. Verlinden pers. comm.).

9.2.5 Ground-based vegetation sampling

Ground-based photographs provide a visual record of the state of habitats. Qualitative information can be obtained from comparison of ground-based photographs from earlier observers (Dublin 1991). More quantitative information can be derived from such an approach if the photographs are taken as panoramas from precisely the same spot on repeated occasions (Dunham 1989). There are limitations to this technique, since as plants become more sparse and distant from the photographic point, they are increasingly difficult to recognise.

Ultimately the most detailed data must come from examination and enumeration of plants in ground-based vegetation sampling. The most accurate and repeatable measures come from vegetation plots. It is necessary to examine the vegetation in sample areas which are representative of the area as a whole. Sample sites should be located on the ground without bias and this can be done by using a map with an overlying grid and choosing the points to sample with a random number table. However, as Anderson and Walker (1974) point out, it is best to locate sample sites within zones or strata which are relatively uniform or homogeneous plant communities, rather than on the ecotone or boundary between types. Such stratified vegetation sampling can be done with the use of a map of the main vegetation community types.

The method of sampling may also be
“plotless”. Such methods include the Point Centred Quarter (PCQ) technique (Croze 1974) which measures the distance to the nearest plant, or the occlusion quadrat or Bitterlich stick (Lewis 1991) which uses the angular overlap of tree canopies with a calibrated measuring gauge to estimate cover and density. These methods may be useful for a one-off survey but they tend to give over- or under≠estimates when vegetation is dumped or cover is high or variable. They are also difficult to replicate at later dates.

The most reliable method involves counts within defined areas on the ground (e.g. Anderson & Walker 1974; Barnes 1983; Guy 1981; McShane 1987; Mueller-Dombois 1972; Mwalyosi 1987). Since this method is the one most commonly used by researchers in the study of elephant - habitat interactions, it is discussed in more detail in Box 9.1.

Measurements of individual plant species should include plant density, canopy cover, canopy volume and extent of damage by elephants or other agents in broad categories (Anderson & Walker 1974). Plant height or classification into categories such as adult trees (>3m), shrubs (1-3m), seedlings (0.15-im) and new seedlings (<0.15m) should be recorded. It should be noted whether plants in the lower size categories appear to have been reduced to a coppiced shrub by elephant impact. Categories for percentage damage to tree canopies should

BOX 9.1: GROUND-BASED VEGETATION PLOTS

Ground-based vegetation plots involve counting plants in defined areas on the ground. The number of plants counted can be converted to density by dividing the total area sampled. The number of plants in different height categories or damage classes can be expressed as a proportion of the total number counted.

Vegetation plots can be of different configurations: either "belt' transects or square or circular quadrats of varying size. Generally the most convenient to use are transects since they can be aligned on a compass bearing down the centre line, with a constant width measured by a tape measure stretched out on either side. It takes more time and effort to measure and delineate a square quadrat on the ground and there is a greater chance of incorrectly counting plants at the edge of the quadrat. Transects can also be aligned to fall within narrow vegetation types, such as riverine fringes, or to run at right angles to known gradients in environmental conditions so as to minimise the variation between transects. A circular plot, with a fixed point in the middle and a measuring tape used to delineate the outer boundary may be used for relatively small plots, such as up to 100m in radius. This method may be particularly useful for one-off surveys.

Decisions on the size of the sample plot, such as the length and width of transects, should be based on the number of trees, shrubs or seedlings which can be included. This is a function of plant density and generally, shrubs are more numerous than trees, and seedlings more numerous than shrubs. This means that, along a transect, the broadest width dimension must be used for counting trees, with narrower widths for shrubs and seedlings. Anderson and Walker (1974) recommend that at least 10 individuals of the dominant woody species be included in each transect and I would recommend at least 20 should be included. In their examples, Anderson and Walker (1974) used transects of length 50-100m and of width 1-10m for shrubs and 5-100m for trees.

Vegetation is patchy and both plant density and impact effects are not likely to be distributed evenly across the study area. For this reason, it is necessary to have several replicate transects within each habitat type to include the range of variation present but still have acceptable confidence intervals on the measurements taken. As a rough guide, at least 20 replicate transects should be measured. The aim should be to count several hundred, and if possible thousand, trees of the species of concern in each habitat type.

Some initial sampling of trees in transects of varying dimensions should be down to allow you to determine the size and number of transects which will give reasonable confidence intervals, on the order of 10-20% of the estimate.

Statistical analysis should include descriptive statistics such as the calculation of means and confidence intervals and comparison between habitat types or of the same type at different time with analysis of variance. Count data obtained for trees in transects are not normally distributed so these will need to be transformed by taking the (natural) logarithm of the count + 1 (since one cannot take the logarithm of zero). Analyses should be performed on the log-transformed data, then restored back to counts for the display of results. Note that the restored confidence intervals will not be symmetrical.

include: 0, 1-25, 25-50, 50-75, 75-99, 100 (the latter indicates the tree is dead). Estimates of percentage bark stripping should be recorded separately. Finally, it should be noted whether damage is new (i.e., fresh, within the last year) or old.

Unless the intention is to gather data quickly and not to return to the same plot, the plots should be permanently marked so that they can be returned to for repeated measurements. Concrete or stone markers, probably a pyramid or cone buried in the ground, are needed because elephants will disturb less permanent markers (G.C. Craig pers. comm.). A detailed record should be kept of the location of the plot, with distance and compass bearing from the nearest road, and notes on landmarks and vegetation. However, vegetation may be of limited use since elephants may remove the trees. When available, Global Positioning System (GPS) receivers should be used for locating the exact geographical coordinates of vegetation plots.

9.2.6 Survivorship studies

The rates of survivorship of trees of different size classes, and promotion or reversal of trees to different classes is best studied with tagged trees. Metal tags with a number punched on them can be nailed to tree trunks or wired to smaller stems. These must be visited regularly so that the loss of tags can be distinguished from the disappearance of the tree. Counts of tagged trees killed by different damage agents from one visit to the next can be used to calculate the survival rates per unit time of different size classes. Notes on individual tree locations, such as distance along a transect and perpendicular distance from the centre line should be kept to assist with identification. A knowledge of the relationship between size and age of trees is also important at this level of analysis (Dublin *et al.* 1990).

9.2.7 Experimental approaches

The most effective experimental approach to assess the effects of elephant impact on vegetation is to assess plant responses under differences in elephant density. It is important that other factors, such as soils or habitat structure are held constant so that the only factor which varies is elephant density.

Exclosures, where an area of habitat is protected by an elephant-proof fence, as in Sengwa (Guy 1989) or a ditch as in Murchison Falls National Park, Uganda (Lock 1993) or Tsavo National Park, Kenya (van Wijngaarden 1985) only give an indication of plant dynamics in the total absence of elephants. If an exclosure is established when elephant densities are low but rising, it can show how vegetation conditions would remain had the increase not occurred. If established at high density after impact has occurred, it can give information on recovery rates of vegetation. Exclosures are often used in conjunction with fire exclusion plots to separate the effects of elephants from other environmental factors (Lock 1993).

It may be possible to make use of manipulations which produce variations in elephant density in different areas e.g. different culling intensities, inside versus outside parks, etc. The former was proposed for Tsavo (Laws 1969) and is being contemplated for Kruger National Park, South Africa (A. Hall-Martin pers. comm.).

Density gradients are the most powerful method of obtaining information on the relationship between animal use and vegetation condition (Andrew 1988). This happens at naturally occurring sites which are attractive to elephants, such as water sources or mineral licks or when there is concentration in a national park due to poaching (Western 1989). However, because these are also generally associated with gradients in soil type and vegetation communities, the effects of simple differences in elephant density are confounded. There are two possible approaches to this sort of problem. One is to study the vegetation at artificially created water points or salt licks, especially if they are in otherwise uniform habitat. The other is to establish transects which run parallel to the known environmental gradients but at a distance from the waterpoint sufficiently far so as to avoid the effects of density J.ndu Toit pers. comm.).

Elephant densities will converge on artificially constructed waterpoints. such as those in Hwange National Park, Zimbabwe (Conybeare 1991). It is then possible to measure vegetation on radial transects (Thrash *et al.* 1991). It is also necessary to have a measure of elephant density along the transect, which can be assessed by dung counts or direct observations.

In such cases It should be possible to relate directly elephant densities to change in habitat structure. It is critical that the length of time of elephant occupancy at the different densities is known. For example, in the analysis of vegetation change around waterpoints for livestock in the Kalahari of Botswana, Perkins and Thomas (1993) found that both age of the waterpoint and livestock stocking rate were important factors in determining habitat condition.

The data for this type of experiment can be examined by plotting the measurements against distance from the waterpoint and looking for correlations with elephant density measures. The development of a gradient in vegetation condition over time can be followed, as the elephants/area! time variable increases. A further experimental level can be added by varying the regime of water provision to look at the change and recovery of vegetation after different periods of sustained impact (Child 1968).

9.3 ELEPHANT BIOLOGY. DIETS AND IMPACT ON VEGETATION

The areas of interest in the study of elephant habitat interactions are elephant population densities in the study area through time, food choices, and rates of impact on woody vegetation by elephants in relation to environmental factors.

Elephant densities may be measured in the whole area or in key areas of concern in different seasons. There should be an examination of elephant distribution in relation to habitat resources such as minerals and water supplies. Elephant densities can be expected to be high near water sources in dry seasons and there may be changes through time in elephant densities. Increase in density can occur as numbers increase through reproduction or immigration into protected areas. Declines in elephant density can occur after culling operations or poaching.

Feeding choices may be examined by direct observations of behaviour (see Chapter 10) or more indirect methods. While the former is the most obvious way of obtaining direct information about elephant diets, there are a number of problems. It is not always possible to observe elephants, if the animals in a given area are not easy to approach because of the lack of visitors or the presence of poachers. Viewing conditions may not allow it in dense habitat, rough terrain, or at night-time. There is a need to achieve balanced sampling with respect to use of areas and habitat types. Differential feeding rates may mean that observations of diet choice are biased against foods with high intake rates.

Indirect methods of estimating diet include examining stomach samples from shot elephants, analysis of faecal samples and plant-based methods (Chafota 1994; de Villiers *et al.* 1991).

9.4 MODELS OF ELEPHANT- HABITAT INTERACTION

Models of the responses of plant populations to elephant impact have been developed by Caughley (1976), Norton-Griffiths (1979), Barnes (1983), Dublin et al. (1990) and Craig (1992). Of these, the approach taken by Dublin *et al.* (1990) in modelling tree population dynamics may be the most useful. All these models have their particular advantages, but tend to depend on the nature of the mathematical formulae involved. An approach which avoids this drawback is rule-based modelling, as advocated by Starfield and Bleloch (1986).

9.5 OTHER SPECIES AFFECTED BY THE INTERACTION

Censuses of other mammals, birds or other animal species can be conducted to determine which are affected negatively or positively by the habitat change induced by elephants. More detailed study of the habitat requirements of such species would reveal the aspects of habitat which are most critical.

9.6 CHOOSING A STUDY APPROACH AND METHODS AND PREPARING A RESEARCH PROPOSAL

As Taylor (1993 and in Chapter 2) notes, the design of a research or monitoring programme should be linked from the outset to clear management goals, and this is especially true in the case of elephant-habitat interactions. In broad terms, research involves observations or experiments aimed at testing hypotheses about ecological processes, and is not always directly related to management. Monitoring is a form of research which is specifically intended to detect change in ecosystems and can be designed to provide feedback on the effectiveness of management actions in achieving pre-determined goals. Research may be undertaken in short or long term projects while monitoring is expected to provide results over the medium to longer term. If the management of ecosystems is truly “adaptive”, its actions or even goals are reassessed and modified on the basis of results from research and monitoring. Equally, research or monitoring approaches may be modified as results come in or management goals change.

Deciding on what to study will require giving much thought to both the goals of the research and the logistical constraints under which you are operating, so that the study is focused very clearly on the questions you want to ask and your ability to obtain answers in a reasonable time period. It cannot be emphasized too strongly that the extra time spent at the beginning in designing a research plan can save a vast amount of wasted time, effort and resources later on. A clear research proposal should be drafted and circulated for comment, both within the government or research institution where you work and among professional colleagues, by correspondence if necessary. You should not be shy of consulting the established national or international experts in your field of study, and if you are in doubt about whom to contact, you may start with the IUCN/SSC African Elephant Specialist Group, the body specifically constituted to encourage technical cooperation on elephant management.

It is recommended that the relevant management authorities are consulted in the development of a research or monitoring plan. It is likely that the process of consultation may at least alert the management authorities to your activities and could well initiate a degree of mutual understanding. Whether or not you receive useful comments from the managers, the process should at least make you aware of their concerns and open the possibility of dialogue.

Different objectives require different types of treatment. If the managers want quick estimates of the rate and extent of woodland loss, a one≠off, extensive survey of trees is called for. This may be necessary on a broad geographical scale or only in key areas of concern. If a more comprehensive understanding of woodland dynamics is called for, then sites of fixed vegetation plots should be returned to on a regular basis, possibly yearly. The age structure of the tree population should be assessed, along with survival rates of different size classes, reversal rates to lower size classes and recruitment to the adult stage. Repeated measurements of permanently identified stands of trees are needed for this type of information.

The study proposal should set a time schedule for research activities and a deadline for achieving results and preparing a report on them. This is particularly important in studying elephant -habitat interactions, since the time scale on which the ecological events occur is long, but the time scale on which answers are required for management decisions is generally short. There is a danger with an open-ended study of a difficult problem that no answer will be emerge apart from the unsatisfactory "more research is needed". Another danger is that the researcher will be asked to provide answers that go beyond what his results can provide into the realm of unsupported opinion. An agreement in advance between researcher and manager would help to avoid these twin evils.

There are different scales in space and time that must be considered in planning a study approach:

a) Geographical or spatial scale
This involves the location and types of area concerned, from protected areas to areas with a limited degree of human occupation to areas adjacent to or including intensive human activity. The study area may encompass the whole range of the national population or focus on key areas of specific concern.

b) Time scale
Knowledge of past events and trends in the vegetation can place the present measurable conditions in context, and provide insight on the large-scale processes already underway. Information on tree populations and elephant densities from as far as back as possible into the past up to the present is needed for the determination of the rate and direction of change and for generating possible scenarios for the immediate, short-term and longer-term future.

Logistical aspects to consider include the availability and competence of biologists and field workers, time, equipment (including transport), other running costs and methods of analysis to be used. An overbearing constraint on all these aspects is the funding available to support the proposed activities.

A successful approach to a large problem, such as elephant - habitat interactions, is to divide it into manageable parts, so that an overall research programme can be defined, composed of individual projects each of which are "do-able" and which may be tackled in order of priority as and when resources allow. A summary of the methods which are recommended for use in addressing the different questions raised by a consideration of management objectives can be found in Table 9.1.

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Research questions	Historical accounts	Satellite imager	Aeral photographs	One Off vegetation survey	Repeated vegetation samples	Exclosure and / or gradients	Elephant population studies	Elephant behaviour studies	Modelling interaction dynamics	Studies of other species
Goegraphical distribution of habitat structure types and damage in elephant range	L	SML	SML	S	ML					
Amounts of woody cover and damage in specific areas	L		SML	S	ML					
Rate of change in habitat structure	L	ML	ML		ML	ML				
Distribution of elephant density	L							SML		
Rate of change in elephant density	L							ML		
Effect of elephant density on habitat structure	L	ML	ML		ML	ML		ML	SML	SML
Effect on other animal species	L									SML
Scenarios for different management options									ML	

Table 9.1 The research methods which are most appropriate to address questions derived from management objectives. Coded entries in the table refer to the time scale addressed: S= short term, the current situation. M= medium term, reflecting events over, say, 2-5 years. L= long term, covering a period ranging from 5+ years to several decades.

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CHAPTER 10

STUDYING THE BEHAVIOUR OF ELEPHANTS

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10.1 INTRODUCTION

Why study behaviour? Among elephants, as in any species, behaviour provides insights into the ways in which animals live and die, what they eat and how they find it, how they form groups, mate and rear young. Behavioural studies can examine ranging patterns, feeding behaviour, social dynamics, mating, care of young and communication. They can thus increase our understanding of basic biology and sociality of elephants in the wild, and form an integral part of management strategies and conservation programmes.

The first step in any behavioural study is to decide the kinds of questions which will be addressed. This is particularly important, since once a question has been defined, then the kinds of data needed, the detail and quantity of data required and the duration of the study will become clear. In the past, field biologists would locate their subjects and basically record all behaviours of interest. However, more recent behavioural studies recognise that time and money are limited. The most effective ways to collect information are to formulate a hypothesis, or test a model; or to highlight one particular aspect of behaviour which specifically needs investigation in a specific population. Hypothesis testing and model building are relatively complex and require a good familiarity with the appropriate literature before the study begins. Studies of specific populations also need some background research, both to identify the question of interest and in order to make broader comparisons with other populations. These two approaches, the theoretical and the population specific, are not mutually exclusive, and in many cases data collected from a particular population can be used to revise and refine existing models. The important point remains; first define your question in order to determine the best way to gather data!

How, then, is the focus of the study decided? There are both practical and theoretical ways to decide how to select behaviour for study. For elephants, practical questions are often of greater immediate relevance than more theoretical issues. But even if the choice of a research question is determined by practical considerations, a number of basic principles in the study of behaviour should be borne in mind. In terms of classical ethology or studies of behaviour, there are four main areas of investigation (Tinbergen 1963). These are development, causation, function and evolution, defined as follows:

i) Questions about development address how the behaviour comes about during the life of the animal. A developmental question can chart the presence and form of behaviour from infancy to adulthood, for example the change from suckling to independent feeding, or it can focus on a single phase during development, such as play fighting and its relation to aggression.

ii) Causation relates to how the behaviour is produced and the mechanisms by which a behaviour is evoked. It often has a physiological, anatomical or neurological component. For example, the heightened aggressiveness of bulls in musth (see Chapter 1) can be understood in part in relation to the hormonal changes with are associated with the musth state.

iii) Function seems relatively straightforward; what does the behaviour accomplish? However, the current utility of behaviour (what the behaviour does at the present moment) can be examined separately from the more general adaptive function (i.e, to increase survival or reproduction). At this level of study, the focus should be on immediate function -what does the behaviour achieve at the time it occurs?

iv) Evolution of a behaviour can rarely be tackled through a study of existing behaviour, In most cases, a behaviour evolved in the history of the species, and it may or may not serve the same function at the current moment. This emphasises the need to keep the questions of current utility and past adaptation separate in generating hypotheses.

If the behavioural study takes a theoretical approach, an understanding of the difference between these four areas of study is crucial to the establishment of the specific hypotheses which will be tested. An hypothesis is an explicit statement of a link between cause and effect. In the sense of classical logic, "if A, then B". An hypothesis may be difficult to prove definitively, but it should be capable of being disproved - or falsified. A behavioural study using hypothesis testing must be designed to test the proposed causes and their effects, and will need careful attention to statistical methodology.

On the other hand, practical issues may be central to the determination of the research question. For example, an ecological study of elephant - habitat interactions may be necessary in order to assess the impact of elephants on vegetation in a confined area over the long term. In this case, the behavioural component of the study might be to examine elephant feeding rates, food choice, seasonal ranging patterns, and group distribution, in combination with a programme of vegetation monitoring (see Chapter 9). Another example of a practical problem leading to the formulation of a behavioural research strategy might be the conservation issues involved in studies of the genetics of small populations. By observing mating and rearing behaviour in a population, far greater information on the genetic contributions of different individuals to subsequent generations will be made available, and the assumptions of the genetic models can be refined and made specific to the particular population.

10.2 DEFINING BEHAVIOUR

10.2.1 General

In order to study behaviour, it is first necessary for the observer to define the behaviour. In most studies, these identifications take the form of a definition, which is made by the observer. Behaviour can be defined either by its motor patterns or actions; for example categories of locomotion can be straightforwardly defined as walking, standing or running. Alternatively, these same motor actions can simply be lumped together in a category called "locomotion" or "moving". Here, the behaviour is defined by its outcome rather than by any specific actions. However, if an elephant is taking a mouthful of grass for every two steps forward, the definition of this act as feeding or as walking is subjective, and the actual term applied to the behaviour depends on the goals of the study. If the aims of the study are energetic or ecological, the term "feeding while walking" might be most appropriate, and a careful assessment of steps per mouthful is essential in defining the behaviour. If, however, the study is examining play behaviour among calves, a more general term such as "moving" might be sufficient as a description of the activity. Behaviour can also be defined by its context, such as a general category called "oestrous behaviour" on the part of a female elephant, which is expressed specifically in the presence of a bull (see Moss 1983 and Chapter 1).

The important point is that the activities are observer defined"- and as such a record needs to be kept of the definitions and their rationales. This record should be referred to during the course of the study, to ensure that the formal, written definition and the practical categories actually recorded over time remain the same. It is also important that categories of behaviour are mutually exclusive - each action or outcome is used only in a single definition; they should be easily replicated both by the same observer in separate observations and by different observers; and finally, the categories should be limited in number. This will reduce errors leading to unreliable data collection. Some familiarity with previous studies is helpful in that terms and definitions can be standardised with other researchers allowing for comparisons with a number of studies.

The identification of a behaviour of interest, and the associated definition, present problems of subjective judgement. Often a behaviour's apparent function may be confused with its definition, thus limiting the observer's perspective on the behaviour, or his or her ability to see the behaviour outside its specifically defined context. For example, the simple act of calling head to head, tusk to tusk contact between bulls'"play fighting" assumes that the males are a) playing and b) using motor patterns seen in fighting. Neither assumption needs to be true, and thus calling the behaviour"“sparring” eliminates this potential source of bias. The problems of bias in the study of behaviour must be addressed constantly, from the initial step of deciding the study's aims, then with the definitions of behaviour, and subsequently with how the data are collected, analysed and interpreted.

10.2.2 Categories of behaviour

Elephant behaviour can be divided into the broad categories of activities, interactions, and associations. Activities are those acts performed in normal maintenance or on a regular basis, such as foraging, drinking or travelling. Interactions are behaviours exchanged between individuals. An interaction can occur between two animals (dyadic) or three (triadic) or several more (polyadic). The interaction can either be one where individuals simultaneously engage in some behaviour, or one where there is a sequential exchange. For example, two calves playing can take the form of head-to-head pushing -simultaneous and similar behaviour, or alternatively, one chases and the other flees - sequential behaviours, simultaneously exchanged (Lee 1986). Depending on the nature of the study, it can be important to distinguish between these types of interaction. A further important aspect of interactions can be distinguished during data collection; the identity of the individual who initiates the interaction and that of the recipient can be recorded. For example, during aggressive encounters between bulls, musth bulls are more likely to initiate a chase, while the non-musth subordinate males are more likely to flee (see Poole 1987, 1989).

Associations are not behaviour in the strict sense of the term; however, the determination of associations is often vital to understanding behaviour, its context and its consequences. An association reflects the propensity or likelihood of individuals to be found in the same place at the same time. Several general measures of associations can be made. The first of these is the “nearest neighbour”. The identity (for example, age/sex class) of two individuals and the distance between those individuals can be recorded to provide information about the strength of an association. Alternatively the number and types of individuals found within some specified distance to a single individual can be noted.

Distance measures can either take the form of estimates of real distance such as metres, which need to be practised for accuracy. Alternatively, the distance could be expressed as “elephant lengths”, using some standard reference length (e.g. adult female body length, or trunk length). Measures of proximity can be complemented with another measure of association, that of approaches and leaves. Here the individuals who initiate any change in proximity and the subsequent response of others are recorded, as if the change in distance between them was an interaction. Analysis of these types of data will be discussed below.

One problem raised by the study of associations is that of defining an elephant group. Since elephants can be found in ” groups” that range in size from two to 2,000, an operational definition of a group should be an essential starting point for a study. Sufficient information exists to use as a starting point the concept of a co-ordinated body of any number of elephants engaged in similar activities, travelling in the same direction and none of whom is further away than the diameter of the main body of the group (Lee 1987). This definition contains no assumptions about the composition of the group, whether bulls, cows and-calves or mixed sex groups, nor does it imply that a group and a family unit are synonymous. Indeed, a careful definition of a group allows for detailed studies of group composition and individual stability in association patterns.

10.2.3 Duration of behaviour

In general terms, elephant and other animals' behaviour occurs either as a discrete event or over a longer period, as a state of behaviour. Events tend to be characterised by a single quick occurrence, for example placing a trunkful of grass in the mouth is a single event of short duration. However, the state of feeding or taking a number of trunkfuls, can last for several consecutive minutes or even several hours. The way in which the behaviour is to be sampled depends on whether it is an event or a state. Events are best sampled as frequencies (number per unit time), while a state can be expressed as a function of its duration (time spent in the state). The recognition of the type of behaviour, event or state, is of crucial importance to sample design and determines how frequently observations are made and for how long.

Several types of measures have been defined (e.g. Martin & Bateson 1986). These are the latency of the behaviour, expressed as the time between one new food, One means of ensuring that each event and the occurrence of some specified second event. For example, the delay between a threat and a retreat can be measured in terms of latency to respond to aggression. The next is that of frequency, or how many times the behaviour occurs within a specified time period; e.g. the number of trunkfuls of food per minute. This can be expressed as a rate of occurrence per unit time. The duration of a behaviour is the measure of how long the behaviour lasts, and is expressed as seconds or minutes (length of time) per event. Finally, the intensity of the behaviour can be recorded. Here, some qualitative assessment of the level of arousal is made, and this tends to be a subjective decision, or a post *hoc* determination made during analysis. For example, a greeting accompanied by vocalisation, defecation and urination can be rated as of a higher intensity than simple trunk to face contact (Moss 1988).

A final consideration is that of bouts. If a behaviour consists of a discreet motor pattern or act which is followed by another act of the same type, the behaviour can be considered to occur in a bout. For example, a suckling calf may make nipple contact, break off sucking for a short time to take a step, then make contact and suckle again. The problem presented here relates to the issue of dependence; the several nipple contacts are all behaviourally linked together. The calf continues to suck until some milk intake has been achieved, and scoring each separate contact as a suckling event would artificially inflate the frequencies of suckling. This is a problem because the behaviour at the start of the suckling attempt actually determines the behaviour that will follow that event, and the starting behaviour also determines how long the state will last. Thus each record of suckling behaviour is statistically (and practically) dependent on the previous behaviour. To overcome this problem, the separate contacts to the nipple can all be classed within one bout of suckling, and another separate suckling bout can be determined after a set time has elapsed. Here, the latency to resume suckling can be measured and a criterion for separating bouts determined from these latencies. Another example of the problem of dependence in bouts is that of feeding. If an elephant is feeding in the first record of behavioural observation, then what is the probability it will still be feeding in the second record? If the interval between records (sampling intervals) is small, then the second record is statistically likely to be a consequence of the first record. If, however, the interval between records is longer, then there may be an equal probability that the elephant will be moving or feeding new food. One means of ensuring that each record is equally likely to sample any behaviour (and thus be an independent record of events) is to use a long interval between records. However, this may mean that rare events are completely missed during sampling. Statistical methods for the analysis of behaviour thought to occur in the form of a bout have been devised and are discussed by Slater and Lester, (1982). These examples show that recording behaviour in fine detail allows for more exact analysis, and that issues of how best to analyse the observations must always be considered in designing the sampling methodologies.

10.3 BEHAVIOURAL SAMPLING

10.3.1 Sampling techniques

How the behaviour is to be sampled depends initially on the study’s aims, which determines which behaviours are to be recorded. Sampling procedures are then dictated by the need to record behaviour that occurs as an event or to record the duration of states, And finally, they will be affected by the biases or dependency in the behaviour.

The best technique for sampling animal behaviour is to make a continuous recording of the selected behaviours from a specific individual. This is the Focal Animal Sampling method pioneered by Jeanne Altmann (1974). A single animal is chosen, and a record of its behaviour is made for a specified period of time. The subject must be relatively easy to identify, to locate and to remain with during the sampling period. These requirements limit the applicability of this technique in many studies of elephants. However, focal animal sampling can be extended to groups or age/sex classes. The principle of this technique is to remain with and record behaviour from a specific sample group, for example a family unit, at established intervals for a set length of time. Again, the period of time chosen for the focal sample needs to reflect the possibility of observing the behaviour of interest during that sample. A focal sample designed to examine feeding could be as short as ten minutes, if feeding occurs every two to three minutes. However, if the behaviour of interest is rare, such as suckling or play, then samples of several hours duration may be necessary in order to pick up the behaviour. Within the focal sample, behaviour can be recorded either only at specified intervals during the sample, such as every five minutes for a one-hour period, or continuously throughout the specified period (Fig. 10.1). Sampling intervals are pre-determined points in time during an observation when behaviour will be recorded, and the determination of the interval depends on the rate of occurrence and the duration of the behaviour. It is essential to avoid the problem of bias in data collection, which occurs when the sampling interval is short, relative to how long a behaviour lasts. This is the problem of dependence in the data, which was mentioned in relation to bouts.

Interval Sampling£can be either instantaneous, in that only the behaviour which occurs at the specified time point is noted, or zero-one sampling where only the first occurrence of an event is recorded during the specified interval. This latter technique poses analytical problems in that no duration can be measured and frequencies of rare events tend to be over-represented, while those of very common events tend to be under-represented (Altmann 1974; Dunbar 1976; Martin & Bateson 1986; but see Rhine & Linville 1980). The technique of continuous recording allows for precise durations to be attached to events, and accurate rates of occurrence can be determined. Such samples are, however, time-consuming in terms of both data collection and analysis and prone to unexpected termination due to poor visibility or loss of the focal animal. They also limit the number of individuals that can be sampled during a short study period. Such samples are probably best made using an event recorder or computer.

One alternative technique is that of Scan sampling. In this method, a number of different individuals are located and their behaviour is recorded at a specific time. This is a powerful and effective means of sampling for basic activities and common interactions, or for associations between individuals. However, it must be stressed that repeated scans on the same individuals or a number of individuals in the same group carry a risk of producing dependence in the measured behaviour. Care must be taken to ensure that if more than one record is made from a group, each scan is made at intervals great enough to ensure that the first behaviour recorded will not determine the subsequent records - in other words at independent intervals. It should also be recognised that group activities are often co≠ordinated, and therefore records from several elephants will be dependent on the location and group activity; for example if the group is at a water hole, it is likely that several elephants will be drinking, and the proportion of time spent drinking will again be artificially raised. Furthermore, if two animals are interacting, and scans are made of both, then the rate of interaction will also be doubled in comparison to the "real" rate of interaction. If individual A is playing with individual B, then recording two scans of playing will over-estimate the frequency of play as well as the degree of association. The scan intervals and choice of subjects need to be carefully designed to avoid this problem. It is very important to sample evenly across the range of age and sex classes represented in the group to minimise the potential sources of bias.

TIME ———>

A	S	ST		S/ST		S/ST		ST		ST
B	O	F		O/F		O/F		O		F
C	1	2	3	4	5	6	7	8	9	10
	P	P		P		P		P	P	P
D	1	2	3	4	5	6	7	8	9	10
	Y	N	N	Y	N	Y	N	Y	N	N

Fig I0.1 An illustration of different sampling techniques in relation to the occurrence of behaviour. A the behaviour to be sampled (S= Start, ST = Stop); B Continuous recording (0 - Behaviour On, F = Behaviour off); C; Instantaneous recording on the interval (P = - Behaviour Present on interval); D; Zero-one records of behaviour during the interval (Y = Behaviour recorded during interval, N = Behaviour not recorded, since only the first occurrence is noted). Numbers relate to the consecutive intervals in which the behaviour is to be sampled.

Behaviour-Dependent sampling is designed to maximise data collection on rare events. If, for example, the study is to focus on relatively infrequent events, for example calf play or the behaviour of oestrous females during matings, then the most efficient means of collecting data is to begin observations only when the behaviour of interest occurs. While this maximises the detail that can be collected with respect to the specific behaviour of interest, such samples cannot be used to determine frequencies of events.

A final category of observation is that of *Ad Libitum Sampling*. This is really a grand name for writing down specific behaviour of interest when it occurs unrelated to any interval or time sampling technique. It is useful only when the visibility of all individuals is similar, so that all animals are equally likely to be randomly recorded in a specific behaviour, and for behaviour which does not vary in the likelihood of attracting the observer's attention. It is, however, an excellent means of gathering data on events which are unlikely to occur in normal samples such as births, and for interactions where the direction of the interaction is of specific interest and the event is too rare to be sampled extensively by other means, such as threats or fights between bulls (e.g. Poole 1987).

10.3.2 The problems of bias

There are methodological and statistical problems associated with all these techniques, and the method chosen will usually be a compromise between observation conditions, absolute accuracy, complete independence and sample sizes. The main problems to overcome are those of dependence in the data collection, which can either be incorporated into the sampling design or into the analysis. If the behaviour is recorded at minute one, and again at minute 10, these two intervals can only be used in an analysis of frequency of behaviour if it is known that the behaviour did not occur for the entire 10-minute period. Otherwise a behaviour that has only occurred once with a duration of 1O minutes will be counted as occurring twice, and the frequencies grossly inflated. In most cases, sampling intervals which are practical in the field tend to under-represent rare events and over-represent states with long durations. Some balance needs to be struck between these problems, and this is best achieved by ensuring that the primary sampling interval is longer than the mean duration of the main behaviour of interest. During analysis, it is possible to exclude intervals which appear to be subject to dependence. Thus, if behaviour lasts for seven minutes on average, the data from 10 minute intervals can be analysed. It is better to over-sample slightly and then reject data at a later stage than to wish that more samples had been taken after the fact!

It is important to consider some other general biases. One of these is time of day. If certain activities are more likely to happen at specific times of the day, then over-representation of these times during observations can produce distorted estimates of rates of occurrence (see Harcourt 1978). For some behaviour, such as maintenance activities, it is essential to ensure that samples are evenly spread throughout the day. If certain behaviours are more likely to occur at the same time, for example if suckling is most likely when animals are resting, then determining the frequency of suckling if all observations are made during feeding periods will be futile. Such problems usually become apparent only during the analysis phase, and it is worth bearing them in mind during data collection and adjusting sampling intervals or sampling intensity (the frequency of sampling) over the course of the study.

Another bias can be that of habitat. When behaviour is associated with specific habitats then efforts must be made to sample evenly across habitats. Some behaviour, such as feeding or drinking, is obviously habitat-dependent, while resting may be more frequent in wooded areas. These considerations are critical if the sampling is designed to estimate the proportion of time spent in specific activities. Another habitat. specific bias is that of visibility. It may be impossible to observe elephants in dense bush, or in deep wet swamps. Alternatively, elephants may be nervous or disturbed in some habitats, such as those with poor visibility or near human settlements or farms. While these problems are unavoidable in any study, their potential effects on data collection and results of subsequent analysis need to be considered.

The dynamics of an elephant group can also pose problems, in that activities may be tightly synchronised within the group, as noted above. The resulting frequencies of a behaviour may thus depend on the size of the group when the behaviour is recorded. This emphasises the need to have a large enough sample to be able to account for observations drawn from groups of different sizes. The methodological drawbacks need to be borne in mind, although it may be impossible in practice to ensure that samples are representative of all the possible groups sizes. Such data should be presented with the cautionary note.

A final bias may be that of the observer's presence. Humans often change the behaviour of the animals they observe simply by being nearby. Wariness, flight and aggression are all possible elephant responses to human observers. Ensuring that subjects are relaxed around observers, or that observations are made at a distance great enough not to alter behaviour is an essential part of any study. The process of habituation'- getting animals used to the observer - is time-consuming (see Chapter 7).

10.3.3 Field experiments

There are times when the most appropriate method for studying behaviour is to manipulate a behaviour and observe the consequences. It can not be stressed too emphatically that in order to accomplish successfully a field experiment, the range of potential consequences should be known. Blind experimentation with a large, intelligent and long-lived animal with excellent individual recognition and memory (see Moss 1988) cannot be justified. However, many forms of field experimentation, when carefully approached, can produce extremely useful information, especially those relating to vocal and olfactory communication (see Poole & Moss 1989 and Chapter 11). Field experimentation typically consists of presenting a known stimulus to a novel group or individual and recording the consequences of this presentation. The choice of stimulus, its mode of presentation and the recording of behaviour are subject to the same constraints and design techniques as are observations of normal behaviour, with the additional constraint of ethical or welfare considerations.

10.4 DATA COLLECTION TECHNIQUES

10.4.1 Sampling protocol

First find your elephant! This is in fact more difficult to accomplish than might be thought. Choice of animals as subjects needs to be incorporated into the study design. The biases discussed above must be carefully considered, and the effects of time of day, habitat, group size, group composition, activity and so on, all need to be examined with respect to the choice of subjects.

The method least open to subjective or observer bias is to use some random sampling criterion. However, the randomisation of subjects is only possible when it is known that such individuals can be located with relative ease! In a random sampling method, a predetermined list of subjects would be generated. If the subjects are to be bulls, then where individual identities are known, they could be assigned to a sample order from a random number table (a published list of randomly selected numbers). If, as is more likely, identities are not known, then age classes (see Chapter 7) could be randomly sampled. The random assignment of age classes to the priority list of samples might produce a list of subjects as follows: male 1A, male 1A, male 3, male 4, male 2 etc. Thus, the first bull to sample would be a young bull in age class 1A or 10-15 years, followed by another of the same age, then a bull in class 3 or 25-35 years, then one in class 4 or 35-50 years, and another in class 2 or 20-25 years, etc. (see Chapter 7 and Poole 1989). A non-random but also predetermined list could be to take the first bull encountered in each age class, rotating through the classes throughout the sampling period. A list more prone to bias, but easier to follow would be to choose subjects as a function of their first sighting. As long as the next individual chosen was not in proximity to the previous subject, this technique maximises data collection for search time, which is always an important consideration in data collection. It can not be stressed too strongly that each sample on different individuals should be independent of the previous sample made, and that no single individual or age/sex class should be overly represented in the total samples.

One excellent means of locating and sampling independent groups or individuals of appropriate age/sex classes is to use a transect method. A predetermined search route is established, and all elephants contacted along this route are sampled over a specified time period. A transect has the specific advantage in that the chosen search route can be designed to sample evenly specific habitats or areas, and thus an accurate representation of elephant distributions and group sizes in each habitat can be made. However, the transects must also be made so that factors such as time of day are also considered. Thus a route that is followed on one day at a specified time should also be taken at different times of day and in different seasons, producing an equal number of points for day, month and year in each habitat. One minor problem is that elephants tend not to concentrate on routes at the observer's request. Thus the elephants of interest can be known to be elsewhere, and the transect will produce what is known as negative sightings or no record of elephants in the area. These negative sightings are also important, for they allow for an accurate assessment of preference and avoidance of specific areas.

An alternative method is simply to choose the first animal or group containing the appropriate age/ sex class which is contacted at a specific time of day in a habitat. This group or individual can then be observed for a set period of minutes to hours, or even over 24 hours where possible. While this tends to bias observations towards those groups which are more readily located, such as very large and visible groups, or towards habitats where visibility is good, it maximises sampling intensity and minimises time loss through searching. Typically, some compromise will be struck between the random and the first sighting techniques which will depend on the time and energy available for observation.

It should be noted that the method of observation again depends on the aims of the study. A study of young animals will obviously benefit from selectively and intensively sampling only those groups with relevant potential subjects such as calves, while one designed to examine habitat use needs to ensure equal representation of habitats used or not used by elephants. The intensity and effectiveness of sampling techniques depend on the ability to locate elephants, and to approach or observe them, and this will influence the study's design.

10.4.2 Recording data

a) Checksheets

The least technologically complicated, and thus the least prone to failure (and the cheapest) way to record data is to use a checksheet (Fig. 10.2). Checksheets are merely a means for ordering observations onto paper, and thus can be designed to collect data at any level of complexity. A simple checksheet will consist of a number of columns wherein predetermined categories of

STANDARD RECORD:

Sample/Identity	Date/Time
Location/Habitat	Weather
Group Size	Group Type

TIME	ACTIVITY	NEIGHBOUR	DISTANCE	NEIGHBOUR ACT.
00				
05				
10				
15				
20				
25				
30				

TIME (S/ST)	APPROACH	AGGRESSION	CONTACT	VOCAL	PLAY

Figure 10.2 A sample checksheet including both an instantaneous record for events and a timed continuous record for states and interactions. In the standard record, background information relevant to the sample is noted. In the next section, activities and nearest neighbours are recorded at five minute intervals. In the third section, the time of all interactions (start and stop) within the 30-minute observation can be recorded and the type of interaction coded into the appropriate column.

behaviour can be scored as and when they occur. Typically, standard information will be assigned to each checksheet - for example, date, time, location, weather conditions, sample number. Then specific information is encoded such as the individual or the age-sex class under observation, its group size, activity, habitat, and individuals **in** proximity or the general group composition. For a scan sample, this may be all that is recorded before proceeding to the next scan. In a focal sample, a number of such scans will be made on the same individual at the predetermined intervals, and along with this information a continuous record of all other behaviour or interactions can be made in the appropriate columns (see Fig. 10.2 & 10.3). Checksheets allow for rapid, accurate recording within predetermined categories, using codes placed within columns. Alternatively, categories of behaviour can simply be ticked as and when they occur. Greater detail can be written out in longhand, if some space is kept for notes. Checksheets using columnar form are also very easy to analyse, since it is quick and efficient to sum events in each column.

b) Field notes

Field notes tend to be a longhand record of all observations of interest, which can be transcribed onto a checksheet later. Field notes or observations can also be made into a tape recorder and subsequently coded onto sheets. These records can either be of the *ad libitum* type, or of standardised sampling protocols, where the recording device is in the first instance a notebook. These have the advantage of being inexpensive and easy for anyone to use, the sequences of behaviour can be preserved, and behaviour which does not easily fit into categories can be recorded. However, notebooks have the disadvantage of requiring considerable writing.

c) Tape recorders and video cameras

Tape recorders and video cameras are useful when much behaviour is occurring with great rapidity and the observer does not wish to lose visual contact with subjects to write on the checksheet. However, like all equipment, tapes, tape-recorders and video cameras are prone to failure in the field; considerable training is required before they can be used properly; and they are costly in terms of subsequent time needed for transcription or video tape analysis. Video cameras are especially useful when some documentary evidence would come in handy.

d) Computer event recorder

The most technologically complex mode of recording observations is the computer event recorder, where all sequential and continuous observations of acts and interactions can be coded together with time and identity keys. Computer events recorders require constant power levels, rather complex programmes for the encoding of data and even more complex programmes for the subsequent decoding and analysis. If computers are to be used in the field, it is essential to procure a hard (paper) copy of the observations on a very regular basis to guard against equipment and programme failure. As these machines become smaller, more powerful and more robust, they will prove to be the checksheets of the future. However, for those on a tight budget or with little access to power and technology, the checksheet remains a potent observational tool.

Scan Sheet No:

Date	Time	Loc	Hab	GP Size	B/ CC	ID	Act	Food	NN Act	NN Food	NN Dis	NN

Fig. 10.3 A sample check sheet used to make scan samples on groups of elephants, for sampling activity and proximity from a range of age/sex classes. Location (Loc) and Habitat type (Hab) are entered for each separate group or elephant sampled, along with group size and composition (e.g. the number of bulls and cows/calves -B/CC). Then the identity or age/ sex class of the scan subject (ID) is noted for that time along with the identity of the nearest neighbour (NN), its activity and food types, as well as distance between elephants. Other information could easily be incorporated, such as the general group activity, the presence of interesting elephants (oestrous females, musth bulls), the identity of the families composing the group and so on.

BOX 10.1: SMAPLING PROTOCAL FOR STUDYING ELEPHANT BEHAVIOUR

Priority 1: Determine which elements of behaviour are to be investigated, and why.

a) Establish the research question, its theoretical or practical aim, its cost and how long it will take.

Example:

	Mother-calf dynamics
Theoretical relevance:	Maternal investment, development of sex differences
Practical issues:	Calf survival, family dynamics, reproductive rates, growth
Cost and Duration:	Specific to site and methodology used

Priority 2: Ageing and sexing of individuals in the populations, identification, habituation to observer.

a) Establish a contact point with elephants. That is, how they will be observed and where they will be found. Will elephants be observed from hides, platforms or vehicles? Remember that static observation sites will provide site specific and probably activity specific data. Observations can be made on foot, but this carries substantial risk if the elephants are wary.

Evidence of elephant presence (vegetation damage, fresh dung, vocalisations) can aid in determining areas of high use. Transect drives or predetermined search routes through an area known to contain reasonable densities of elephants can be used as a starting point for finding elephants.

b) Age and sex the population (Chapter 7). This will provide the essential demographic information on the populations and the necessary background for choosing the subjects (and topics) for the behavioural study.

c) Identification of individuals (see Chapter 7). While individual identification is not a prerequisite of behavioural studies, far more information can be obtained and the validity of results will be greater when distinctions can be made between different matriarchs, families, or mature bulls. Establish a photographic or line drawing file of ears, tusks, body shape and size, which can be consulted rapidly under field conditions (see Chapter 7).

Example: Identify individual mothers, and where possible, calves; age and sex calves; age mothers; determine family compositions.

Priority 3: Determination of subjects for observational study.

a) Establish the subjects for study. In conjunction with the focus of research, use the information available about the population structure, its distribution through space and individual identification to make decisions about which animals to target in the study.

b) Establish an observation protocol. Determine the frequency and duration of observation periods. Determine how and when to locate and observe new subjects, and how many repeated observations on the same individuals or same age/sex class are needed. Determine how observations are to be spread throughout seasons, months, 24-Hour periods, and across locations and activities if possible.

Example: Choose enough families for observations so as to be able to match subject calves for sex, age and family size. Control if possible, for differences in family composition. Alternate between detailed observations on specific calves (focal samples) and random scans of all calves contacted once per-day to minimise individual variance. Focal sample duration to be determined by maximum period of uninterrupted contact, as well as the frequency of behaviours interest.

Priority 4: Determination of behaviour to be recorded

a) Define the behaviour of interest. For each behaviour type, record a definition so that it can be replicated by others and remain consistent across the duration of the study.

b) Determine the method of recording. Trial samples will probably be needed to ensure that behaviour is recorded accurately, quickly and reliably over time. Establish codes, check sheets or computer inputs for making a permanent record of events, states, durations, interactants, directionality of interactions, outcomes of interactions and associated consequences. Ensure through practice observations that each record of behaviour is independent.

c) Maximise sampling frequency and duration to ensure a statistically reliable sample of behaviour, of individuals and to correct for variance due to time of day, habitat, season and activity. Adjust sampling frequency and duration as the study progresses to ensure equal representation of subjects and correct for variance. Tally (add up or code) observations throughout the study. Keep a record of any changes to the sampling protocol over time.

Example: Calf and mother energetics assessed by record of maintenance activities, foraging, habitat use and group size. Mother / calf interactions, assessed by play, sucking or contact, by taking focal samples on different calves, while measures of time spent in activities or in proximity can be assessed from random scans on claves from a wide range of ages, sexes and family compositions. Additional measures, such as growth, can be determined from footprints, while reproductive events can be continuously monitored during the course of the study.

10.5 ANALYSIS DESIGN

Throughout this chapter, the problem of bias in sampling protocol has been stressed in order to facilitate accurate and reliable analysis and interpretation of results. A number of other features of analysis should be considered in behavioural studies.

Sample sizes must be large enough for robust statistical treatment when the study aims to go beyond simple description and test hypotheses. One specific problem is that many observations of a behaviour will not in themselves produce a large sample size; the observations must be drawn from a large enough sample of individuals or groups so that no single observation will contribute disproportionately to the overall total. Hence the emphasis on the even spread of samples over time, age classes, habitats, etc. If there is not an even spread, few statistical tests will be possible. Good computer software for statistical analysis helps greatly in this area, but students of behaviour should be aware that their observations seldom fit the requirements of normal distributions, matched sample sizes, even variance, etc., required for the application of parametric tests, and thus some familiarity with non-parametric statistics (e.g. Siegel & Castellan 1988) is essential. A statistician will help explain the difference between these two types of tests.

There are three main forms for the analysis of behavioural observations (Lee 1983). Events can be counted (tallied) and expressed as a rate per observation time. The tallies can also be used to produce estimates of the proportion of observation time spent in different events or acts for separate subjects. Direct measures of the duration of states can be made and used to calculate descriptive statistics for the different states. If data are collected from individuals who are known to be different, it is always important to retain the identity of those individuals in the analysis, so as to minimise the differential contribution of any single animal. The same is true if samples are collected from recognised age/sex classes, so as to ensure equal representation across a population of animals.

A second form of analysis is that of the ratio. Here the frequency of one event is expressed relative to that of another event. For example, the ratio of steps to trunkfuls can be used to describe the intensity and energetics of foraging. Ratios imply that the behaviours which are analysed together are indeed associated in some way. It is important to demonstrate analytically this relationship before creating the ratio. Finally, the observations can be used to derive an index. An index is specifically useful for assessing elements of relationships or interactions that cannot be directly measured. They do not represent “real” time, and as derived measures, are difficult to use in statistical tests since expected distributions can not be known. However, as an approximation or description of an interaction or relationship, they remain a powerful analytical tool.

There are many indices that have been used in behavioural analyses. Some are simple calculations of the relative contribution of different proportions to an overall sum, such as an index of dietary diversity or heterogeneity. Another is an index which assesses individual responsibility for initiating interactions (Hinde & Atkinson 1970). Another common index used in behavioural studies relates to associations and uses proximity data to calculate an index of association. There are many different association indices available, which vary in the way in which the separate and joint observations are used in calculations (e.g. White & Burgman 1990). One of the more useful indices for elephants is that discussed by Ginsberg and Young (1992) of the simple ratio of sightings as X/N-D, which represents the number of sightings in which individuals or groups A and B are seen together (X), divided by the total number of viewing periods (N), minus the number of viewing periods in which neither A nor B is sighted (D).

A final difficulty to overcome during analysis is how to cope with truncated observations, or incomplete records of states during an observation. In many cases, a sample may be interrupted by the loss of visibility. If this happens, a record of"“out-of-sight” should be noted, so that proportions of time can be corrected. If poor visibility leads to an incomplete record of a state, then again, this observation should be discarded in analysis. In some cases, a timed sample may start when the animal is already engaged in a behaviour. Again, the duration for the ongoing state is incomplete, and should be discarded, as should one that carries on beyond the end of the timed sample. In the latter case, it is possible to continue recording the behaviour until it terminates, in order to measure a duration completely, but the extended sample time should be excluded in calculations of frequency It may be best to abandon a sample, and restart it again in its entirety at some later time if the loss of visibility is extensive. Following elephants over rough terrain or through thick bush tends to increase the loss of observation time, and the design of the sampling interval should always keep in mind the probability of completing a full observation period.

10.6 CONCLUSIONS

The study of elephant behaviour is a difficult but rewarding task which needs to be well thought out. The aims of the study should be clearly stated; the methodology should be appropriate to those aims, involve minimal disruption to the elephants’ normal behaviour, and be unlikely to stress the animals. With large, long-lived animals that have considerable individual variation in their behaviour, generalisations can be difficult to make unless sample sizes are large, and the study period is extensive. Nevertheless, data critical to the survival and successful management of elephants can be obtained from behavioural studies, and the practical difficulties can be overcome through the careful design of observations.

10.7 FURTHER READING

Jeanne Altmann’s paper remains essential reading:

Altmann, J.
(1974) Observational study of behaviour: sampling methods.
Behaviour 49:
227-65.

The following books are very useful introductions to behavioural observations and their applications:

McFarland, D. (Editor) (1981)
The Oxford
Companion to Animal Behaviour.
Oxford
University Press, Oxford.

Martin, P. and Bateson, P. (1986) *Measuring*
Behaviour: An Introductory Guide.
Cambridge University Press,
Cambridge.

Sackett, G.P. (Editor) (1978)
Observing Behaviour
Vol. II: Data Collection and Analysis Methods.
University Park Press, Baltimore.

Lehner, P.N. (1979) *Handbook of Ethological Methods.* Garland STMP Press, New York.

Some statistical knowledge is helpful prior to starting a study. Basic texts are:

> Siegal, S. and Castellan, N.J. Jr. (1988)
> Non parametric Statistics for the Behavioural Sciences.
> McGraw-Hill, London.
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> Snedcor, G.W. and Cocran, W.G. (1980) *Statistical Methods* (7th Edition). Iowa State University Press, Ames, Iowa.
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GINSBERG, J.R. & YOUNG, T.P. (1992) Measuring associations between Individuals or groups in behavioural studies. *Animal* Behaviour 22, 377-379.

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SECTION 4

DEVELOPING RESEARCH TECHNIQUES

CHAPTER 11

STUDYING VOCAL COMMUNICATION IN ELEPHANTS

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11.1 INTRODUCTION

The study of vocal communication in elephants is a new and exciting field. Scientists first realised as recently as the 1980s that a large proportion of elephant vocal communication actually takes place below the 30Hz low-frequency limit of human hearing, i.e., it is infrasonic. It has now been established that the vocal repertoires of African and Asian elephants include a wide variety of infrasonic "rumbles", in addition to the better known audible vocalisations such as trumpets and screams (see Berg 1983; Payne et at. 1986; Poole 1988; Poole *et* al. 1988). Humans can usually detect infrasonic calls when they are close to a vocalising elephant, since the harmonics (whole number multiples of the fundamental frequency) in most rumbles extend into the audible range. However, we cannot hear the fundamental frequencies of these infrasonic calls, which typically lie between 14 and 35Hz. These extremely low fundamental frequencies give rumbles an unusual property - the potential to be heard over very long distances (e.g. Payne 1989; Langbauer *et al.* 1991).

Understanding communication in elephants is undoubtedly one of the most important steps in the process of understanding elephant social organisation, and studies of vocal communication are a critical component of this. Communication is at the basis of each elephant's complex social life. The unusually extensive social networks that elephants appear to establish (Moss & Poole 1983) may be at least partly a function of the opportunities for long-distance communication that infrasound affords. Studies of vocal communication can also provide information on the cognitive abilities of elephants - their skills of social recognition through calls and the complexity of the messages that they are able to send and receive. Knowledge of how elephants use calls to co-ordinate their activities could enable us to identify vocal stimuli that, when replayed, might be used to move groups away from areas where they are causing damage. More generally, studies of communication will provide essential baseline information for elephant management and conservation by revealing the nature and extent of social ties within natural populations.

In this chapter I shall outline the techniques that are currently available for studying vocal communication in elephants. Two techniques are central to any study of vocal communication -making sound recordings of calls, and monitoring the responses of listening subjects when these calls are replayed under controlled conditions (McGregor *et al.* 1992). This powerful combination allows the investigator to study not only the structural differences between calls, but also how other members of the species react to them. Most studies of elephant communication will involve a combination of recording and playback, and will be supplemented with vocal analysis. In all cases, this level of study should be preceded and complemented by opportunistic observations of the vocal exchanges that occur between elephants during their normal daily lives. The observational work will be particularly important in helping to define the questions to be tackled in a study and will contribute to the formulation of clear testable hypotheses. Whether the aim is to determine the processes that underlie social recognition, or to identify infrasonic stimuli that could be used to deter elephants from crop raiding, the questions must be well defined at the outset of the study (see McGregor *et* at. 1992; Barnard *et al*. 1993).

11.2 RECORDING ELEPHANT VOCALISATIONS

11.2.1 General

Elephant vocalisations pose quite a challenge to sound recordists - amateur and professional alike. While the elephant ear is specialised for detecting very low frequencies (Heffner & Heffner 1980; Heffner *et al.*1982*)*, this is not true of the human ear, or of the average microphone and tape recorder. Stringent precautions must therefore be taken to ensure that the infrasonic frequencies of calls are being accurately captured on tape. Below, I discuss the rules which should be employed when choosing recording equipment, the range of equipment that is currently available, and the ways in which this equipment can be employed to make high-quality recordings of elephant vocalisations. The goal of the investigator at all stages in the process should be to make recordings that are clear and accurate representations of real vocalisations. The ultimate test is whether these recordings, when reproduced at the correct volume, would sound convincing to an elephant.

11.2.2 Equipment

a) The frequency response of the system
Not being capable of hearing the fundamental frequencies of infrasonic vocalisations ourselves, we cannot assess whether a sound recording system is doing its job properly by simply listening to it. Before embarking on recording, it is essential to check that the proposed equipment is technically capable of recording across the whole range of frequencies that occur in elephant vocalisations. The basic requirements for recording are a microphone, a tape recorder and possibly, depending on the type of microphone used and its compatibility with the recorder, a power supply/pre-amplifier unit to link them.[1] The range of frequencies over which each item of equipment can record accurately will be listed as the “Frequency Response” in the “Specifications” section of the instruction manual. No weak links in the chain can be tolerated - all the items of equipment involved must be capable of recording frequencies down to 10Hz or less. Ensuring that the recording system has an adequate high frequency response is less problematic-most high quality microphones and recorders can deal with frequencies up to 20,000Hz, which is well above the upper limit of the frequencies found in elephant rumbles and trumpets.

b) Microphones
Various microphones offer the required frequency response (see above). When choosing from the available range, it is best to look for a fairly robust microphone, capable of withstanding some exposure to dust and fluctuation in humidity levels and sensitive enough to record over moderate distances. The two types that have been most commonly used by elephant researchers so far are the Sennheiser MKH 110 and the Bruel & Kjaer series oft /2” microphones (e.g. models 4149 and 4155). Of these, the Sennheiser employs an element of directionality, which enables it to capture the upper harmonics of rumbles more efficiently than the omnidirectional equivalent. However, for the lowest frequencies, all the available microphones will effectively behave in an omnidirectional fashion. Microphones should always be used with basket wind shields and covers to minimise distortion caused by air movement close to the microphone (see below).

c) Tape recorders
The microphone should be connected either to an open reel tape recorder or to a digital audio tape (DAT) recorder. DAT records in a format that minimises tape hiss - a particular advantage where the original recording is to be amplified and played back to elephants. DAT recorders are also more compact and thus easier to handle in fieldwork conditions than equivalent open reel tape recorders. It would be advisable to review the specifications of available recorders at the time of purchase. Two recorders that have already proved successful are the Sony TCD D10 DAT recorder with a DC modification (to bring its frequency response down to 0Hz), and the Nagra IV SJ open reel tape recorder which records down to 0Hz on the FM channel.

11.2.3 The tricks of the trade

a) The problem of wind
One of the main obstacles to making good recordings of elephant vocalisations in field conditions is the effect of air movement on the

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[1] The need for a power supply/pre-amplifier unit should beascertained by consulting the manufacturers of both the tape recorder and microphone. Some recorders can power microphones from their own internal supply, while others will require the fitting of a battery operated unit between microphone and recorder, If the equipment specifications indicate a discrepancy between the output signal from the microphone and the required input signal for the recorder, appropriate capacitors may also be incorporated into the power unit to compensate for this.

recording system. As discussed above, equipment appropriate for recording infrasonic calls must be sensitive to frequencies down to 10Hz or below. This is in contrast to normal recording systems that effectively respond only down to frequencies of 50Hz. Individuals who have previously made field recordings with a normal system will be surprised at the dramatic difference the low frequencies make; the wind contains strong low frequency components and while the lowest frequencies are filtered out by a standard recording system, these are fully effective when the infrasonic recording system is used. The strong low frequency components are enough to overload the microphone even at very low wind velocities, and this manifests itself as physical break-up in the record signal. The effect is so great that recording usually has to be confined to periods when it is relatively still (e.g., early morning and late evening). A wind shield (a rigid tube of flexible material on a basket framework) and wind cover (a sock that fits over the shield, often made of artificial fur) should always be used to minimise air movement close to the microphone.

b) The best way to organise a recording session

When first faced with the task of recording vocalisations from a group of elephants, the temptation to try to capture everything on tape should be resisted. The best recordings are obtained when a clear goal is kept in mind during a recording session and a particular individual is singled out as the subject to be recorded. For example, the best recordings of contact calls and answers from adult females are likely to be obtained when an individual female becomes separated from the rest of her family group. In this case, the microphone might be directed either at the separated individual or at a member of the main group that would be expected to call to her. In contrast, if the aim is to study calls between mothers and their calves, mother-calf pairs can be singled out for recording. Rarer events such as mating pandemonia might be treated opportunistically - although if particular females are known to be in oestrus these could be selectively followed to obtain recordings of the oestrus chorus and post-copulatory calls.

c) Operating the equipment

Recordings should be made from a vehicle or hide positioned close to the vocalising subject; distances of 15-25m are ideal if this does not interfere with the behaviour of the elephants. Fixing the microphone in a position where it is pointing towards the subject will add less extraneous noise to the recording than holding it directly. Ideally, the recording sensitivity level on the tape recorder should be adjusted to produce a maximum deflection of 5db to 10db below peak on the peak level meter. One important effect of air movement is to enforce a reduction in recording level. Only when it is completely still can the most sensitive setting be used; with increasing turbulence the recording level must be reduced to avoid overload (which results in the distortion of the recorded signal).

d) Documenting the recordings

Because calling is often difficult to predict, the tape has to be kept running during the recording session. This uses up a lot of tape, but is the only way of ensuring that the best calls will be recorded intact. Tapes which contain no useful calls can be reused in a later session. A running commentary detailing which individual vocalised and the Context in which each call was given should be kept on tape alongside the calls themselves, as should background information such as the date, time, wind speed, etc. (see McGregor *et al.* 1992),

Pin-pointing which animal gave each call is not as easy as it sounds. By virtue of their structure, infrasonic calls are difficult for human listeners to locate spatially. Thus, when the subject being recorded is among other elephants, there will sometimes be doubt as to whether that individual or another in the group was responsible for the call. It is essential to note these uncertainties on tape. There are some visual cues that indicate when an elephant is calling - in particular, calling tends to be accompanied by back and forward ear movement (ear flapping) and may be preceded or followed by periods of listening (see Poole *et al.* 1988). For loud calls, the mouth sometimes visibly opens. This cue cannot be relied upon in every case, however, as the mouth is often hidden by the trunk and for some softer calls mouth opening is often very slight. The same is true of forehead vibration, which has been used as a cue to infrasonic calling in Asian elephants (see Payne *et al.* 1986), but is difficult to pick up in African elephants.

e) Sound recording from a radio collar

The above discussion on recording infrasound applies to sound recordists using hand-held microphones and recorders, which is the usual situation. Scientists in Zimbabwe, however, have actually incorporated small radio microphones into elephant radio collars (Payne 1989). These radio microphones can transmit a continuous record of the collared elephant’s vocalisations back to a base station where it is stored digitally on computer for later analysis. While this is an elegant solution to the problem of recording elephant vocalisations, it obviously involves the major operation of immobilising and fitting cumbersome collars to elephants, and is beyond the scope of most research projects. Furthermore, the recordings are only useful if accompanied by detailed information on the behaviour of the vocalising elephant which can be synchronised with the recording track.

11.2.4 Recording networks

Recent technology offers the opportunity to monitor simultaneously the location and calling behaviour of elephants over a chosen area (Langbauer *et al.* **1991;** Kiernan 1993). A four-channel instrumentation tape recorder can be used to record from four radio microphones placed in a square array (e.g. 0.25km by 0.25km). By comparing the signals recorded from each of the four microphones, using a digital signalling processing board, each vocaliser's location can be calculated relative to the co-ordinates of the microphone array. Using this "passive acoustic location system", it is possible to record conversations between different groups of elephants while pin-pointing their locations at the same time. This sort of approach could be very useful when attempting to study elephant communication on a larger scale, but it requires substantial technical expertise and back-up.

11.3. ACOUSTIC ANALYSIS OF CALLS

11.3.1 General

The aim of acoustic analysis is to classify the calls by their structure so that differences between individuals and differences between call types can be picked out. Having established measurable differences, playback experiments may be used to test whether these structural differences have any real meaning for the elephants i.e., whether the elephants also distinguish between different calls on this basis, While vocal analysis is an important part of studying vocal communication in elephants, it is a specialist topic in itself (see Ladefoged 1962), and I shall review the techniques only briefly here.

11.3.2 The equipment

As was the case for the recording system, the specifications of the analysis equipment must be checked to ensure that it can deal adequately with frequencies down to 10Hz. A wide range of options are available, but the equipment tends to be very expensive. For this reason it is more sensible to make use of existing facilities at university and government research laboratories than to set up a new system.

Sound analysis breaks down vocalisations into their component waveforms, providing a visual representation of how the vocal energy in the call is distributed on a frequency axis, a time axis, or both. Three of the most useful formats for displaying elephant vocalisations are spectrogram, power spectrum and waveform outputs (see Fig. 11.1). Spectrograms (Fig. 11.la) show how the energy content of a call is distributed across its component frequencies over a chosen time window. In this format, frequency is represented on the vertical axis, time on the horizontal axis, and the "blackness" of the trace represents the relative amount of energy at each frequency. Power spectra (Fig. 11.1b) average the energy over a selected slice (in time) of the call and show how it is distributed across the frequency spectrum. Here frequency is on the horizontal axis and the energy content (or amplitude) is on the vertical axis. Waveforms (Fig. 1l.lc) display the individual vibrations that make up the sound wave. In this sort of display, time is on the horizontal axis and phase (stage of the wave cycle) on the vertical axis. Some sound analysis systems (e.g. the Kay DSP 5500 Sonagraph) provide all three display formats.

11.3.3 Making acoustic measurements

The best way to take an initial look at a call is to display it as a spectrogram. In this format most call types will appear as a series of narrow black bands at regularly spaced intervals; these represent the fundamental frequency and harmonics. The fundamental frequency, seen as the lowest of the narrow black bands, is the primary frequency of vibration of the elephant's vocal cords and the main determinant of call pitch. Wider areas of black, spanning several harmonics, are also visible on the spectrogram. These "formants" are the product of resonances in the elephant's vocal tract, and affect the quality of the call. Measurements of the fundamental frequency and formants can be made by using the spectrogram display, supplemented with information from the spectrum and waveform formats (see e.g., Fig. 11.1). On the basis of these characteristics and additional ones such as the

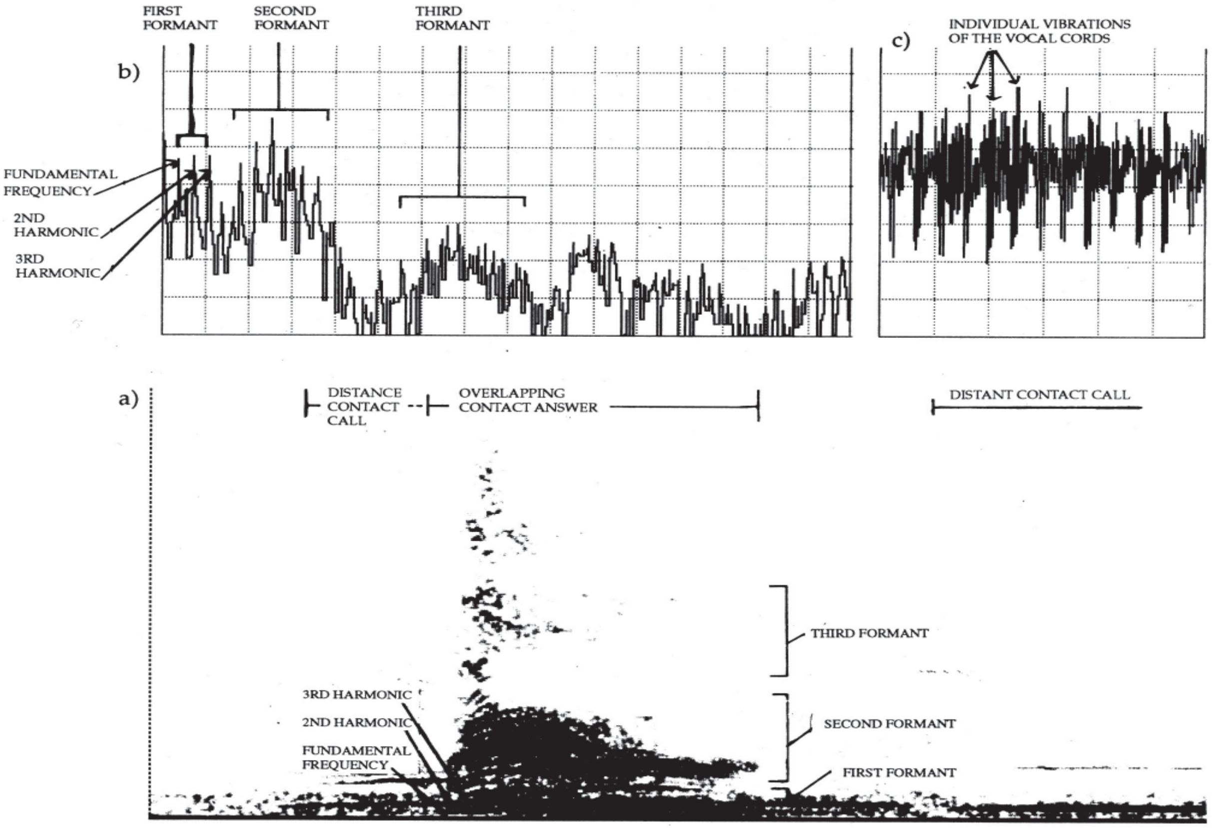

Figure 11.1: Common forms of sound analysis display for elephant “contact answer” vocalisation (overlapping a more distant contact call).
a) Spectrogram Time (0-15.13 secs) on the horizontal axis and Frequency (0-1000HZ) on the vertical axis.
b) Power Spectrum (taken at peak fundamental frequency) Frequency (0-1000Hz) on the horizontal axis and Relative Amplitude on the vertical axis.
c) Waveform: Time (0-0.59secs) on the horizontal axis and Phase on the vertical axis.

length and tonal quality of the calls, different call types and differences between individuals in calls of the same type can be identified (for statistical tests see Barnard *et al.* 1993; Siegal & Castellan 1988; Sokal & Rohlf 1969).

11.4 PLAYBACK

11.4.1 Preparing calls for playback

Calls that are selected for playback should be clear, with the level of the recorded signal high relative to the level of the background noise on tape. However, calls that were recorded at such a high level that they caused microphone overload, i.e., the peak level meter registers above peak for the recorded signal, should not be used as these are likely to be distorted. Calls that have not been recorded intact (e.g. the beginning of the call has been clipped), calls that include breaks due to wind noise and calls that include unnatural background noise must also be excluded. All the signals recorded on tape will be amplified for playback - thus wind breaks and background noise will become much more noticeable. Having selected the best calls, these can be used either in their original form for playback, or edited onto another tape. Editing might simply involve transferring a selected call intact to another tape, to make it more accessible and to isolate it from the preceding and subsequent recorded signals. Computer-based editing facilities are also available, however, and can be used to modify call structure or to synthesise new versions of the call.

11.4.2 The problem of habituation

Elephants show a diminished response to stimuli to which they are repeatedly exposed. This “habituation” should be avoided at all costs, for it is rarely reversible. To minimise the chances of habituation one must: 1) leave at least a week, preferably longer, between playback experiments to the same group of subjects; 2) use short playback signals - it is better not to exceed one or two calls, or a single sequence of calls, during a playback session; 3) never use recordings that sound “abnormal” as playback stimuli - subjects will habituate to these more quickly. It is important to be on the lookout for signs of habituation at all times, and when it is evident that particular groups of elephants are starting to ignore playback signals, additional playback experiments should not be conducted on these animals.

11.4.3 The equipment

To reproduce calls from a tape recording, the line output of the tape recorder must be connected to a power amplifier and speaker. Again, both these items of equipment should have flat frequency responses from approximately 10Hz.

a) Amplifiers
As the equipment will usually have to be operated under field conditions, it must be possible to power the amplifier from a 12V battery supply. Good quality car stereo amplifiers are particularly suitable. The power output of the amplifier should be such that it can, when used in combination with the speaker, reproduce the calls at their natural volumes. There is no substitute for trial and error here - the efficiencies of different speakers will vary according to their design (see below), and while a 300W amplifier may produce the required amplification for some, a higher wattage will be needed for others. The correct playback volume for each call should be determined prior to conducting experiments by adjusting the settings of the playback system until the speaker produces a sound pressure level (SPL) typical of an elephant giving that call type from the same distance. It is usual to measure the SPLs of calling elephants with either an SPL meter or a calibrated recording system, and to match the speaker volume against this using an SPL meter. Poole *et al*. (1988) document the SPLs typical of the common call types.

b) Loudspeakers
Loudspeakers that can deal with frequencies as low as 10Hz tend not to be available as commercial products and usually have to be custom-built for the purpose. One of the major problems associated with producing elephant calls is the need to vibrate the speaker diaphragm back and forward accurately at the natural frequency of vibration of the elephant’s vocal cords (14 times/second for some infrasonic calls). The excessive strain that this exerts on the drive unit can be dealt with either by building an extremely large and heavy duty speaker that has the rigidity to force the air back and forwards at approximately the required rate, or by building speaker enclosures that themselves modify the pattern of vibration of the diaphragm, making it more accurate and efficient (bandpass boxes and horn speakers). Because of their’ higher fidelity reproduction and greater efficiency (less power required to drive them), bandpass boxes and horn speakers are preferable to the simpler heavy duty options. Of these two, bandpass boxes can be built as lighter, more compact units than equivalent horn speakers and thus probably provide the best option for elephant playbacks. A sixth order bandpass box, with dimensions of 0.75m x 0.75m x 0.75m and a weight of around 40kg, has already been used successfully for field playbacks to elephants.

11.4.4 Outline of a playback experiment

The loudspeaker should be moved into position prior to the start of the experiment and sufficient time left for the elephants to settle down before playback begins. The vocalisations may be played from a vehicle, if the subjects are habituated to the presence of vehicles, or from a position on the ground if sufficient cover is available. While the distance between the speaker and the subjects will obviously depend to some extent on the question that is being asked, it is inadvisable to use playback distances of less than 50m unless vegetation cover is very thick. The aim is to create a situation that is realistic for the listeners; the farther away the speaker, and the thicker the cover, the less these elephants will expect to see or smell the calling elephant. Where responses to different calls are being compared in a series of playbacks, subject-speaker distances should be kept constant throughout.

Playbacks may be given to single individuals or to groups, depending on the question that is being addressed by the experiment. The best situation for a playback is one where the subjects are resting or feeding quietly in one place. It is, in general, very difficult to orchestrate a playback experiment if elephants are on the move. As well as the logistic difficulties of positioning the speaker, moving elephants tend to be focused on reaching their destination (e.g., a watering place) and may ignore stimuli to which they would otherwise have responded.

Having found an appropriate group of subjects, provided that they remain settled during the pre-playback period (see below), the playback signal can then be delivered at the appropriate volume (details in Section 11.4.3). It is inappropriate to play the subjects any of their own calls, as this would obviously create a highly unrealistic situation and jeopardise the success of future playbacks to the same group.

11.4.5 Monitoring elephant responses

Video provides one of the best formats for recording elephants' responses to playback. It can give a more complete record of events than a written summary, and may be accessed repeatedly to extract further information. This is a particular advantage at the start of a series of experiments, when it allows the observer to remain flexible about which behavioural measurements to take. When using video, the investigator should make a prior decision on which individuals to follow with the camera if the group becomes dispersed. Choosing always to include the matriarch in the record, for example, is one way of allowing a standardised comparison to be made across groups.

Notable responses to playback include: listening (ears extended and stiffened while body is held still), smelling (with trunk in raised or lowered position), approach to or retreat from the speaker, calling, increases in group cohesion (group members "bunch up", calves in particular tending to move closer to adults) and increases in temporal gland secretion (pers. obs.; see also Poole & Moss 1989; Langbauer *et al.* 1988 & 1991). Because many response measures can be gauged only in relation to previous behaviour, several minutes of pre-playback behaviour should also be recorded on videotape. The inclusion of a running time clock on screen during a playback record will allow latency measurements to be made more easily, e.g., time between onset of playback and onset of approach to the loudspeaker.

Once the responses to playback have been summarised as behavioural measurements of the type described above, statistical comparisons can be used to investigate whether different categories of playback elicit the same or different responses. Depending on what the playbacks are being used to test, the categories might be calls given in different contexts, calls given in the same context by different individuals or sexes, calls played back from different distances, etc. Where different categories do elicit different responses, spectrographic analysis may help to determine the basis on which listeners are making a distinction.

11.5 CONCLUSION

This chapter provides information on the range of techniques currently available for studying elephant communication. Individual investigators must decide which of these are most appropriate for their own particular studies. The choice should be made on the basis of the question that is being addressed, and will usually be straightforward once the hypotheses have been defined clearly. For studies involving sound recording and playback, sufficient funding must be secured at the outset. The purchase of specialist items of equipment for recording and playback may cost upwards of US$8,000. All studies should be preceded by careful consultation of the existing literature on vocal communication in elephants and on methods of observation and experimental design (Chapters 7 & 10; Martin & Bateson 1993; McComb 1992; McGregor *et al.* 1992; Barnard *et al.* 1993).

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CHAPTER 12

SATELLITE TRACKING OF ELEPHANTS

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12.1 INTRODUCTION

In Chapter 8 you have seen that the radio tracking of wild animals has been an essential tool of wildlife research and management, providing information about the movements of individuals which could not have been collected any other way. Most radio tracking is done using 'conventional' collars, which transmit very high frequency (VHF) radio pulses. Animals are located by homing, or by triangulation from the ground, or from aircraft, using a directional aerial and purpose-built radio-receiving equipment in line-of-sight of the transmitter. Depending on the local conditions, and the power output of the collar, this distance may be from a few hundred metres to over a hundred kilometres. Radio tracking of this kind is also known as 'conventional' tracking, and it suffers from a number of limitations (see Chapter 8).

In view of the limitations of conventional radio tracking, it is not surprising that the idea of remote tracking of wildlife, using signals received by satellites orbiting above the earth, has been received with considerable enthusiasm. Under ideal circumstances, this can allow one to follow the movements of animals night and day, wherever they may be, without having to stir from a computer terminal and armchair.

Satellite tracking of wildlife has been possible since the early 1980s, using a system operated from France by Service Argos and the National Oceanic and Atmospheric Administration (NOAA) meteorological satellites. It has been successfully carried out on polar bears, caribou, musk oxen, wandering albatrosses and a variety of other species (Fancy *et* al. 1988; Harris *et at.* 1990). It has also been used on elephants in Namibia (Lindeque & Lindeque 1991), Kenya (Thouless *et* al. 1992), Cameroon (M. Tchamba pers. comm.) and Zaire (K. Hillman-Smith pers. comm.). However, for a number of reasons to be discussed later, satellite tracking of elephants presents some particular difficulties, and results have not always satisfied expectations. Further advances are being made, both with the Argos System and with other techniques of tracking animals by satellite, and it is possible that many of the problems currently experienced will soon be overcome.

12.2 THE ARGOS SYSTEM

The Argos system depends on TIROS satellites operated by NOAA, which orbit round the earth at an altitude of 850km, about 14 times each day, passing close over the north and south poles. There are supposed to be at least two in orbit at any one time (although there may actually be between one and four in operation), and there are plans to launch new satellites on an annual basis to maintain continuous operation.

Coded radio signals are sent out from the transmitter, or platform transmitter terminal (PTT), on the elephant, at intervals of typically 60-90 seconds. As an orbiting satellite passes over a transmitting PTT it may detect some of these signals. If a sufficient number of signals are received during the course of a satellite overpass, the satellite can calculate the location of the PTT. (Actually, it will calculate two possible positions; one on either side of the satellite's track. The more likely of the two positions is determined from previous locations and transmitter velocity.)

The location of a PTT is estimated using the Doppler shift (the change in the apparent frequency of the signal as a result of the relative movement of the transmitter and receiver) in the signals from the PTT received by a satellite while it passes overhead. As the satellite is moving towards the PTT, the detected frequency will be slightly higher than the transmitted frequency of 401.650MHz, and the frequency becomes lower as the satellite moves away. Calculations of the rate of change of the frequency and the point at which the received frequency should be the same as the transmitted frequency allow the satellite to calculate the distance and direction of the PTT from its orbital path at the closest point. The clearer and more consistent signals that are received from the PTT, the higher will be the precision of the calculated location. Service Argos grades locations from Class 0 (NQ0), which has a low associated accuracy, and may be derived from as few as two signals, to Class 3 (NQ3) for which Argos claims that 68% of locations will be given within I50m of the true position. We have found Class 0 locations to be of little value, since errors are often greater than 20km (Thouless—*et al*. 1992). Data collected by the satellite are downloaded to various ground stations and then to the Argos data processing centres in Landover, Maryland, U.S.A., and in Toulouse, France. Results are distributed to users by telephone modem, telex, hard-copy printouts or floppy discs. Data can also be collected directly from the satellite using a Local User Terminal (LUT) which includes an antenna, a dedicated receiver and a microprocessor (Lindeque & Lindeque 1991).

12.3 FREQUENCY AND QUALITY OF LOCATIONS

For a particular satellite overpass, the chance that a position can be resolved is determined by how many signals are received from the PTT during the time that the satellite is overhead. This in turn is determined by the strength of the emitted signals, the pulse repetition rate of the PTT, and the angular altitude of the satellite. If the path of the satellite is sufficiently distant from the PTT that it passes over low on the horizon, then the time available for receiving signals from the PTT will be reduced, and there is likely to be more interference with the signal from vegetation, but if it passes nearly vertically overhead, it is more difficult for the satellite to calculate a location.

Transmitters on elephants have generally produced poorer quality information than those on other animals, as measured by the number of locations determined, and their quality. There appear to be three main reasons for this:

i) Most elephant studies have been carried out relatively close to the equator. The polar orbit of the TIROS satellites means that there are fewer overpasses per day on the equator than in temperate or polar latitudes. Because all satellite overpasses or orbits pass over both poles, but each successive orbit passes over different points on the equator, as you get closer to the equator a smaller proportion of orbits come within sight of a particular point on the ground. With two satellites receiving data there may be more than 20 useful overpasses at high latitudes, compared with as few as four at the equator (Fancy et al. 1988).

ii) The large fluid mass of an elephant's body close to the PTT's aerial reduces its effectiveness and results in less power being radiated from the transmitter. As a result, putting a collar on a elephant may produce less than half the number of locations that would be produced while being tested on the ground (Thouless *et* al. 1992). Better results have been obtained in Cameroon (M. Tchamba pers. comm.). This may be because the collars used in the study had a spacer keeping the aerials away from the elephant's skin, thus improving transmission efficiency.

iii) Although external whip aerials provide good signal transmission, the strength and dexterity of elephants make it necessary to use a less efficient antenna bonded inside the collar

12.4 THE PROBLEM OF PRECISION

Analysis of data on animal movements assumes that locational information is fairly accurate. Locational errors in conventional tracking may result from inaccurate triangulation, or because the maps of the study area are unsatisfactory. Large errors can result from signal bounce, but they can often be identified by field workers, because of their experience with the animal, and knowledge of the study area (see Chapter 8). The general magnitude of expected errors is often well known, and observations will not differ greatly in their errors. This is not the case with satellite tracking, since the tracker is often remote from the study area.

The precision of locations from conventional tracking can usually be described in a simple manner, for instance, that all the locations are accurate to within 1km or 200m. Describing the precision of locations from satellite tracking is more complicated; Service Argos says, for example, that 68% of Class 2 locations are accurate to within 350m. A higher proportion of locations will be accurate to within 500m, and it is likely that only a small proportion will be in error by more than 1km. However, it is possible that a very small proportion of locations will be in error by a much larger amount, and because the tracker is not on the spot, he or she may not be able to identify and eliminate these occasional errors, which will provide faulty biological information. In species and study areas where it is possible to get several locations during the course of a day, faulty locations can be eliminated by comparison with others, but for elephants this will be more difficult. It may be possible to eliminate some false locations on the basis of physical improbability; for example, Lindeque and Lindeque (1991) rejected locations in the Atlantic Ocean, but often they will not be so easily detected.

The known causes of error are:

i) Altitude
Argos calculates the location of a PTT on the assumption that the transmitter is at a particular altitude. A difference between the true altitude of the PTT and the assumed elevation will result in error. These errors are primarily on an east-west axis because the satellites travel in nearly north-south orbits. When signals come from PTTs that are higher than the assumed elevation, Argos interprets them as coming from locations that are closer than they actually are to the satellite along its across-track direction (Harris *et al.* 1990). French (1986) showed that for a maximum satellite elevation of 26o , an altitudinal error of 500m results in a range error of 250m. According to Argos, under certain geometric conditions (with the platform close to the ground track) the longitude error can reach four times the altitude error.

ii) Speed of displacement
For any FIT speed of Xkm/hr, the error in metres is 100 to 200X. Thus, for an elephant moving at 10km/hr the error will be from 1000m to 2000m. The effect of small-scale movements, for example movement of the head during feeding, is unknown, but probably small.

iii) Transmitter instability
If the frequency of signal output by the PTT changes during the course of a satellite overpass. then inaccurate locations may be obtained, particularly in the longitudinal axis. PTTs are certified to vary less than three parts per million over their operational temperature range, but rapid temperature changes of the PTT electronics can cause frequency shifts, which lead to errors.

iv) Satellite orbital error
The calculated track of the satellite during its overpass may be incorrect, and this will lead to errors in its calculations of the location of the PTT. This source of error can be reduced by using a reference beacon with a Local User Terminal (see Section 12.5.2).

Little is known about which of these factors is most significant, and the only way to find out the level of locational precision is to locate the elephant on the ground during satellite overpasses, and collect a large number of simultaneous true and calculated positions, which can be compared with one another. Ground testing the collar before placing it on an elephant is likely to give an unduly optimistic picture, because system performance when the collar is not on an elephant will be relatively high.

12.5 SATELLITE TRACKING EQUIPMENT FOR ELEPHANTS

12.5.1 Collar assembly

The majority of satellite collars used on elephants have been manufactured by Telonics Inc. of Arizona, U.S.A. These consist of electronics and power supplies hermetically sealed in metal housings, fixed to machine belting collars, with an external urethane shock buffer. Collars are attached by a brass plate with four bolts which pass through holes in both flaps of the collar and are secured by four nuts and another brass plate. The aerials consist of a dipole antenna, with approximately 20cm of antenna protruding from each of the two sides of the transmitter at 1800. The antenna is sewn into the collar and covered by about 3mm of belting on both sides. To maximise transmission efficiency, the PTT should sit on top of the elephant’s neck, therefore a counterweight is necessary. If an additional conventional VHF transmitter is included in the package, then this can be made heavier than the PTT, and can thus act as the counterweight. In any case, the collar and transmitters will be considerably heavier than standard VHF collars. One satellite-collared bull elephant in Kenya was found to have suffered abrasion from the collar, and it is important to establish whether this problem is common, and whether it was due to collar tightness, or to excessive weight of the collar.

The advantages of including a VHF unit are that this transmitter can be used to relocate the elephant from the ground, so that it will allow one to remove the collar once the satellite transmitter has stopped transmitting, and it can be used to check the locations provided by the PTT.

There are trade-offs between the PTT package size and power output because of the weight of the battery. If a prolonged life span is required, then the PTT's microprocessor can be programmed to switch the transmitter on and off on a regular basis, resulting in, for example, a''duty cycle' of 22 hours on/26 hours off. Duty cycles must be programmed in advance and cannot be changed once the collar is on an elephant. With a 24 hour on/24 hour off duty cycle Telonics transmitters for elephants are expected to last over a year.

Other kinds of data can also be collected via satellite, if the appropriate recording devices are incorporated within the transmitter package. On other species data has been collected on such factors as activity levels and temperatures.

12.5.2 Local User Terminal

A Local User Terminal (LUT) is a small satellite receiving station which allows one to collect data from the satellite as it is passing overhead. Although LUTs are expensive (minimum cost is about US$30,000), their use can reduce running costs, and without an LUT there may be an unacceptable delay in the time that data take to return to the field. In addition to providing immediate information on the location of tagged animals, LUTs also provide more detailed information on the signals received from PTTs and may be used to improve the quality of locational information. With an appropriate LUT, one can also receive 1x1 km resolution image data on the area that the satellite is passing over, which can be used to produce maps of sea surface temperatures, weather phenomena, fires, floods and vegetation state.

LUTs can also be used to improve the accuracy of locations in conjunction with a local reference beacon (a transmitter placed at a known location), which will allow correction for errors in the assumed path of the satellite.

12.5.3 Uplink receiver

The signal produced by a satellite PTT cannot be received by a conventional VHF receiver, so in order to test PTTs in the field, it is necessary to purchase a specialised receiver. This can either be a test receiver, which just indicates whether the PTT is transmitting, and can cost less than US$100, or an uplink receiver, which receives and analyses PTT output, and may cost over US$5,000. This may be an unnecessary expense, unless calibration of, for instance, temperature or activity data is required.

12.5.4 Software

Certain computer software or programmes may assist with interpretation of satellite data. The satellite prediction programme can be valuable if ground truthing is to be carried out, since information on satellite overpass times and the height which the satellite will reach above the horizon will allow one to predict which overpasses have the best chance of providing good quality locations. The LARST software package is being developed by Bradfield University Research Ltd. and the Natural Resources Institute of UK, for use with a LUT System. This programme will collect detailed information on received frequencies from an overpass, and calculate the best estimate of the position of the PTT by working out which location provides the lowest inconsistency between values. It will also process and present the ground environmental information for better understanding of animal movements. Telonics Inc. is also developing a LUT with a software package called TIRIS.

12.6 VHF VS. SATELLITE TRACKING

Neither conventional nor satellite tracking are ideal under all circumstances. Deciding which one will be most appropriate is dependent on the precise conditions in the study area, and a number *of* other considerations.

i) Cost
Satellite tracking is expensive, in terms of equipment and Argos charges, though personnel and aircraft costs may be substantially less than for conventional tracking. 1994 prices for elephant PTTs with collars are about US$4,500 each (Telonics Inc.). Daily rates for Argos location data are 60FF (approximately US$9-10) per PTT. Charges are made for any day with reception from a particular PTT; therefore using a duty cycle where the transmitter is on for a short period each

day may be expensive. by using an LUT the daily rate will be reduced to 25FF, but capital costs will be considerably more. To dart elephants and remove collars is also an expensive business, and the shorter life span of satellite collars, compared with conventional ones, is a serious consideration.

Conventional collars are considerably cheaper than satellite collars, but whether or not conventional tracking is cheaper than satellite tracking depends on whether one has to use an aircraft, how long it takes to find the animals, and whether one is paying full commercial rates for aircraft time. In general, satellite tracking will be better value for a study involving relatively few animals, since costs for satellite tracking (without an LUT) increase linearly with the number of animals collared, while the flying time per animal located for conventional tracking, which is usually the major expense, will reduce with the number of elephants collared.

ii) Logistic limitations
There are many circumstances under which conventional tracking is not possible, because of lack of availability of aircraft, international movements by the elephants and so on. Under these circumstances, satellite tracking is the only option available, even if it does not fully satisfy data requirements.

iii) Data requirements
The appropriateness of satellite tracking is dependent on what kind of information is required. Because of the problems with lack of precision, it is most appropriate for working out general movement patterns of elephant populations where annual movements are relatively large compared with daily ones. It is not suitable for looking at detailed use of space. For instance, any study looking at habitat use with habitat patches smaller than tens of kilometres across, or nocturnal movements of elephants across boundaries of protected areas into adjoining cultivated fields, would probably draw false biological conclusions using satellite tracking. It may also be unsuitable for calculating home range sizes using the standard minimum convex polygon technique. As sample size increases, so will the number of outlying false locations, and thus home range size will appear to increase with sample size. Other techniques for calculation of home range size will need to be developed for analysing the results of satellite tracking, once the errors are better understood.

Satellite tracking can be used to collect other information apart from location, and this has been very useful, for example in transmitting data on dive lengths for marine mammals. However, remote collection of data by satellite prevents one from obtaining detailed data on factors such as habitat use and group size, which require direct observation.

12.7 FUTURE DEVELOPMENTS

12.7.1 New satellite systems

Satellite collars have a restricted life span because of the high energy demands of transmitting to a satellite and the need to transmit even when the satellite is not overhead. Considerable savings in battery power can be achieved if the satellites stimulate the collars to start transmitting. The technology to achieve this does exist, but these systems do require a receiver to be included with the PTT package. This results in increased complexity, cost and current drain, and the technique has not so far been used for wildlife applications. It is anticipated that two new satellite systems, SAFIR and STARSYS, will operate in this way.

12.7.2 Use of GPS technology

Another satellite system which can be used to determine location is the Global Positioning System (GPS). This system uses the time differences between signals received from each of four or more satellites, which are in view simultaneously, to calculate the position of a receiver. Locations are more consistently accurate than those from Argos, and they are available 24 hours per day. Since transmission is from the satellites, not the ground, smaller (but more sophisticated) aerials can be used on the receiver.

A GPS unit attached to the elephant can record its position, but does not have the capability to transmit the information it is collecting to an observer. In order to do this one needs to have a transmitter unit attached to the receiver to relay the information. Two ways have been suggested to do this. One is to build an interactive unit that will transmit a data stream when it is interrogated by a suitable radio pulse. This requires being able to get within line of sight of the transmitter at appropriate intervals - which will be dependent on storage capacity of the chip and how often locational information is collected by the receiver. In order to do this, it will be necessary to include a VHF transmitter in the collar assembly for ground location.

The other approach is to send out the digital data stream via the Argos system. It may seem odd to use two different satellite systems in this way, but in fact, Argos is a very reliable way of transmitting remote information: its failing is in producing consistently accurate locations, and this is where GPS excels.

Prototypes of GPS animal tags have been constructed using the Argos output system by Telonics Inc. (Degler & Tomkiewicz, 1993), and by Lotek using the interrogation system. It is anticipated that functioning systems should be available within the next two years. Recent tests of a GPS collar on an elephant bull in Amboseli show promising results, but further modifications will be necessary (I. Douglas-Hamilton).

12.8 ADDRESSES OF SUPPLIERS

Telonics Inc.
932 Impala Ave. Mesa,
Arizona 85204-6699, USA
Tel: (602) 892-4444.
Fax: (602) 892-9139
Suppliers of transmitters, LUTs, ground
telemetry equipment.

Dr. J B Williams,
Natural Resources institute.
Chatham Marine,
Kent ME4 4TB, UK.
Tel: 0634 880088.
Fax: 0634880066.
Suppliers of LARST software and BURL
local user terminal

CLS Service Argos.
18 Av. Edouard-Belin,
31055 Toulouse Cedex, France.
Tel:61394700.
Fax: 61 75 10 14.

Lotek - Wireless Telemetry Systems.
115 Pony Drive, Newmarket,
Ontario L3Y 7B5
Tel: 416 8366890.
Fax: 416 836 6455.

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CHAPTER 13

STUDYING THE REPRODUCTIVE PHYSIOLOGY OF ELEPHANTS

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13.1 INTRODUCTION

Reproductive physiology is the study of how reproductive organs and systems function normally, resulting in successful mating, fertilisation, implantation, parturition and lactation. While we have a good understanding of the reproductive systems and functions of many mammals, we know little of the reproductive physiology of elephants, such as the hormones that control the oestrus cycle. While the study of such functions may appear to be of academic interest only, the knowledge could have important management implications. For instance, if we understood fully which hormones control the female sexual cycle, we could possibly prevent pregnancy and thus manipulate elephant population dynamics.

The level of hormones in the body depends on the animal's reproductive condition. Hormones are carried in the blood, but their metabolites are passed out from the body in urine and faeces and may be analysed from urine and faecal samples.

This chapter describes how to collect hormone samples from elephants and how to analyse these samples as a means to providing a better understanding of the elephant reproductive cycle. This chapter assumes some knowledge of elephant physiology. If you are unfamiliar with some of the terms, you are advised to consult a basic biology textbook.

13.2 REPRODUCTIVE HORMONES

Hormones are chemicals produced by specific parts of the body and transported through the blood to a target organ which is some distance away. Different hormones control different body functions and those affecting reproduction are simply called reproductive hormones. Basically, two groups of hormones exist:

i) Steroids
These are products of the breakdown of cholesterol. Steroids are not fully soluble in water, and are thus bound to carrier protein molecules before they are transported to target tissues. The hormones are linked to sugar and! or sulphate molecules before excretion which makes them water-soluble, and therefore easily passed out of the body in urine. Steroids in faeces are not usually linked to sugar molecules because the microbial activity in the lower intestine destroys the link.

Oestrogen and progesterone are the major steroid hormones influencing reproduction in mammals. These hormones are produced mainly by the ovary during the oestrus cycle. During pregnancy, the hormones are produced by the ovary alone in some species and by both the ovary and the placenta in others.

In the elephant, plasma progesterone levels have been found to be low during the follicular phase and elevated during the luteal phase of the oestrus cycle and thus indicate the oestrus cycle length of between 14 and 16 weeks (McNeilly *et al.* 1983; Brannian *et al.* 1988; Plotka *et al.* 1988; de Villiers *et al.* 1989). During pregnancy levels of this steroid increase to a maximum value at mid-pregnancy (9-12 months) before declining as the gestation term is reached (de Villiers *et al.* 1989). Patterns of plasma oestrogen levels have so far failed to provide complete information on the oestrus cycle (Brannian *et al.* 1988; Plotka *et* al. 1988), but levels increase during early pregnancy (Hodges *et al.* 1983).

ii) Proteins
These are chains made of amino acids (peptide chains) which are linked to form a large molecule. Among the major reproductive protein hormones are prolactin, follicle stimulating hormone (FSH) and luteinizing hormone (LH).

Plasma FSH and LH concentrations are not indicative of the oestrus cycle. However, levels of LH peak before the onset of behavioural oestrus (McNeilly *et a!.* 1983; De Villiers *et a).* 1989). Plasma prolactin levels have been found to increase to consistently higher values by the fifth month of pregnancy (McNeilly *et al.* 1983).

13.3 HORMONE SAMPLING

13.3.1 General

There are four factors that one has to consider when attempting to study hormones in wild elephants. One must decide on (i) the hormones one wants to study, (ii) the kind of samples one would like to collect, (iii) the feasibility of collecting the desired samples and (iv) whether or not the intended hormone can be measured from the desired samples.

13.3.2 Approaching elephants f or sample collection

a) Blood samples
Blood is the best medium for analysis of any kind of hormone. Perhaps that is why it has been used extensively in the studies on elephant reproduction mentioned above. Blood samples can be collected from an immobilised elephant (see Chapter 17) or following an elephant cull (see Chapter 18). One should note that the stress of bleeding or the events preceding it, e.g. chasing, capturing, immobilisation, etc. may affect hormone levels in blood.

For logistical reasons, blood sample collection is not feasible when repeated sampling of the same animal needs to be done.

b) Urine samples
Unlike blood samples, urine samples can be collected with minimal interference to the animal. One should take care not to cause undue disturbance to the elephant, and also to ensure one’s own safety. You should wait for an elephant to finish urinating before moving towards it. Otherwise, you will make the elephant wary and the elephant may attempt to walk while urinating, spreading the urine over a wide area and making it difficult to collect. If you are using a vehicle, always drive towards the animal cautiously and slowly. Turn the engine off as soon as you are close enough to the elephants to collect your sample. It helps to keep the urination spot on the side of the car away from the elephant so tab you can have easy access to it. Urinary hormone levels have been used in the study of reproductive physiology of free-ranging male elephants (Poole *et a!.* 1984).

c) Faecal samples
Faecal samples may be collected when the animals are a good distance away, thus no interference is necessary.

13.3.3 How to collect samples

a) Blood samples
Blood is drawn from the ear veins of an immobilised elephant using a 10ml syringe fitted with a 19-21 gauge needle. The sample is then poured into a glass vial and kept in an ice-filled cool box for some time to allow clotting to take place. The serum is then removed by decanting. A centrifuge that could be run manually or electrically through the car battery will help in further cleaning the sample after decanting. The decanted serum is spun for 30 minutes and the clear serum removed into a clean, labelled vial before freezing at -20ºC.

b)Urine samples
A urine sample can be collected from the ground immediately after urination using a plastic syringe (without a needle). This works particularly well in areas with non-porous soils. The sample is emptied into a vial and kept in a cool-box with ice for one hour, letting soil and other organic debris settle. The urine can then be decanted off, and centrifugation of the sample will then clean the sample further. The centrifuge need not be very powerful, and one with a maximum speed of 2000 revolutions per minute is adequate. More powerful centrifugation equipment is usually available in laboratories, and samples which are not sufficiently clean may be further centrifuged at higher speeds before analysis. The sample should be labelled prior to storing in the freezer at –20ºC.

c) Faecal samples
A faecal sample is available long after defaecation, making such samples the easiest to collect in the field.

The peripheral part of the dung is usually richer in liquid and digested vegetative matter than the central part, and should, therefore, be targeted for sampling. A faecal sample is collected by scooping about 200-300g of faecal mass into a vial. The vial is labelled and kept in a cool-box with ice, and frozen within 2-6 hours after collection.

13.3.4 Labelling, storage and transport

Good labelling is of crucial importance in sample collection. Water-resistant pens must be used. The kind of sample (when many different kinds of samples are being collected simultaneously), date of collection, and the name and/or reproductive state of the elephant are among the important details to be fixed on the sample container. The use of codes will greatly reduce the amount of writing, making the labelling neater.

The samples must remain frozen throughout the storage phase, including during transportation to the laboratory so that the activity of enzymes, produced by micro-organisms in the atmosphere or those in the sample, is maintained at minimum levels. This ensures that the hormones are not digested before analysis. Samples can be transported to the laboratory in dry ice or liquid nitrogen.

13.4 SAMPLE ANALYSIS

Several techniques of analysing hormones from blood, urine and faeces have been developed, but immunoassay methods such as Radio Immunoassay (RIA) and Enzyme Immunoassays (EIA) are preferred. Immunoassay methods are based on antibody-antigen reactions. Antibodies are proteins produced by specific cells in the body when a foreign body or substance (antigen) is introduced. The antibodies are specific to the substances or antigens they are produced against.

In RIA and EIA techniques, fixed volumes of chemically labelled and unlabelled (standard and sample) hormone are added to a fixed volume of a solution containing excess molecules of their respective antibody. The labelled and unlabelled hormone molecules will compete for the restrictive sites on the antibody molecules. Thus, in the condition of excess antibody, the concentration of the unlabelled hormone in the sample or standard is inversely related to the amount of labelled hormone bound. Therefore, measurement of bound labelled hormone is used to calculate the amount of hormone in the sample and standard.

The label used is the radioactive hydrogen, tritium, for RIA and an enzyme molecule for EIA. The radioactive hydrogen used is part of the multiple hydrogen atoms found on hormone molecules; therefore, measurement is done by direct counting of the amount of radiation emitted by the labelled hormone per minute. This is done using specialised counters, depending on the kind of radiation being emitted. Beta (B) radiation is the weakest and relatively safest to use, but there are restrictions on the use of radioactive compounds in many laboratory establishments.

EIAs are used in most laboratories. The method operates on a principle similar to RIA. In the EIA, the amount of bound labelled hormone is determined by the amount of colour change which occurs after addition of excess amounts of the enzyme substrate. The colour changes are measured using a spectrophotometer. All the reagents used, antibody labelled hormone and enzyme substrate, are commercially available. The procedures used in sample analysis by RIA or EIA including preparation of solutions and tubes or plates, are available in a laboratory where the analysis should be carried out.

13.5 APPLICATIONS OF REPRODUCTIVE HORMONE ANALYSIS

We are only just beginning to understand the reproductive physiology of elephants, but such studies may have an important role to play in the future. When we have a thorough understanding of the hormonal cycle in elephants, it should, theoretically be possible to develop compounds that would act as contraceptives in elephants.

In areas where elephants are coming into conflict with humans or are causing undesirable habitat changes, elephant managers may wish to control elephant numbers. So far, culling has been the only way of reducing elephant numbers, although most recently translocation schemes have been carried out to move elephants from one area to another. It is likely that in small populations where all adult females are known and can be recognised, contraception will become an extremely attractive alternative to culling as a means of limiting population growth (Whyte 1994).

Theoretically, the ability to detect precisely the ovulation period will also enable one to carry out an artificial insemination programme for free-ranging elephants. While this is not being practised at the moment, artificial insemination may become important in a situation where an elephant population is declining and/or when males are scarce (e.g. during periods of heavy poaching).

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CHAPTER 14

WHAT WE CAN LEARN FROM TUSKS

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14.1 INTRODUCTION

Ivory or elephant tusks can potentially provide useful information on elephants. But what is ivory? And what constitutes a tusk?

An elephant tusk is the elongated upper incisor externally exposed in older elephants, and extending from the base of the pulp cavity in the upper jaw to the narrow tip outside.

In all species that have them, which include hippopotami, elephants, walruses etc., tusks are specially adapted teeth, and the chemical structure of both the teeth and tusks is similar. The word ivory has traditionally been applied exclusively to elephant tusks. Espinoza and Mann (1991), however, provide an identification guide for tusks of different mammalian species, and state that the word ivory can correctly be used to describe any mammalian tooth or tusk of commercial interest.

14.2 WHAT CAN TUSKS TELL US?

Tusks can tell us a variety of things in different circumstances. Tusks can enable us to age and sex elephants, and identify individuals and populations (Laws 1966; Moss 1988). They can be used to determine population trends, and the absence of tusks from carcasses can suggest that the cause of mortality was poaching for ivory (Pilgram & Western 1986a; Douglas-Hamilton 1975). Paleontological tusk material provides clues on the evolutionary process (Wyckoff 1972), and provides information on diet and distribution of elephants in paleo-times (Van der Merwe & Vogel 1978; Gathua 1992). Tusks can also provide information on rates of tusk growth (Laws 1966; Laws *et al.* 1975).

It is impossible in this chapter to cover all the ways tusks can provide the above information. This chapter, therefore, will cover the aspects that would be of immediate practical value to protected area staff and researchers: namely, how tusks can be used to age and sex elephants, to identify individuals and populations, and to determine population trends.

This chapter will also discuss the use of tusk material in obtaining information on elephant ecology, and the use of ivory to determine the source of tusks. Both these initiatives require specialised, high-technology laboratories, trained staff and large amounts of funding. As such, they may be beyond the scope of many protected area authorities, but they are discussed here because they potentially have profound implications for elephant management. If one can determine the source of ivory, one could, theoretically restrict the ivory trade to only countries that are sustainably managing elephants.

Before going into details of how ivory can provide all this information, it is worth noting the limitations of the methods. First, as we will see, much of the research on the ways that tusks can provide information has not been done. Second, ivory only yields its full information content in the context of a comprehensive data framework which details where it is from, how it was found, etc. which is usually not available.

14.3 AGEING, SEXING AND IDENTIFYING INDIVIDUALS AND POPULATIONS

14.3.1 Ageing elephants

Tusks grow throughout an elephant's life (Laws 1966). There is a quantitative relationship between tusk size and elephant age, and one can use tusks to age elephants. In general, the larger the tusks, the older the elephant. When used together with other parameters like facial appearance and body size, measurements of tusks can greatly improve age estimates (Chapter 7; Moss 1988).

Because tusks break and wear when elephants use them, their circumference at the lip is a better estimator of age than length (Pilgram & Western 1983; Pilgram & Western 1986a). Surprisingly, tusk weight is also as good an estimator of age as lip circumference implying that tusks wear and break in a relatively uniform way (Pilgram & Western 1986a). The older the elephant the higher the probability that tusks have been altered. This means that tusk measurements would be expected to be more reliable in ageing younger elephants. This is in fact so, as tusk age estimates become less reliable beyond the age of 30 years (Pilgram & Western 1986a).

Tusk weight is difficult to measure in live elephants, and therefore tusk size will always be the parameter of choice for ageing live elephants. Ageing elephants by tusk size starts with the age of tusk eruption, which tends to be between two and three years of age. While some variation occurs within populations (Laws 1966; Moss 1988), there is little information indicating whether differences exist between populations (Moss 1991).

Direct measurement of tusk size is only practical for dead, immobilised or relatively tame elephants. The exposed length and lip circumference (see Fig. 14.1) of the tusk are most commonly measured (Pilgram & Western 1986a). For live, free-ranging elephants, tusk size has to be estimated from a distance.

If baseline information relating age to tusk size in a population exists, size can easily be correlated to age. If no such data exist, size alone can give an indication of the relative ages of elephants in a population. Reference to other populations whose baseline data exist should also help. An ideal way to proceed would be to compare the tusk size of individuals of known age with the tusk size of individuals whose age is unknown, and thus age the latter. Whatever the situation one should aim to make the best of all available baseline information, experience, and available measurements.

14.3.2 Sexing elephants

Tusk size and shape enable one to differentiate between the sexes. Males generally have larger tusks than females of the same age. Male tusks erupt earlier and grow faster as the male gets older, while in females the growth rate of tusks remains steady (Laws 1966; Moss 1988). Male tusks also tend to be thicker and more tapering or conical in shape, while female tusks are more uniform in circumference or cylindrical in shape (Pilgram & Western 1986a).

Some African elephants are tuskless. The frequency of this trait is low (Parker & Martin 1982), and most non-tuskers are females (McKnight 1994). All tuskless elephants in Amboseli are females (Moss 1988). It is, therefore, reasonable for one to assume a female when one encounters a tuskless elephant, but it would still be necessary to confirm the sex.

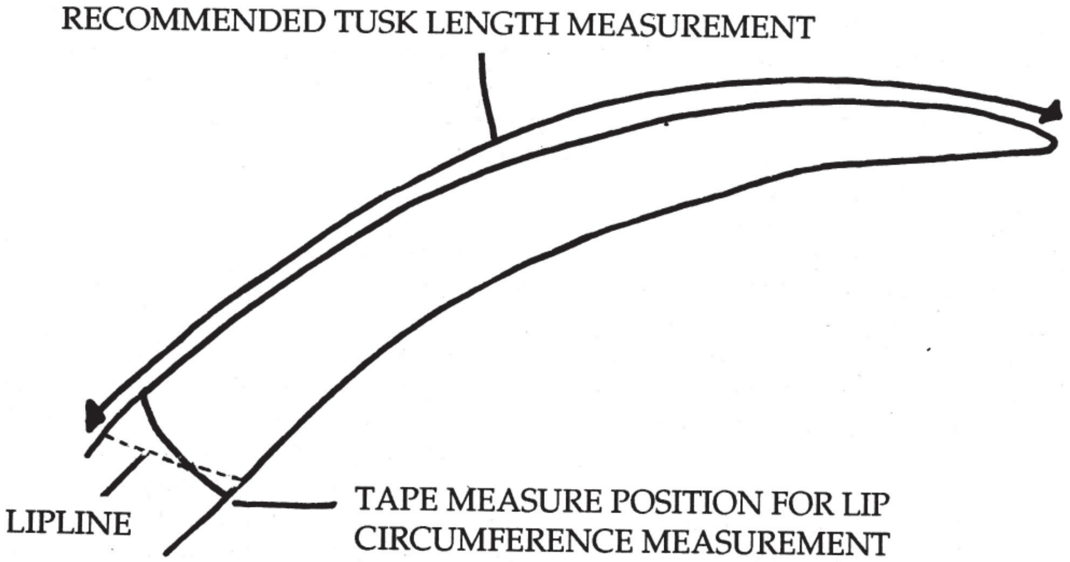

Fig. 14:1: Measuring an elephant tusk.

14.3.3 Identifying individuals

Tusk size, shape, colour and texture in elephants are genetically determined and so vary among individuals. Tusk size and shape also vary due to growth and use (Pilgram & Western 1986a). Tusks can, therefore, be used in the identification of individuals, which is important in behavioural studies (see Chapters 7, 10 and 11). Previous behavioural and population studies used tusks in combination with other features for identifying individuals (Douglas-Hamilton 1972; Moss 1988). Tusklessness or the presence of only one tusk can also be used to recognise individual elephants.

14.3.4 Identifying populations

Elephant tusks are known to vary between populations and can thus be used
to discriminate between populations. Some populations, for example, have tusks that show greater differences in size for a particular age group than others (Laws 1966). Others have unique tusk shapes. For example Kilimanjaro elephants can be distinguished from Amboseli elephants, by their smaller, thinner tusks (Moss 1988). The possibility of separating regional subpopulations of African elephants on the basis of tusk proportions, colour, hardness and surface texture has also been suggested (Pilgram & Western 1986a).

14.3.5 Data requirements

The most reliable size measurements for ageing and sexing elephants are the circumference at the lip and the exposed length (see Fig. 14.1 on how these are measured). Where an estimate of size is required for free-ranging, live elephants, a camera whose pictures can be calibrated to the true measurements may be useful (Douglas-Hamilton 1972). This technique is known as photogrammetry.

To measure the circumference of tusks that are detached from the elephant, one needs to clearly identify the lip line. This point is usually discernible from the lip tissues attached to the tusk. In addition, small perforations occurring from the tusk base to the lip line can also be used. The weight of tusks that have been detached from elephants can be measured using a weighing scale.

Data on shape and colour of tusks can be collected by photography, detailed verbal descriptions or sketches. Colour can be referenced to a standard colour chart.

14.4 DETERMINATION OF CAUSE OFDEATH AND POPULATION TRENDS

14.4.1 Rationale

When examining an elephant carcass the presence or absence of tusks can give an indication of the cause of death. The absence of tusks in a dead elephant that was evidently a tusker usually suggests that it was a victim of hunting for ivory, especially if it looks like the tusks were hacked out in a hurry. The absence of tusks is, however, not always an indication of hunting for ivory since people, and even elephants, can pull out tusks from elephant’s that died of other causes (Douglas-Hamilton & Douglas-Hamilton 1975; Moss 1988).

The presence of tusks in a carcass is even more confusing. The elephant could have been killed for ivory and the carcass left to rot to make the tusks easy to remove (Moss 1975). The elephant could also have been killed in tribal rituals (Moss 1988), or by cultivators disgruntled with the elephant’s crop raiding. And finally, the elephant could have died of natural causes.

Tusks can also provide information on the status of a population. If one increasingly finds smaller tusks in a population, it may be an indication that there are fewer older and larger elephants. Since older males are the most important in reproduction (see Chapter 1) and older females are important in ensuring the survival of younger elephants in hard times like droughts (Moss 1988), such a population can be regarded as unstable, and possibly on the decline.

If one finds a population with a high or increasing frequency of tusklessness, it is a probable indication of selective removal of tuskers from the population (Pilgram & Western 1986b; Sukumar & Ramesh 1992).

Since an individual tusk that is detached from its source represents a dead elephant, tusks alone can also tell us about their source populations and individuals. The ivory stores of a protected area can thus provide much information on the status of the population. The rate of tusk recovery, with the exception of very young age classes (Corfield 1973), can indicate mortality rates. If one notices increasingly smaller tusks arriving either at a local ivory store, a central government store or a ware house, it suggests that the source population is probably declining and the age structure of the population is changing. Since ivory hunters selectively take large tuskers and female tusks are generally smaller, the proportion of female tusks in the market can indicate that the large tuskers have already been taken out, and this can be used as an indicator of the status of the populations supplying the market.

14.4.2 Data requirements

To maximise the value of data on elephant mortality and population trends it will be necessary to put in place a reporting and analysis system for data associated with ivory and elephant carcasses. These reports can be in the form of a few pages in a standard notebook which can be designed for other information as well. The pages reserved for information on ivory should be in the form of datasbeets that maximise the amount of information on tusks and their source. The area in which the tusks were found, the cause of mortality, the sex of the elephant, etc. can all be recorded. The effort put in to recover tusks in terms of time or patrol days should also be noted (see Chapter 16).

If tusks are collected for the local ivory store, they should be appropriately marked to make sure no information is lost. A master record with all information obtained in the field but also other information like measurements of size and weight of the tusks should be kept. Cross-referencing of that information with the collected tusks should be readily accessible.

If the tusks are to be transported, for example, to a central store, a system of registration that ensures maximum retention of information from the source area should be devised. If samples, for biochemical analysis (see below) are taken, information from the source area should again be retained.

A good system would maximise information from tusks, ease data processing and interpretation of results.

14.5 STUDYING ELEPHANT ECOLOGY AND SOURCING IVORY

14.5.1 Elephant ecology

14.5.1.1 Background

Elephant tusks can potentially provide information on elephant diet (Van der Merwe *et al.* 1990). They can also tell us something about elephant movements and habitat use. The potential for tusks to provide information on elephant ecology stems from the way they grow. Dentine, which is the main component of ivory, is added from cells called odontoblastic cells which line the pulp cavity in the centre of the tusk. These cells deposit dentine in layers of consistent thickness in the pulp cavity. The point of a tusk furthest from the pulp cavity, therefore, contains the dentine formed earliest. The potential of ivory to provide information on elephant ecology lies in understanding the way various chemical elements are incorporated into plant tissues and subsequently into animal tissues.

14.5.1.2 Carbon isotopes

Isotopes are forms of a chemical element that differ in atomic mass, and most elements exist as two or more isotopes. During photosynthesis plants convert atmospheric carbon dioxide and water into tissues. There are two major biosynthetic pathways by which plants do this, and depending on which they use, they are called C-three (C_3) or C-four (C_4) plants. Put simply, C_4 plants incorporate ^{13}C, an unstable isotope of carbon, at a faster rate than C_3 plants, and thus contain more ^{13}C than ^{12}C (the stable carbon isotope). In Africa C_3 plants comprise mainly trees and shrubs, whereas C_4 plants comprise mainly grasses in warm or dry habitats.

Elephants tend to eat plants in the relative proportions that they occur in the environment and the carbon isotopes which are incorporated into their tissues track the above ecological differences (Van der Merwe *et* l. 1988). For example elephants feeding mainly on grasses will have higher ^{13}C values.

Since tusks grow by addition of dentine layers at the pulp cavity, the carbon isotopic ratios incorporated in the layers at any one time depend on the ratios found In the diet at the time. One can, therefore, tell how the diet of an elephant varied over its life time from isotopic differences along its tusks.

14.5.1.3 Other elements

Other elemnts can be used as indicators of elephant diets. For example, there is a negative correlation between rainfall abundance and nitrogen isotopic values in plants (Van der Merwe *et al.* 1990, Vogel *et al.* 1990). Plants in arid areas are particularly rich in the stable nitrogen fifteen (^{15}N) compared to those from moist areas. The difference is reflected in animal tissues, and allows discrimination of elephants from wet versus dry habitats.

Elements from soil, incorporated into plants and then in turn, into elephant tissues, also provide information on elephant food plants. Strontium eighty-seven (^{87}Sr) and lead two-hundred-and-six (^{206}Pb) result from radio active decay of rubidium eighty-seven (^{87}Rb) and uranium two-hundred-and-thirty-eight ^{238}U) respectively. In Africa, soils derived from very old, granitic crusts which were rich in rubidium and uranium have higher ^{87}Sr/^{86}Sr and ^{206}Pb/^{204}Pb ratios than those with either young, volcanic or marine based sediments. As with nitrogen and carbon, tusks have the same lead (Pb) and strontium (Sr) isotopic composition as elephant food plants, and these directly track the isotopic composition of underlying soils and bedrock. This again allows discrimination of elephants from these areas using tusk material.

14.5.2 Sourcing ivory

14.5.2.1 Background

The sourcing of ivory is linked to the various aspects of elephant ecology discussed above. All the compounds mentioned can help us track the origin of ivory found in the market. The tracking of ivory can also be enhanced by the fact that DNA (genetic material) from tissue attached to the tusk of the same elephant can also provide some clues to origins.

It follows from the discussion on carbon that differences in carbon isotopic ratios along a tusk reflect changes in the relative frequency of $_3$ and C_4 plants in one area for elephants that have not been migrating. The same differences reflect elephant movements between different habitats whose relative frequencies of C_3 and C_4 plant have not been changing. In the same way differences in ^{15}N values along elephant tusks either reflect temporal changes in the rainfall of one area, or elephant movements between areas with different rainfall values (Sukumar & Ramesh 1992; DeNiro & Epstein 1978). Since lead and strontium in one geologic formation barely vary over time, their variation along an elephant tusk can only reflect large scale elephant movements.

The bulk of the thrust for attempts to source ivory using isotopes came as a result of the ban imposed on international ivory trade by the seventh conference of parties to the Convention on International Trade on Endangered Species (CITES) in 1989. It was hoped that the use of all the isotopes, in combination, would greatly improve the discrimination process and allow for the sourcing of ivory (Van der Merwe *et* al. 1990). Although initial attempts to apply ivory isotopic composition in the regulation of ivory trade have shown promising results, the lack of a continental database prevents realization of its full potential (Van der Merwe 1993; Koch & Behrensmeyer 1992). It is also extremely expensive and, therefore, not a practical method Africa-wide.

14.5.2.2 The use of DNA

DNA cannot be extracted from pure ivory, but in the absence of other sources, the degraded DNA found in tissue attached to tusks can be made sufficient for analysis (Georgiadis *et al*. 1990). By a technique called polymerase chain reaction, even small quantities of DNA can be multiplied to desired amounts.

Mitochondria are cell organelles that possess their own DNA. This DNA is exclusively passed onto offspring via female eggs. In species where females do not migrate far, their mitochondria accumulate genetic markers unique to a population. The analysis of this DNA provides a potential way to discriminate populations by tusks, although there is great overlap across populations of Loxodonta africana (Georgiadis *et* al. 1990).

14.5.3 Data requirements

Samples for isotopic analysis of tusks can be taken from any part of the tusk. All tbat is required is a piece of tusk the size of a thumb-nail. The actual position where the sample is taken, however, depends on the objectives of the analysis. If, for instance, one wants to find out the diet of an elephant immediately before its death, one has to go for samples closest to the pulp cavity. If the objective is **to** trace the isotopic composition of an elephant's diet during its lifetime, one needs to take samples along the length of the tusk. The objective of the study should determine the detail to which each tusk is analysed. One may also want to obtain samples from ivory artifacts.

Because chemical analysis requires that samples are not contaminated, only ivory that is neither stained nor cracked should be used (Harbottle & Silsbee undated). Details of isotopic analysis of the elements discussed above can be obtained from Koch & Behrensmeyer (1992) and Van der Merwe (1988 and

1990), but, in general, the procedures involve preparation of samples for mass spectrophotometry. The reporting of isotope values is detailed in Van der Merwe *et* al (1988). More information on DNA analysis can be obtained from Georgiadis *et al*. (1990), but in general, the procedures involve preparation of samples for mass spectrophotometry. The reporting of isotope values is detailed in Van der Merwe *et al.* (1990).

Further research into DNA, microchemical and isotope analysis will require substantial time and resources. While DNA analysis per sample may be relatively cheap, many samples are required for comprehensive research (Chapter 18 **-** Box 18.1, Georgiadis 1990). On the other hand, the cost of isotope analysis is very expensive, ranging from approximately US$50 per sample for carbon and nitrogen to US$150 per sample for lead and strontium (Koch & Behrensmeyer 1992). Van der Merwe (1993) has estimated that a continental database of ivory isotopic composition would require up to US$ 400,000, assuming that the necessary equipment is available. To include additional trace elements the available microchemical techniques might be too expensive for routine use (Wyckoff 1972).

14.6 CONCLUSION

Elephant tusks can potentially provide useful information on the individual and population level. They can tell us a variety of things in different circumstances and sometimes they are the only source of information on the elephants that have died. Further research is needed in order to realize the full potential of information from elephant tusks. At the same time, the reality of the costs of such research and potential applications must be taken into account.

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SECTION 5
ELEPHANTS IN THEIR HUMAN CONTEXT

CHAPTER 15

ASSESSING THE IMPACT OF HUMAN-ELEPHANT INTERACTIONS

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15.1 INTRODUCTION

Throughout Africa elephants exist as island populations surrounded by humans, and a major component of the relationship between humans and elephants is the conflict over land use. Elephants are a large, space-demanding species. In their search for food and water they have traditionally engaged in extensive seasonal migrations, and while the majority of these movements have been curtailed in recent years, elephants still require large tracts of land. At the same time the growing human population in much of Africa means that an increasing amount of marginal land is being converted to agriculture, encroaching increasingly upon land that was once available to wildlife. Both these trends mean that elephants and people are overlapping in their use of habitats and are coming into more and more conflict.

The type of conflict that occurs at the meeting of humans and elephants depends largely on the primary economic activity of the people affected. Where people practice agriculture, conflict arises when elephants consume and destroy cultivated crops; and where the primary economic activity is keeping livestock either in cattle ranches or traditional pastoralist regimes, the conflict revolves around demands for grazing and water sources.

The ultimate challenge that staff of protected areas face is to reduce the conflict between humans and elephants, solving the problems people encounter as a result of living with elephants, while at the same time conserving the elephants. It is only if this challenge is met that elephants and humans can continue to cohabit the continent.

Prior to finding solutions to the problems of human-elephant conflict, one needs to have a good understanding of them. One needs to know the nature of the conflict, its extent, its impact in economic terms, and its impact on elephants. This chapter sets out to guide one on how to begin assessing the impact of elephants on people and the impact of people on elephants.

Elephants are not the only wild animals that come into conflict with people, and although this chapter is written focusing on investigating human-elephant interactions, one should bear in mind that the methods can be extended into a wider investigation of human-wildlife conflict involving other species.

15.2 ASSESSMENT OF THE IMPACT OF ELEPHANTS ON HUMANS

15.2.1 General

The conflict between humans and elephants usually revolves around the destruction of crops by elephants, human injury and mortality caused by elephants, competition over the use of limited water resources between elephants and people, damage of watering structures by elephants and the killing of livestock by elephants. Preliminary investigations will provide you with an idea of what the problems are in your area, and guide you in what steps to take in making further enquiries.

15.2.2 Preliminary investigations

It is likely that reports of conflict will come to you or you will hear about them long before you think of attempting to investigate them. People are always quick to report the costs incurred through living with wildlife. Your initial task simply becomes the verification of these reports.

Walk or drive around the area where the problems are said to be occurring, look for the signs of damage, and ascertain that elephants are causing it. Elephant footprints, dung and the debarking or felling of trees (characteristic elephant feeding behaviour) are telling signs.

Asking people questions will enlighten you further, as the local people are likely to know when elephants visit the area, and they will describe in great detail the damage elephants cause.

Once you have identified the major problems people face, you will be able to design a strategy to assess comprehensively the impact of the contact between people and elephants. Some key methods of assessing the impact of elephants on humans are:

- to ask people questions or to carry out a questionnaire survey;
- to make independent assessments of the costs of living with elephants, such as the extent and value of crop damage;
- to consult existing records for information; and
- to observe the elephants.

The best assessments of human - elephant conflict are obtained by using a combination of these methods. You will have to determine those most appropriate to use for your situation, as each provides a different kind of information.

Questionnaire surveys are a quick way of obtaining information from a cross-section of people. They will provide you with an assessment of the problem from the people's perspective, and enable you to seek information on a number of issues at the same time. You may, however, need to complement this information with more objective assessments. Independent assessments of crop raiding can give you very accurate information on the frequency of crop raiding and the economic loss to the farmers, but they take a lot of time. Consulting existing records such as park incident records or local government reports is an easy way of gathering information, and is particularly useful if you are seeking a historical perspective, as the records can go back for a number of years. Unfortunately, such records are only as good as the people who keep them, and it is difficult to assess what proportion of incidents of any kind are recorded. Observing elephants enables you to identify "problem" elephants and study their patterns of movement. This will give you further information with which to apply suitable solutions. Let us now look at each of these methods.

15.2.3 Asking people questions

Not surprisingly, much of the impact of elephants on people can be determined by asking people questions or carrying out a survey. The term "survey" usually implies a sample survey designed to gather information from or about a fraction of the population only (Heguye 1988). That fraction, however selected, constitutes a sample. This is in contrast to a "census" which is designed to gather information either from or about each and every member of the population (Heguye 1988; Moser & Kalton 1979).

Heguye (1988) states that the primary purpose of a survey "is to collect data, usually through interviews, in as unbiased a form as possible, and to provide as accurate and complete a picture as you, the researcher, need or are interested in."

Both the philosophy and methodology of carrying out surveys have a long history and much has been written about the topic. The outline provided here, for the specific purpose of assessing the impact of elephants on people, should, where possible, be complemented by reading the texts in the further reading section at the end of this chapter.

a) Defining the goals or objectives of the survey
The first step in carrying out a survey is to define its goal. The information obtained in the primary investigation stage will be particularly valuable here, as having identified the general problems, you will have an idea of what to investigate. "To determine the impact of elephants on people" would be a typical general goal. Arising from this would be such sub-goals as "to assess the prevalence of crop damage by elephants", and "to determine people's attitudes towards elephants".

At this point, you may need to consider whether you can obtain the information you need by carrying out a survey just once, or whether you will need to do a series of surveys on the same subjects. For example, if you want to determine the impact of erecting a fence around a cultivated area to prevent elephants from entering the zone, then you may want to carry Out the survey before the fence goes up and three months or so after the fence has been erected, or in the next growing season.

b) Practical issues

In planning your survey you will also need to consider some practicalities. For example do you have enough money, time and people to help you carry out the survey? You may not have the resources you need and you may have to seek another way of obtaining the information, as surveys can be time-consuming and expensive.

c) Defining the population

The next stage in designing a survey is to decide on whom you will carry out the survey. Is your survey going to be representative of all the people living in the district, or all the people using one water source, or all the people living within a 50km band around a protected area? Deciding on this is called "defining the population" (Moser & Kalton 1979).

You then have to consider if you can talk to all individuals in the population, or whether there are too many individuals and you can only address a proportion of them. If you decide to talk to everyone in the population, then you are carrying out what is technically a "census" and you need not bother with the following considerations of selecting a sample.

It is usually the case that one does not have the time nor the resources to cover the entire population, so one has to select a portion of the population or select a sample.

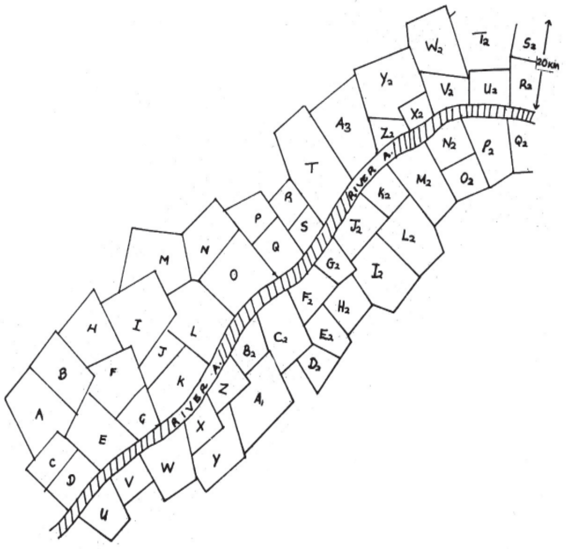

Fig. 15.1: Map showing all settlements along the River A. The "population" in this case would *be all* the *land* holdings within 20 km of River A. The "sampling unit" is the land holding. The "sampling frame" would *be* the *list of* all land holdings in the population, that is A, B, C, D …, etc.

d) Selecting a sample

In selecting a sample there are a number of questions to be considered: What size should the sample be? What is the appropriate sampling unit or is one going to sample households, individuals, land holdings or agricultural plots?

Most people carrying out surveys have to go through much deliberation about what sampling unit to use. In trying to assess elephant impact on people, I feel it is better to use a geographical unit such as settlement or land holding rather than an individual as the sampling unit. You will need to know the general components of this unit, like how many individuals live in a settlement or depend on the land holding, in order to interpret the findings of the survey fully, but these units enable one to work with a fixed subject that is easy to find. Furthermore, analysing information at the level of settlements or land holdings should suffice in most cases.

To sample, you need a sampling frame. This is a list of all the units which exist in the population. If the sampling unit is the individual then you need a list of all individuals living in the population. If the sampling unit is the land holding or settlement, you need a list of all the names of the land holders or settlements, and also a map showing them all (see Fig. 15.1).

A slightly different question to consider is what the unit of enquiry should be. Will you be asking about individuals and their experience or the experiences of the settlement or land holding? In surveys about elephant impact on humans, it is usual to make the unit of enquiry the land holding or the settlement. As such, the sampling unit and the unit of enquiry are the same.

Once a sampling frame has been determined, you need to select from it those units to be surveyed. That is, to select the sample.

There are numerous and complex statistical considerations at this stage which may influence the course of action you take. Among them is the concept of how representative of the population the sample is and how you can use the Information gathered from the sample to make inferences about the population. The most accurate information on a population is obtained by collecting data on all members of that population. In theory, the larger the sample the more representative of the population it will be, but if a population is fairly homogeneous, or there is little variation between members of the population, then even a small sample will give an accurate picture of the population. However, if you have enough information to know that the population is homogenous then you do not need to carry out a survey! Making a sample as random or unbiased as possible also increases the likelihood of its being representative of the population. For a detailed discussion of the statistical assumptions of sampling see Moser and Kalton (1979).

On a more practical note, you have to decide how large the survey is going to be. How many sampling units do you wish to cover and how many can be covered given your resources? Usually a balance needs to be struck between these two. Aiming for a truly random sample of 10% to 20% of the defined population should give an indication of the trend in the population. But you should note that statements about samples are only probability statements (Moser & Kalton 1979), and they only indicate trends in the population.

The main challenge of sampling is to ensure that the units sampled constitute a "fair" cross section of the population or one that was chosen with enough rigour to satisfy an observer that the selection was not influenced by the most obvious sources of bias, such as asking questions only of people who wanted to answer questions or those nearest to one's work base!

There are a number of ways of drawing or selecting a sample, all of which have some statistical assumptions. These are described in Box 15.1.

e) Drawing up the questionnaire

After you have selected the sample, the next stage is to design the questionnaire or survey instrument to be used. This is a much less straight forward task than it seems and there are many things to take into account.

The first is to ensure that you design questions which provide you with the information you need or the data you require to meet your overall goal. You will want information on the problems you encountered in the preliminary investigations. For example, you may want to know how widespread

BOX 15.1: SAMPLING METHODS

Drawing a Simple Random Sample involves drawing units from a population in such a way that each has the same chance of being selected. To do this it is essential to have a sampling frame which identifies all the units in the population either by name or number. If the population is small, one could write the names on cards of equal size, put these in a hat and draw out as many as are required for the sample. If the population is large, one can give a number to the units in the population and select those to be included from a list of random numbers (published series of numbers arranged in non-systematic order).

Another common way of selecting a sample is to carry out Systematic Random Sampling. This also requires complete lists of all units in the population. The sample is then drawn, by selecting a figure from a random number table, for example, 4, and then selecting all sample units with the number. In this case 4, 14, 24, 24, 40 – 49, 54 will all be selected, until the required number of units is selected.

Alternatively, you could select a sampling fraction such as 1 in 6, start at a random figure, say 4, and select every sixth unit which in this case will be the 10th, 16th, 22nd unit. This second method has the disadvantage that you must be sure that the sampling fraction does not correspond to a cycle or pattern in the sampling frame (Heguye 1988).

Stratified samples can be drawn, either to ensure that the researcher has equal or representative numbers in the sample of certain categories. One may decide to have equal numbers of pastoralist settlements or agriculturalist land holdings in the survey so half the sample would be drawn from the list of agriculturalist settlements and half from the list of pastoralist settlements. It may be the case that in a certain area one-third of the households keep livestock and two-thirds grow crops. A proportional representation of the population would mean that on-third of the sample would need to be drawn from the livestock keeping households and two-thirds from the crop growers.

Alternatively, you may want to sample an equal number of men and women or an equal number of men and women or an equal number of people in different age groups. In this case you will require a list of all men and women or all members of the population by age as your sample frame.

When selecting a sample it is useful to select four or five more than you need, as reserve sampling units, in case you cannot interview all of the original sample. (Adapted from Heguye 1988).

crop raiding is. When does it occurs? What crops are damaged? You may also want to know how many farmers have had livestock killed by elephants or how many people in each settlement have been injured or killed by elephants.

In trying to assess the impact of elephants on humans, typical questions would be:

- Do elephants come into your agricultural plot?
- Do they eat the crops you grow?
- In what season do elephants come to your plot?
- At what time of day do elephants come to your plot?
- How do you chase elephants away?
- Have you (anyone in your family) been hurt by an elephant?
- Have any of your livestock been injured or killed by an elephant?
- How would you feel if the elephants were removed?

You will also need to ask questions that Will give you information about the respondent. For example, how long have you lived here? How many people depend on this piece of land? The answers will enable you to interpret the information on impact in the light of parameters of the population. In considering which questions are relevant, you should try to consider the kinds of analyses you plan to undertake with the results of your survey.

Other considerations in designing questionnaires are what type of questions should you ask. Should they be closed, providing the respondent with a series of possible answers to choose from? Should the interviewer field code the responses into categories which he has, but which are not communicated to the respondent? Should questions be open where the interviewer asks the question and takes down, in longhand, the full response given, for coding at a later date?

Each of these types of questions has advantages and disadvantages. Giving the respondent a response category obviously influences their response, and I recommend avoiding this type of question for interview surveys. Field coding where the interviewer has a number of responses to tick and interprets the respondent's answer there and then has the advantage of being quick, but the disadvantage of wasting or losing information. Easy answers can be pre-coded for example, Do elephants come into your plot? Yes = 1, No = 2 and the interviewer can tick the right number in the field as soon as the response is given.

More complicated or interesting answers should be taken down in longhand and coded later, as it is a pity to lose some of the information before you have had a chance to think about it.

Questionnaires take up the time of the respondent who will have many other things to do, so you should try to make them as short as possible, while meeting your research requirements. Remember questions are expensive! A long questionnaire results in a long interview which means you pay interviewers more. You also spend more on replicating the questionnaire sheet and you spend more on sorting out the data at the end!

Once you have determined which questions to ask, you should consider the order in which to ask them. It is good practice to ask simple questions which do not threaten the respondent first, and place questions about sensitive issues at the end. By the time you ask these, it is hoped some rapport has been built between the interviewer and the respondent.

It is also a good rule to start with general questions and then narrow down to specifics, such that you do not influence the answers of the respondents. Also remember to group related questions, again starting with the general and leading on to specifics.

For ease of reference to interviews it is worth giving each questionnaire a unique number as its identifier. This should be at the top of the questionnaire sheet, and on each of its pages.

If your questions are to be asked in different languages, you need to ensure linguistic equivalence, or that, once translated, each question means the same thing in all the languages.

At this point you should test your questionnaire to determine if the questions are understood and you are obtaining the information you need. Pre-testing will also give you an idea of how long the interview takes. Remember to test the questionnaire on members of the population who are not part of the main sample. If people have problems understanding questions, change the wording. If the interview is so long that the respondent's interest fades, reduce the number of questions. Spending time and thought pre-testing and adjusting your questionnaire will save you much wasted effort in the long run.

f) Interviewing

Once you have selected the sample and drawn up a questionnaire and pre-tested it, you are ready to carry out the survey. If you are going to use "enumerators" or other people to help you carry out the survey, you will need to train them to ensure they understand the questionnaire, and the importance of addressing the questions to the pre-selected sample of people, as you will be assigning a portion of the sample to each interviewer. It is wise to involve the enumerators in the pre-test.

It is important that each interviewer asks the question as it appears on the questionnaire and records the answer accurately, not biasing it by his or her own attitudes or predispositions. It may be worth accompanying each of the interviewers to check that they are asking questions correctly. You should also check the completed questionnaires as they come in, to detect any problems at an early stage.

You should try to carry out all the interviews within a relatively short space of time, as the problems you are interested in may vary seasonally.

When approaching people, one needs to be friendly and pleasant. Go back another time if it is not convenient for the respondent to answer your questions at the time of your first visit. Depending on how much time you have and the distances you need to cover to reach your respondents, you may decide to substitute one of the sampling units with one on the reserve list after two or three unsuccessful visits.

g) Processing and presenting the information

Once some data is collected, you can turn your attention to coding it. The first step is to establish all the codes to be used and come up with a coding sheet. This will involve going through some of the questionnaires and summarising the categories of responses. You can then group the responses into categories and assign codes for processing the information. Be sure to include a category for no response. Codes should not overlap and should cover all possible answers. Some examples of coding:

A. Sex of respondent:

1 = Male
2 = Female
3 = Not indicated

B. Problems encountered:

a) Crop Raiding
    1=Yes 2=No 3=No answer

b) Human injury/mortality
    1=Yes 2=No 3=No answer

c) Livestock injury/mortality
    1=Yes 2=No 3=No answer

d) Damage to watering structures
    1=Yes 2=No 3=No answer

e) Damage to food stores
    1=Yes 2=No 3=No answer

Once you have established your coding list, you should go through all the questionnaires assigning codes to them. The way you handle these codes depends on the facilities available to you. You could enter the codes onto tabulated sheets of paper that will make it easy for you to carry out some hand counts and analysis, or you could enter the codes into a specially designed database on computer.

The next step is to try to understand what the data you have collected mean. Counting up the different codes for each category is a good first step. For example, 70 of the 115 land owners complained about crop raiding. Ten of them had members of their family or household injured or killed by an elephant, etc. Try to grasp the meaning of these numbers.

The final stage is to write up a report of the survey. Evaluate the results in relation to the questions you were asking, the problems of the community, and the ways you see to solve these problems.

It should be noted that while the steps in carrying out a survey appear chronologically distinct, each phase depends on the others for its success, and forward and backward linking should be a key activity of survey design (Moser & Kalton 1979). For Instance, as you decide on the questions to ask, picturing the kind of tabulations and graphs you would like to draw at the end of the survey will enable you to clarify what data you are seeking. It is very much worth thinking through the whole operation before the first step is undertaken.

h) Possible sources of bias

There are numerous opportunities for bias to enter into a survey. Asking leading questions is one of them. A question like “What problems do elephants cause you?” assumes that elephants are a problem and influences your respondent’s frame of mind, even before they answer you. Questions should always be neutral.

It may be the case that you work in an area where people would prefer to be interviewed by male enumerators, or that women prefer to be interviewed by female enumerators. You should be aware of the gender consideration and biases in your community and select your enumerators accordingly.

The responses people give will sometimes depend on what they think you would like to hear, or what they think you will be able to do to help them. Sociologists have overcome or reduced this problem by asking the same question in different ways at different points in the questionnaire. This helps one to check for inconsistency.

Enumerators dressed in a protected area authority uniform may cause the respondents to answer negatively in the hope that the authority will help them. Conversely, people may resent the protected area or local government authority and not want to have anything to do with enumerators in uniform.

It is impossible to remove all bias from a survey, but being aware of how it might arise will help you tackle the most obvious problems. In writing a report on the survey, it is always fair to mention where bias may have influenced the results you obtained.

15.2.4 Independent assessments and monitoring of crop raiding

A questionnaire survey will give you a broad picture of the prevalence of crop raiding in an area, and provide you with information on the main crop raiding season which may suffice for your needs.

There are, however, aspects of crop raiding where the information required is best obtained from independent assessments. These are the extent of crop damage and the economic loss thus incurred. Understandably, some people are likely to over inflate the amount they have lost in the hope that they will be compensated at these levels. Over inflation of the loss also results from the emotional perception of loss. When you ask someone how much of his crop has been damaged, the response is likely to portray his perception of loss rather than the actual loss and these can be significantly different. In fact, it may be interesting to compare the difference between the perceived and actual loss.

The value of independent assessments is greatest when they are part of a systematic study. To assess the extent of crop raiding, the first step would be to select randomly several farms or land holdings to be monitored, using the same methods for random selection described above for questionnaire surveys. Once you have selected the farms, you should plan a regime for visiting them on a regular basis, asking questions about the number of crop raiding incidents since your last visit and inspecting the cultivated area to assess damage.

Crop raiding problems are invariably seasonal, and are best studied over time. The ideal scenario is to carry out the study over a year, but shorter spells may be adequate if you do not have the time. It would then be best to do some monitoring in the dry season and some in the wet season.

You could leave a data sheet or calendar for the farmer to write down each time the elephants come to his or her plot of land to crop raid. You could then use these data to calculate the mean number of crop raiding incidents each month by adding up all the incidents reported in all the farms for each month and dividing this by the number of farms. Plotting these data for each month will give you a graph like the one in Fig 15.2. This analysis provides you with information on when crop raiding by elephants is at its worst. This is important information. If your management authority is to place a problem animal control unit in the field, you will know when it is needed the most!

It is important not to base all your assessments on the reports of the farmers. You could, if time allows, make repeated visits to farms to ascertain that reports are correct by looking for fresh signs of elephants in the fields. Better still, a series of night watches at the farms will help increase the quality of your information.

You might want to assess the economic loss

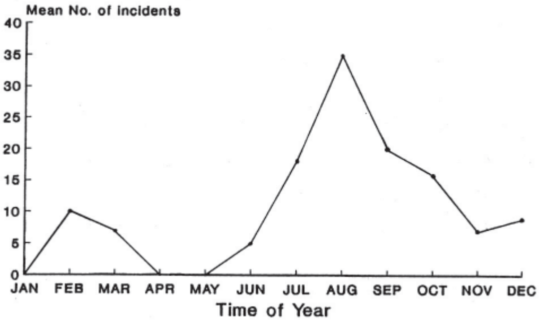

Fig. 15.2: Line graph showing the mean number crop raiding incidents in Mango District during 1994.

caused by elephant crop raiding. The best way to do this is to visit the farms you have selected as regularly as you can and estimate the damage caused when elephants crop raid. This will involve measuring or estimating the area of the crop that has been damaged and, if necessary, expressing it as a fraction of the total area under cultivation with that crop by that farmer. *Sukumar* (1989) used a quadrat to measure the area of damage and, where relevant, counted the number of individual trees damaged. Ngure (1992) used string to measure the area of damage and also counted individual plants.

There are different approaches to estimating the cost of the damaged area. One is to estimate the value of the yield for the crop in the damaged area if it were to mature and fetch market prices, but this is problematic. If the crop was damaged just prior to harvesting it would be fair enough to estimate its value at market price. However, with an immature crop one cannot be sure it would reach maturity uninfluenced by natural catastrophes such as drought or floods and so one is assuming much in giving it a market value. A more cautious approach is to estimate the cost of the crop by simply adding all the inputs up to the stage it was in when it was damaged.

An agricultural officer working in the area should be able to help you with the costing of all inputs and the valuation of the crop. If you begin with a list of all the inputs to the entire crop to the date of damage, you can then multiply this by the area of damage to get an estimate of what the loss is worth. Among the inputs will be the cost of seeds, fertilisers, insecticides, labour and irrigation.

By visiting a farmer regularly over a growing season, you can obtain a cumulative figure of all the damage to his crop over one season. A sample of farmers will give you the data to work out the average loss per area of cultivated crop and you could multiply this figure by the total area under cultivation in the region to get a figure for loss in monetary terms per season for the whole area.

These figures will be important in considering what management strategy to take, If people are losing nearly all their crops, management may need to come up with good ways of preventing elephants from entering crop fields.

15.2.5 Consulting records

An additional source of information on human-elephant conflict can be found in the incident records and reports in protected area and local government offices. It would, thus, be useful to consult these records.

Protected area staff are likely to keep records of people injured and killed by wildlife as well as records of livestock killed by wildlife. Searching through these records you may be able to determine how many elephant incidents occur. It may interest you to compare these findings with the answers you got on elephant incidents in your survey.

It is unlikely that these reports will be complete, but they will provide you with an indication of the number of incidents which are reported each year. At any rate they will provide you with the number of reported and recorded incidents, which is useful information in itself. If you are in a position to influence the keeping of official records, it is worth encouraging your colleagues to keep records as complete as possible.

15.2.6 Observing elephants

Useful information on the impact of elephants on people can be obtained by observing elephants.

By staking out a cultivated field, and using a powerful flash light you will be able to see which elephants are crop raiding. Night watches can be followed up by tracking the elephants once it is light. For example, in Amboseli I was able to follow the footprints of a group of 17 bulls through a series of crop fields back into the National Park where I found the bulls resting. When the elephants moved away, I went through the dung they deposited, having noted which bull deposited which pile, and found tomatoes, maize and onions in the dung. I was thus able to identify exactly which bulls had been crop raiding the night before.

Many sections of this book are relevant here. Knowinghow to age and sex elephants and identify individuals (Chapter 7) will enable you to identify crop raiding animals. It has been observed that culprit elephants are consistent and it may only be a few who are causing the problem (Sukumar 1989). If you can identify the "problem" elephants, removing them may be the solution.

Studying elephant movements (Chapter 8) will show you whether the human habitation is part of the home range of any particular elephants. Certainly, knowing the main routes of entry into and out of cultivated areas will enable you to position barrier fences strategically.

Combining the reports taken from people with observations of elephants will give you a fuller picture of human-elephant interaction, and is worth doing.

15.3 ASSESSMENT OF HUMAN IMPACT ON ELEPHANTS

15.3.1 General

Not all the impact of human-elephant conflict is suffered by humans. Elephants have also incurred major losses, with numbers crashing to the verge of extinction in many parts of Africa, primarily due to the poaching of elephants for ivory. Elephants have also had to adapt their movement and foraging habits to an increasingly populated continent.

While quantifying how humans are influencing elephants is less easy than quantifying elephant impact on humans, you may be able to carry out some useful studies. You could, for example, determine how human use of an area is influencing elephant use of the same area. You could also look at how humans and elephants share a limiting resource such as water. Where there are good records of elephant mortality, you could determine the proportion of deaths caused by humans. The trick here is to be adaptive and use whatever method seems sensible to give you the data you want.

15.3.2 Looking at elephant distribution in relation to human use

Carrying out dung counts in the tropical forest of central Africa showed that the main factor in determining elephant distribution is human habitation (Barnes *et al.* 1991). I used dung counts to determine the distribution of elephants in relation to Maasai settlement in Amboseli (Kangwana 1993). Details of the dung-counting method are given in Chapter 5. You can modify these methods to carry out a study of elephant distribution in relation to people as follows.

You will need to divide your study area into strata according to distance from human settlement, and then distribute your counts in these strata. Your strata could be 0-5km away from settlements, 5-10km, and 10-15km, etc. A reconnaissance (see Chapter 5) in the area will give you an idea of where to place your transects.

Once you have collected the data and have your dung densities for each of the transects and strata, you can begin to look for trends in the distribution. For a study of elephant use of areas you do not need to convert the dung density to elephant numbers, as relative use of areas is usually sufficient. However, you may need to carry out a study of the rate of dung decay as it is useful to know how long dung lasts on the ground (see Chapter 5). This will give you a time frame in which to assess your dung distributions.

You are likely to find that elephants avoid areas of human settlement. You can infer from this that if the number of settlements in your area increases, elephants will have to find alternative areas to use or have less area available to them.

15.3.3 Looking at dual usage of watering resources

In some areas elephants and people may be forced to share water sources, and it is interesting to observe how they do so. This may also be a good way of observing the results of direct contact between humans and elephants.

The first step is to identify an area which is used regularly by both people and elephants. Once you have done this, you can devise a scheme of watching the area. Setting a time frame for observing the area helps. For example, you may want to observe the area for two or three months, or for one month in the wet season and one month in the dry season to compare the use of the resource each season.

You should then divide the day into time blocks for watching the watering place. Say early morning (6:30-9:30am), late morning (9:30am-12:30pm), early afternoon (12:30am – 3.30pm), late afternoon (3:30-6:30pm) and evening or night. Over the time period that you decide to observe the area, you should spend one or two of the time sessions observing use of the area by people and wildlife. Which sessions on any day you watch the area should be random but you should cover an equal number of blocks in each time zone during your study time. Let us say on the first day you watch the area from 6:30- 9:30am, on the second day you could watch it from 3:30- 6.30pm and so on.

The data you will be collecting are on human and elephant use of the area. You could design a simple data sheet to help you do this (see Chapter 10). In this case you will want to note the date and time as well as when elephants and people come into the zone and when they leave, what they do when there and how many elephants and humans come in at any one time. It will also be interesting to estimate the distance that elephants and humans stay apart.

The data you obtain here will give you an indication of how the area is used by both, and the times with the highest probability of conflict. In an ideal world, you could then advise people to use the area at times elephants are least likely to use the area. It has been shown, however, that elephants can adjust their times of use of a watering hole around the times humans use it (Kangwana 1993).

In your preliminary investigations you may have come across the fact that elephants destroy man-made watering structures such as wells and boreholes. The above regime for watching a watering place could be used to watch a well or borehole. Carrying out this study will give you an idea of how elephants use the structure, what damage they cause, and how you can decrease the damage or prevent elephants from using these structures.

15.3.4 Human contribution to elephant mortality

In places where there are good records of elephant mortality, it may interest you to try to determine how many of the elephant deaths are caused by humans. Human causes of elephant mortality include poaching for ivory or meat, killing in retaliation and hostility as a result of damage, ritual hunting and sport hunting. Protected area records are a good source of information on elephant deaths and their causes. Chapter 16 provides you with guidelines and a data sheet for collecting mortality data in the field. We have also seen how ivory stores provide information on elephant mortality trends (Chapter 14).

15.4 CONCLUSION

This chapter has gone through some of the methods you are likely to use in assessing human-elephant conflict. It should now be clear that assessing human-elephant conflict is not a field with its own idiosyncratic methods. It takes a combination of sociology, biology and economics plus some common sense and imagination to bring the relevant elements together to help you assess the human-elephant conflict in your area. Once you have assessed the problem you will need to make management decisions but that is another topic.

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CHAPTER 16

MONITORING LAW ENFORCEMENT AND ILLEGAL ACTIVITIES

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So many men, so many *opinions; his own a law to each.* Terence c.195-159 B.C.

16.1 LAWS AND LAW ENFORCEMENT

Laws may be defined as a body of rules that enjoin or prohibit certain actions, and can be considered as the practical instrument for implementing policy. Laws are basically of two kinds, one written in statutes enacted by a legislative assembly, and the other often unwritten and acting by custom. Laws also operate at various levels ranging from local bye-laws, to national laws, to international treaties. The objective of law-makers is to make prescriptions that regulate human activity for the 'greater good'. However, law-makers have to reconcile a wide variety of interests and their vision of the 'greater good' may well not coincide with everyone's view of their own personal good, which therefore gives rise to the well-known general rule that laws are made to be broken. Nevertheless, those who have made laws, and who believe they have 'right' on their side will wish to see that the law is enforced, that attempts to break the law are kept to a minimum and that the law achieves its particular objective. Given that monitoring consists of keeping track of the components of a system, specifically to assess their progress in relation to the objectives set for the system (Bell 1983), it is as valid to monitor the success or otherwise of the law in achieving its objectives as it is to monitor, let us say, the ecological components of a system such as trends of change in elephant numbers and in woodland cover in relation to the objectives of a culling programme. Indeed, given that around 90% of the staff of African wildlife authorities are employed in the field on management duties related to law enforcement, and that a large component of law enforcement relates to those large and charismatic species with valuable trophies like the elephant (Cumming'*et al.* 1984), it is of paramount importance that the monitoring of this component of the system is accorded a very high priority by wildlife managers. Hence, the main purpose of this chapter is to emphasise the need for establishing a system for monitoring the success of law enforcement activities in African protected areas to ensure that investments are cost-effective. Using one case study, the chapter makes suggestions as to how monitoring can be achieved and discusses some results of relevance from those few studies which have been undertaken in this field. None of this is a new plea, having first been made a decade ago (Bell 1986a), yet sadly is one that has been taken up in very few instances (Dublin & Jachmann 1992; Leader-Williams & Albon 1988; Leader-Williams *et* al 1990).

16.2 LAWS AND THE AFRICAN ELEPHANT

The African elephant poses a particular challenge to the law-maker wishing to reconcile a wide variety of human interests, not to mention the interests' of the elephants themselves. Elephants are a challenge because they and their products attract the attention of many people, ranging from rural farmers, meat and ivory hunters, carvers and users of ivory, tourist hunters and game viewing tourists, to scientists and conservationists. Yet the perceptions of elephants held by these different interest groups vary widely. They range from a complex mixture of motives from''greedy' to 'noble' and from 'intolerant' to 'sentimental'. A local farmer may view an elephant as three tons of meat capable of damaging one year's crop of maize.

Hunters, carvers and buyers may see ivory as a source of income, and a product of beauty, durability and prestige. A tourist, whether hunter or viewer, may see an elephant as trophy to be bagged with a rifle or in a photo. A scientist may see an elephant as species of high intelligence with a social system that is fascinating to study. And a whole further set of moral and ethical dilemmas are presented in deciding whether elephants should be used and shot, or totally protected and left undisturbed, or be allowed to damage human life and property. Such questions will produce different answers among different people, each of whom may be as 'right' as the other.

Whatever the perceptions of the various interest groups, a general rule is that expanding human populations replace wildlife and their habitats, and especially those species that are large and long-lived. Accordingly, written national laws to protect wildlife have existed for centuries in some countries, while international wildlife laws have been formulated more recently. For the African elephant, however, the two have been developed fairly contemporaneously as the written national wildlife laws of range states date to the colonial era and, in some instances, result from an early international treaty, the so called "African Convention", which encouraged African range states to take measures to conserve their wildlife (Lyster 1985). Most national legislation in Africa encompasses prescriptions for the protection of, for the hunting and capture of, for the damage to human life and property by wildlife including elephants. African wildlife laws include clauses establishing wildlife authorities, categories of protected areas and of protected species and clauses covering methods, fees, types of use and who can undertake that use, and penalties for those found breaking particular sections of the law (IUCN 1986). International laws which, in theory, could have some direct or indirect bearing upon African elephants include the "African Convention", which had the catalytic effect noted above in encouraging national conservation measures but now lacks resources and any secretariat to implement the Convention, and the "World Heritage Convention", which plays a role in highlighting key protected areas, including those for elephant conservation (Lyster 1985). But of greatest contemporary relevance to African elephants is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). With the listing of the African elephant on Appendix I of CITES in 1989, any international trade for primarily commercial purposes in specimens, whether living or dead and including any recognisable parts of derivatives thereof, is no longer allowed (Bräutigam 1991).

16.3 COMPONENTS OF A LAW ENFORCEMENT SYSTEM

16.3.1 General

Wildlife laws address many issues as noted above. Therefore, a comprehensive system of monitoring law enforcement could encompass monitoring the success of enforcing every clause on the statute books or every article of an international treaty and assessing whether each clause or article achieves its objectives. Indeed, it would be quite possible to setup a monitoring system for almost any clause or article, given sufficient thought in assessing the objectives of that clause or article and in framing questions that need to be answered in the design of an appropriate monitoring system. However, in practice, research and monitoring budgets of national wildlife authorities and international convention secretariats are limited. Therefore, it is necessary to give priority to monitoring the enforcement of those aspects of the law that relate to major management problems faced by wildlife authorities (Bell 1986b). Clearly, for the African elephant, the major problem confronting wildlife authorities and international conservationists over the past two decades has been the loss of elephants to supply international markets with illegal ivory and whether efforts to reverse that loss have been successful. Hence this chapter will concentrate on this topic and use it to explore the general principles of monitoring law enforcement.

16.3.2 Law enforcement and the illegal ivory trade

The ivory trade has a long and complex chain that extends from the hunter killing the elephant in Africa to the retailer selling a finished ivory product one or two continents away. An equally complex set of national and international legislation attempts to keep the ivory trade within legal bounds and at sustainable levels, while a variety of authorities attempt to enforce these laws at various levels. These include the staff of national wildlife authorities who patrol on foot in protected areas with the objective of deterring and/or arresting illegal hunters, the police and staff of special units who investigate trafficking in ivory and supply of weapons to illegal hunters, the customs officer who checks shipments leaving or entering his country for illegal ivory the trading standards inspector who checks retail outlets, and the police and judiciary who are responsible for convicting and sentencing those caught breaking the laws. The success of law enforcement efforts can be monitored at all these different stages, given sufficient co-operation by law enforcement staff working in areas of sometimes great sensitivity, given sufficient ingenuity in setting up data collection protocols and in analysing the results of activities that are, by their very nature, illegal and circumspect. Before moving to consider examples of monitoring law enforcement activities at various stages of the chain or in relation to various pieces of legislation, certain basic principles of monitoring any form of law enforcement activity will be considered.

16.3.3 Recording data and measurement of effort

To be useful, law enforcement activities should be monitored with data that are collected rigorously and conscientiously. Within any law enforcement unit or anti-poaching patrol, this will usually require the assignment of one staff member to the task of data collection. It is vital that adequate training is provided to the person collecting the data, that middle-level managers provide the necessary leadership to junior staff collecting the data through their own regular participation in exercises and patrols, and that adequate debriefing is carried out at the end of any exercise or patrol by middle-level managers and/or research and monitoring staff who will collate and analyse the data. It will usually be appropriate for staff collecting data to be encouraged to note any other observations they feel are of interest and importance. These additional notes should form a vital component of the debriefing, following the end of the exercise or patrol. A final important point is that law enforcement staff should be given feedback on the data they have collected, once it has been analysed and is readily presentable in graphical or geographical format. The increasing use of micro-computers provides a good tool with which to develop an interactive forum between law enforcement and research and monitoring staff in a manner that should improve the usefulness of everyone’s work.

The priority accorded to different aspects of law enforcement may change over time, whether judged consciously or not. Any monitoring of the success of law enforcement activities should be undertaken bearing two basic pre-requisites in mind. First, it is necessary to make all records of law enforcement activity in standardised categories. On foot patrols in protected areas, these categories could include sightings of live animals, finds of carcasses, encounters with illegal entrants and hunters or signs of their activity, the numbers of illegal hunters captured or seizures of illegal ivory made in terms of numbers and weight of tusks. Second, it is vital to measure all standardised categories against a measure of law enforcement effort (Bell 1986a). The measure of effort used will vary according to the type of law enforcement activity being monitored, and according to the level of complexity that those undertaking the monitoring wish to entertain or to impose upon the staff collecting the data. On foot patrols within protected areas, effort may be measured in area and time units, for example, the number of patrol days per 100km^2 per month. In contrast, in the case of seizures at international borders, effort may be measured in time units, for example, the number of shipments searched per month.

When these two basic principles are followed, it is possible to derive an index of ‘catch per unit effort’. Such an index is an infinitely more valuable measure of the success of law enforcement activity than measures of categories lacking measures of effort. To give a simple example (Table 16.1), if twice as many illegal hunters or twice as much ivory is seized one year compared with the previous year, what does this mean? Very little, unless some measure of effort is available. But if it is known that twice as many poachers or twice as much ivory were caught with half the effort as opposed to twice the effort, then the results become more meaningful through the construction of catch per unit effort indices (Table 16.1). In the first scenario, there has been an increase in the index, while in the second scenario the increased number of captures would appear to have resulted from an increased effort alone.

While seemingly very simple and perhaps even abstract, the point made by these hypothetical examples should not be taken lightly, as will now be illustrated by an example from real life. As noted above, one of the major pieces of international legislation to affect the African elephant is CITES and a major action that required monitoring to see if law enforcement was achieving its objectives, was the listing of elephants on Appendix I of CITES in 1989. Yet, when it was time to ask the question “has the ban

Year	Captures (C)	Scenario 1 Effort (E)	C/E	Scenario 2 Effort (E)	C/E
1	100	50	2	50	2
2	200	25	8	100	2

Table 16.1 Hypothetical example of numbers of captures, e.g. of illegal hunters or of numbers of tusks, when compared with different levels of effort, e.g. days on patrol or numbers of searches undertaken. Catch per unit effort indices have been calculated under two different scenarios of effort(E), in order to show that twice the number of captures(C) in Year 2 needs to be interpreted with caution unless measures of effort are available.

worked? to provide delegates to the 1992 Conference to the Parties of CITES with scientific evidence to enable them to make an informed decision on whether to vote for continuation of the ban, it was next to impossible to provide that evidence. Visits to six range states revealed a paucity of relevant data, especially with respect to effort (Dublin & Jachmann 1992). Accordingly, it was not possible to provide any firm evidence that separated out any increased effort put into law enforcement within protected areas in individual range states as opposed to the effects of the ban itself. Hence, despite all the research that has been conducted on elephants to date, the information needed to monitor the success of such an important management action as banning the ivory trade is simply not collected in the vast majority of key conservation areas (Dublin & Jachmann 1992). Written as this chapter is, a couple of years on and approaching the 1994 Conference to the Parties of CITES, it is hard to imagine the monitoring of law enforcement will have improved around the continent, and that any better answer will be available in 1994 than in 1992[1]. However, it is possible to set up simple systems to monitor important law enforcement actions, as the following case study shows.

16.4 A CASE STUDY IN LUANGWA VALLEY, ZAMBIA

In the early 1980s, the Luangwa Valley, Zambia, had one of the largest remaining populations of elephants in Africa, and conservationists spent a large sum of money attempting to save Luangwa's elephant population from illegal exploitation. Anti-poaching patrols undertaking routine law enforcement duties were used to monitor their own success (Leader-Williams *et al.* 1990). Anti-poaching units patrolled six areas of unequal size during 1979-85. Patrols were undertaken in all months of the year and were of different sizes and lengths. Besides routine law enforcement duties, patrols also made quantitative records of animal sightings, on carcass finds, captures of offenders and levels of illegal activity during 1979-85. Indeed, records from foot patrols undertaken by Game Department rangers provided data on elephant numbers in Luangwa Valley during 1947-69. Encounter rate per effective patrol day was used as the standard unit of patrol effort to make the encounter rates equivalent to 'catch per unit effort' indices. Thus for each day out on foot patrol, one scout was designated to record encounters. Data collected by scouts can provide an accurate record of events (Bell 1986a), and scouts avoided recording information when doubtful about the accuracy of their sightings. The following data were collected:

1) Sightings of elephant herds and/or elephants;

2) Numbers of skulls of elephants, both intact and with trophies axed off by poachers, as an index of the relative proportion of elephants dying as a result of natural mortality and poaching;

3) Total poachers encountered, as an index of concurrent illegal activity;

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[1] Since this chpater was written, a further study of the effect of the ivory ban has been undertaken (Dublin *et al.* 1995). Like the proceding study (Dublin & Jachmann 1982), the results were based on data that were sparse and often incosistent, and were again inconclusive (Dbulin *et al.* 1995). Hence, the message of this chapter still stands.

4) Camps, temporary shelters from cut branches and fires for cooking, as a retrospective index of recent illegal activity;

5) Fresh carcasses, flesh-covered elephant carcasses encountered with trophies axed off, which provided an index of very recent and successful illegal activity that was detectable from a distance (by looking for vultures) but which was confirmed directly;

6) The effective time spent by each scout on foot patrol measures the commitment of anti-poaching units (Bell 1986a). Patrol lengths were counted as the number of days that scouts were patrolling on foot in the bush away from vehicles;

7) Offenders were caught by both foot and vehicle patrols. On foot patrols, as many offenders, weapons and trophies were caught or seized as possible from each gang encountered and returned to headquarters for charging and confiscation. Offenders were interrogated for their names, village and chief's area, and any other useful intelligence information. Offenders were placed in one of two categories depending on whether they were hunting elephants or rhinos, or possessed ivory or rhino horn, or whether they only possessed trophies such as meat or hides from other animals;

8) Guns were classified as automatics (including semi-automatics), rifles, muzzle-loading guns and shotguns. The number of trophies (tusks) seized from each gang was also recorded;

9) The punishments given to arrested offenders were noted, to determine if minimum sentences laid down in law were being upheld and if the serious crime of elephant poaching was being differentiated from other poaching. In other words, were the judiciary supporting elephant conservation?

Vehicle patrols were undertaken for a variety of reasons: reasons: 1) to follow up part of an escaped gang encountered by a foot patrol; 2) following receipt of information of unlawful possession of prescribed trophies or of possession of unlicensed firearms; 3) on an irregular basis, usually by setting up roadblocks at strategic points on the major trunk roads. Offenders caught, and weapons and trophies seized, were categorised as described for foot patrols. Offenders caught on vehicle patrols comprised both escapees from foot patrols and those in illegal possession of ivory or rhino horn who may not themselves have been involved in offences within protected areas.

Clearly other data can also be collected routinely, for example weights of all seized and found ivory the age of all found elephants, other signs of illegal activity and greater detail from carcasses, more sophisticated measures of effort, and so on. However, the main duty of law enforcement staff is to undertake patrolling, rather than to collect data. Therefore, a compromise has to be reached that does not over-burden law enforcement staff with data collection requirements that detract from their main duty.

All of these data were entered onto standard data sheets, examples of which are shown in Table 16.2. The patrol sheet (Table 16.2a) had columns that could be filled in by scouts on a daily basis while on patrol. The column totals were then added at the end of the patrol. Data from these field sheets were computerised for analysis. The arrests made were summarised on an arrest sheet (Table 16.2b) following the return of a patrol, to provide data on the origin and details of offenders, and of the sentences later delivered to them. The information collected was of immediate use in the field to examine trends in animal numbers and illegal activity through averaging the catch per unit effort indices. However, for a formal analysis that was published subsequently in a scientific journal, a complex statistical analysis was necessary because the data on the index of sightings contained many zeros and were therefore termed 'skewed', and corrections need to be made for patrols of different length and in different seasons. While it is not necessary to go into details here, these can be found elsewhere (Leader-Williams' *et al.* 1990). Some results from the study can now be described, and all indices in the figures are expressed as if they were numbers of sightings from a seven-day patrol by four scouts in the wet season.

Using sightings from patrols, trends in elephant numbers were shown to have increased at the rate

a) PATROL SHEET
APU:1 Patrol No: 25/84
Area: SLNP Core
Date from: 21/4/84 Date to: 25/4/84 Effective Patrol Days: 5

Day	Ele herds	Ele nos	Axed skulls	Intact skulls	No. gangs	Gang size	No. camps	Fresh carcasses	Poachers caught	Weapons seized	Ivories seized	Ivories found
1	1	8	2	-	-	-	1	-	-	-	-	-
2	3	25	-	1	-	-	-	-	-	-	-	2
3	4	NR	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	1	8	-	2	3	1SA	4	-
5	2	12	4	-	-	-	-	-	-	-	-	-
6												
7												
8												
9												
10												
11												
12												
Total*	10	NR	6	1	1	8	1	2	3	1SA	4	2

*The totals for the patrol are then available for analysis and entry into the computer from the field sheets.

b) ARREST SHEET
APU:1

Name	Date of arrest	Patrol	Village	Chief	Offence	Weapon	Trophies	Date of sentence	Sentence
Kunda Bwalya	24/4/84	25/84	Chitenge	Mpika	Hunting Elephant	Semi-Auto	4 ivories	25/8/84	Prison:1yr
Solomon Kunda	24/4/84	25/84	Chitenge	Mpika	Carrier			25/8/84	Fine:K500

Table 16.2: Examples of patrol and arrest sheets suitable for collecting standardised data on law enforcement activities.

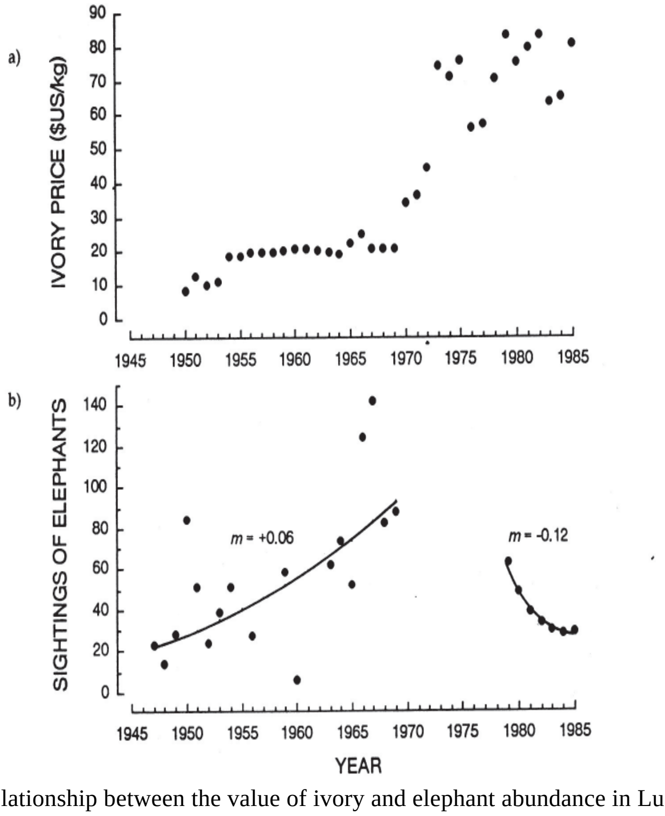

Fig. 16.l: The relationship between the value of ivory and elephant abundance in Luangwa Valley, shown as: (a) the real price of ivory (in US dollars per kg) imported to Japan during 1950-1985; (b) elephant sightings on the Westbank of Luangwa River during 1947-69 and 1979-85 (from Leader-Williams et *al.* 1990).

of 6% per year from l947-69. However, the overall rate of decline of elephants was 12% per year during 1979-85, following rapid increases in the price of ivory on world markets (Fig. 16.1). Trends of decline in sightings for elephants derived in this way compared favourably with the accurate methods of counting elephants from the air, suggesting that the methods used may have value as means of tracking trends in population change. This overall decline in elephants clearly arose from illegal activity as most skulls had their trophies removed. However, elephants increased in some areas of Luangwa Valley due to immigration (Fig. 16.2).

Despite a large decline in elephant numbers, law enforcement units were motivated and successful at capturing offenders involved in illegal activity in Luangwa Valley during 1979-85 (Fig. 16.3). Most staff in anti-poaching units spent about half of each month patrolling on foot under remote and difficult conditions. Offenders caught on foot patrols provided information for making arrests more successfully on vehicle patrols (Fig. 16.4).

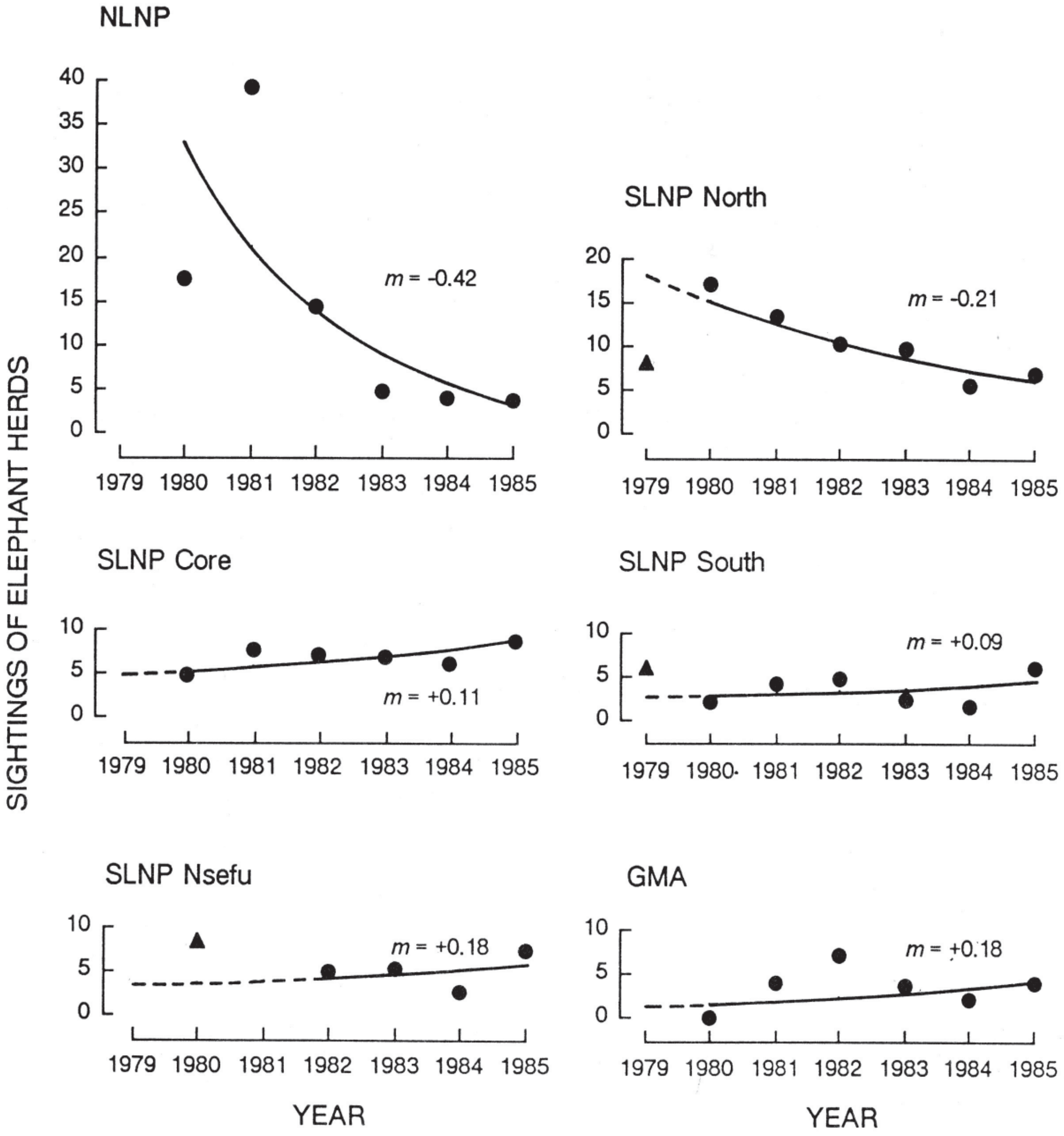

Fig. 16.2: Changes in elephant abundance in different areas of Luangwa Valley during 1979-85 (from Leader-Williams *et al.* 1990)

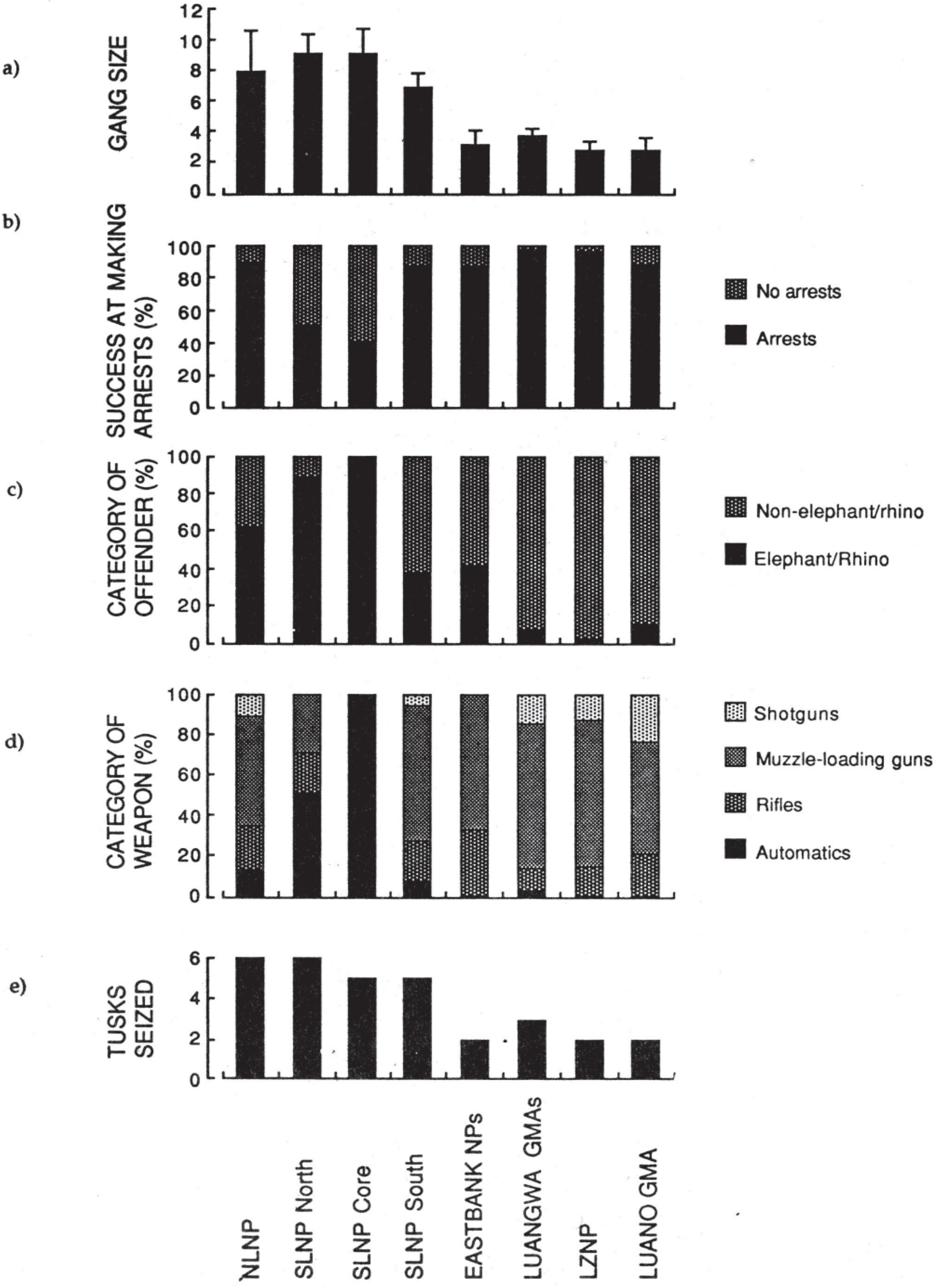

Fig. 16.3: The activities of offenders in different areas of Luangwa, Lower Zambezi and Luano valleys, shown as: (a) mean size of gangs; (b) the success of making arrests; (c) the proportion of offenders involved in elephant/rhino and other offences; (d) the proportions of each category of weapon seized; and (e) the median number of tusks recovered from gangs (from Leader-Williams *et al.* 1990).

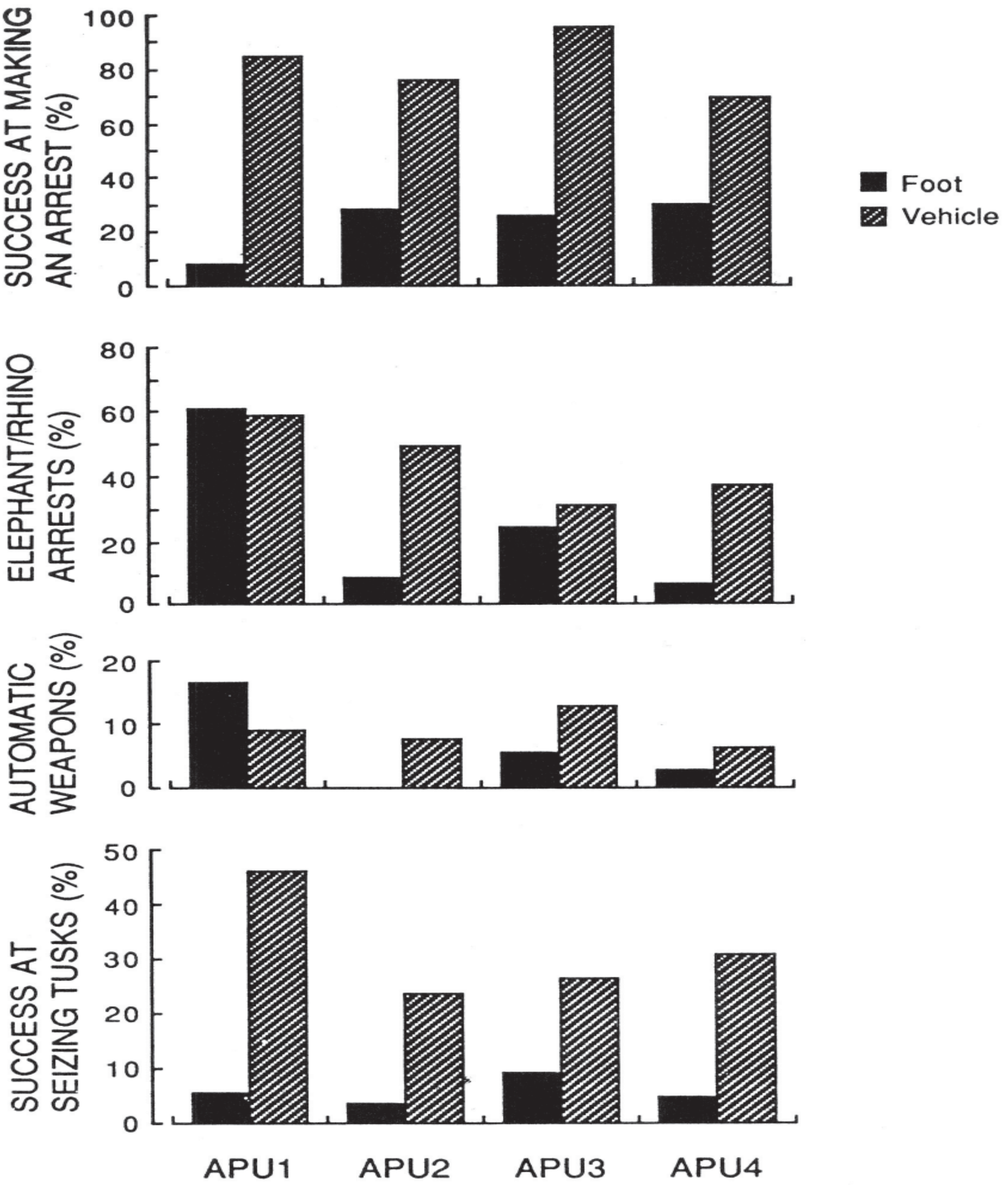

Fig. 16.4: Comparison of the success. of making arrests and seizing weapon and trophies on foot and vehicle patrols by different anti-poaching units (from Leader-Williams *et al.* 1990).

Arrests were made cost-effectively and about 40% of operating costs were recovered from found and seized ivory. Offenders involved in less serious illegal activity originated from most areas of Luangwa Valley. In contrast, well organised gangs, armed with sophisticated weapons, exploited elephants and rhinos, and originated from areas outside Luangwa Valley (Fig. 16.5). Offenders who exploited elephants and rhinos were delivered sentences that did not uphold wildlife laws (Fig. 16.6).

Signs of illegal activity, such as poachers, their camps and fresh carcasses, were encountered throughout the year (Fig. 16.7). Encounters of illegal activity generally showed consistent trends across years within different areas, but most trends in illegal activity showed complex changes

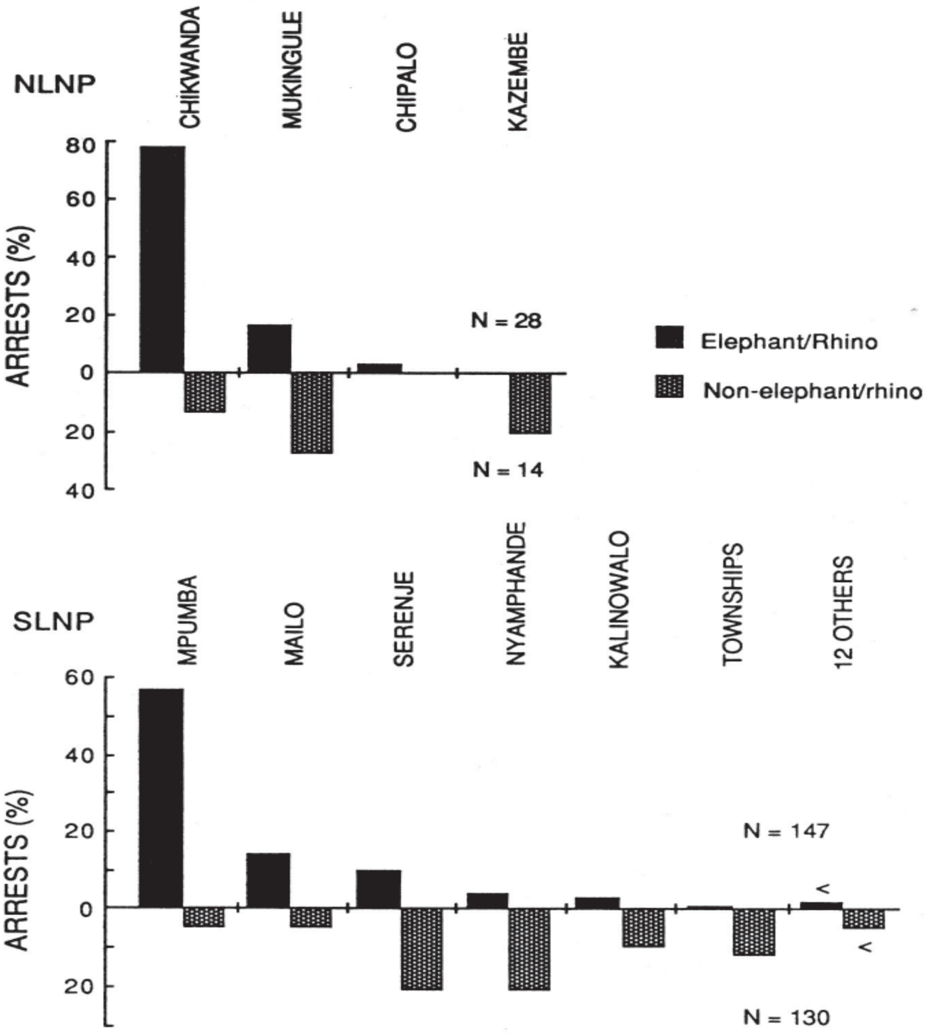

Fig. 16.5: The areas of origin of elephant/rhino ad other offenders captured in North Luangwa NP (NLNP) ad South Luangwa NP (SLNP) (from Leader-Williams et *al.* 1990).

over time (Fig. 16.8). Increased patrol effort affected levels of illegal activity, with less activity in more heavily patrolled areas (Fig. 16.9). Poachers and camps tended to be seen less often in more heavily patrolled areas even though these held relatively more elephants. Finds of fresh carcasses declined with elephant numbers, but also were found less frequently in areas of heavier patrol effort. Differences in patrol effort were related directly to rates of change in elephant abundance, and were sufficient to create areas of relative safety which experienced immigrations of elephants (Fig. 16.10).

The overall conclusion of this study was that the available manpower within law enforcement units was effective at capturing poachers, but was too small to provide effective protection to the large populations of elephants over such a vast area as Luangwa Valley. Predictions suggest that law enforcement staff should have been deployed at effective densities of at least one man per 20km^2 of protected area to have prevented the decline of elephants (Leader-Williams *et* al. 1990). This was equivalent to the spending of US$215 per km^2 of protected area in 1981 (Leader-Williams & Albon 1988).

16.5 CONCLUSIONS AND RECOMMENDATIONS

The case study described above monitors some important information related to a major management problem for elephants and draws conclusions that show where law enforcement capability did not match up to the intent of current wildlife policies and legislation. Several events have occurred since the time that this study was carried out. On the one hand, with inflation the 1981 sum of US$215 is now equivalent to US$340.

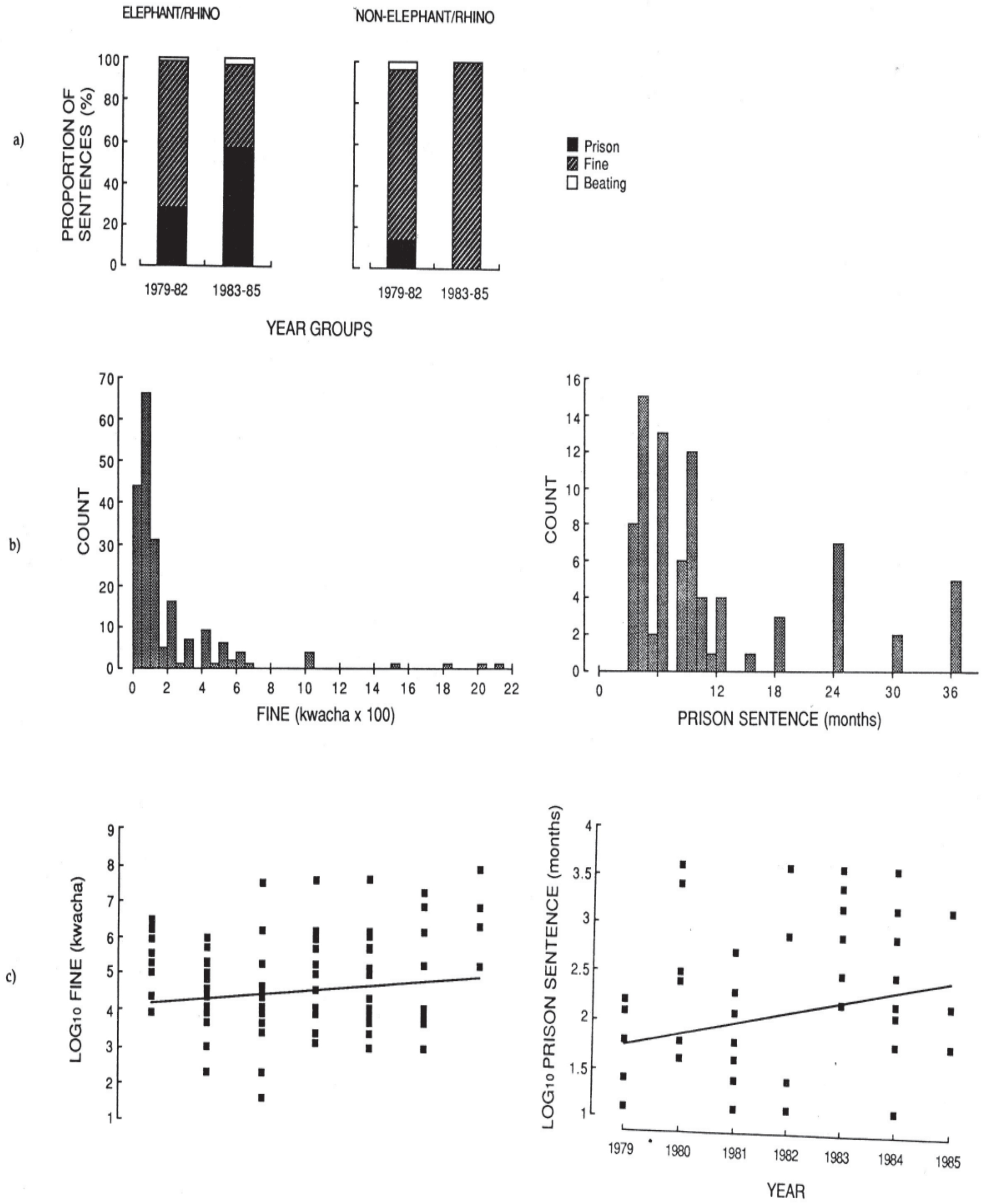

Fig. 16.6: The sentences given to offenders during 1979-85, shown as: (a) the proportions of different types of sentence given to elephant/rhino and other offenders before and after a change in law of December 1982; (b) the skewed distributions of fines and prison sentences towards small sentences; and (c) the slight but significant increases in the size of sentences delivered during 1979-85. None of these changes upheld wildlife laws (from Leader-Williams et *al.* 1990.

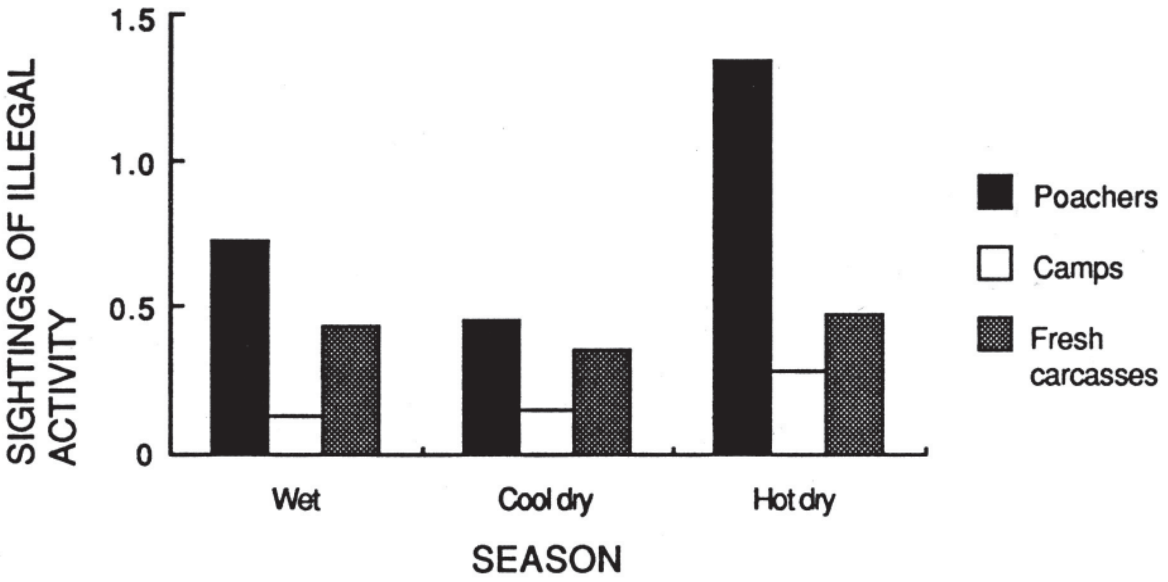

Fig. 16.7: Changes in encounters of each index of illegal activity during different seasons of the year (from Leader-Williams *et al.* 1990).

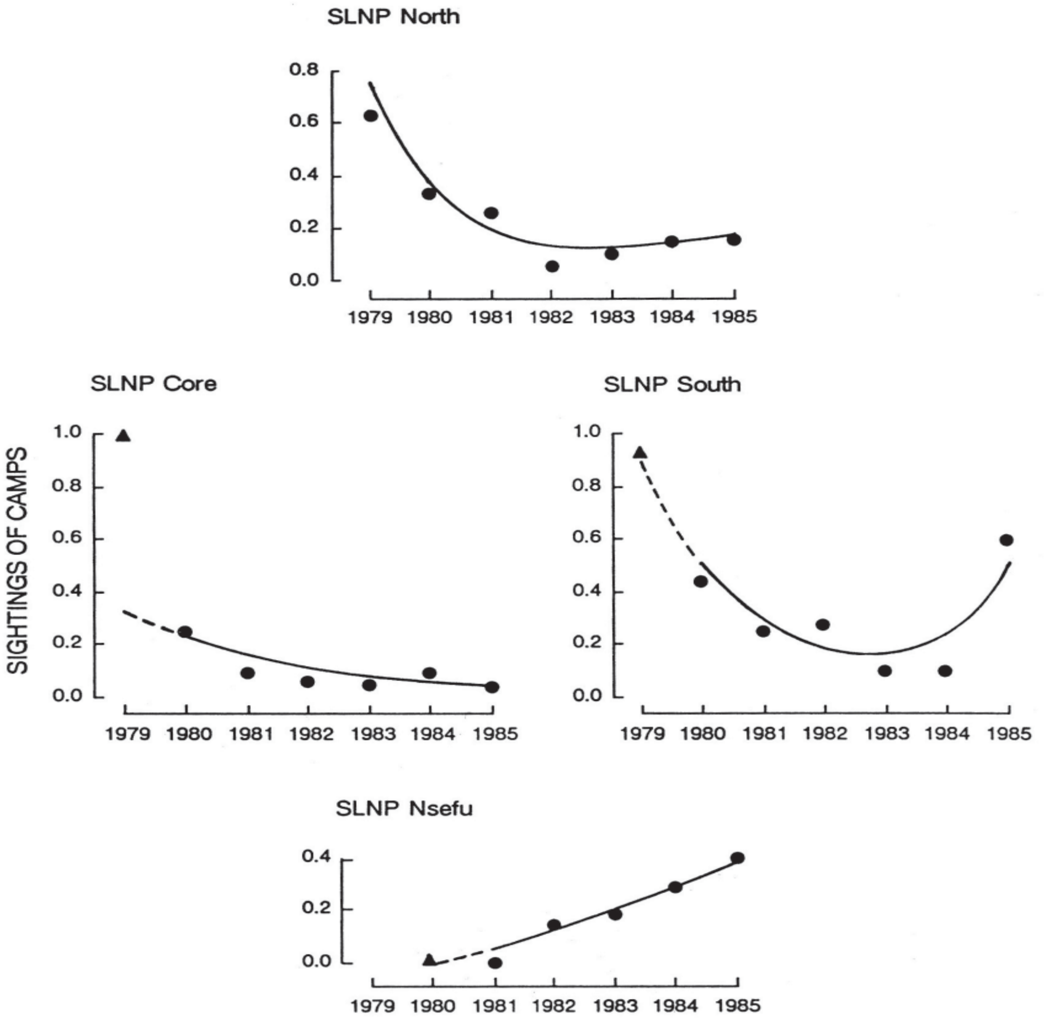

Fig. 16.8: Changes in encounters of camps in four different areas of Luangwa Valley during 1979-85, shown as encounter rates adjusted as if they had been made by 4 scouts on a 7 day patrol in the wet season (from Leader-Williams *et al.* 1990).

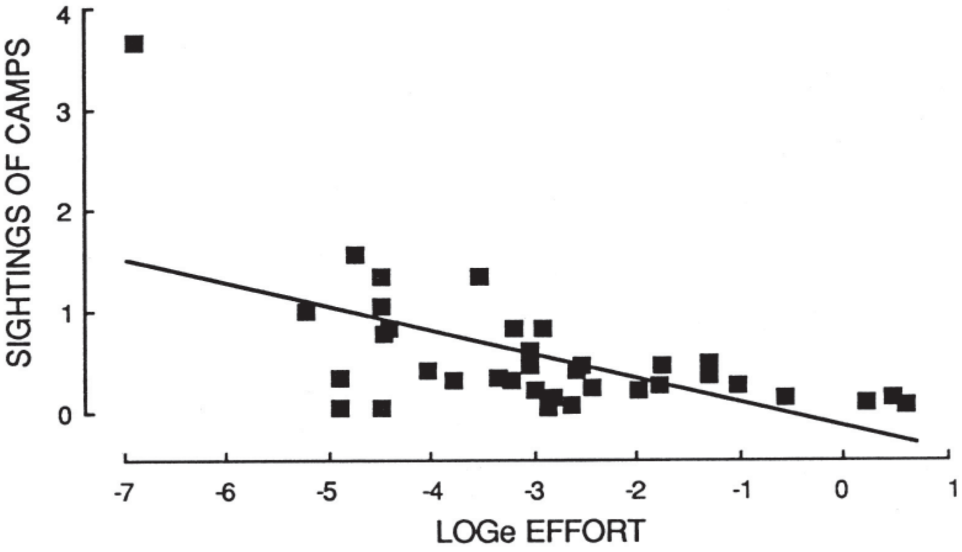

Fig. 16.9: Relationship between finds of camps and levels of patrol effort in different areas during 1980-85 (from Leader-Williams et al. 1990).

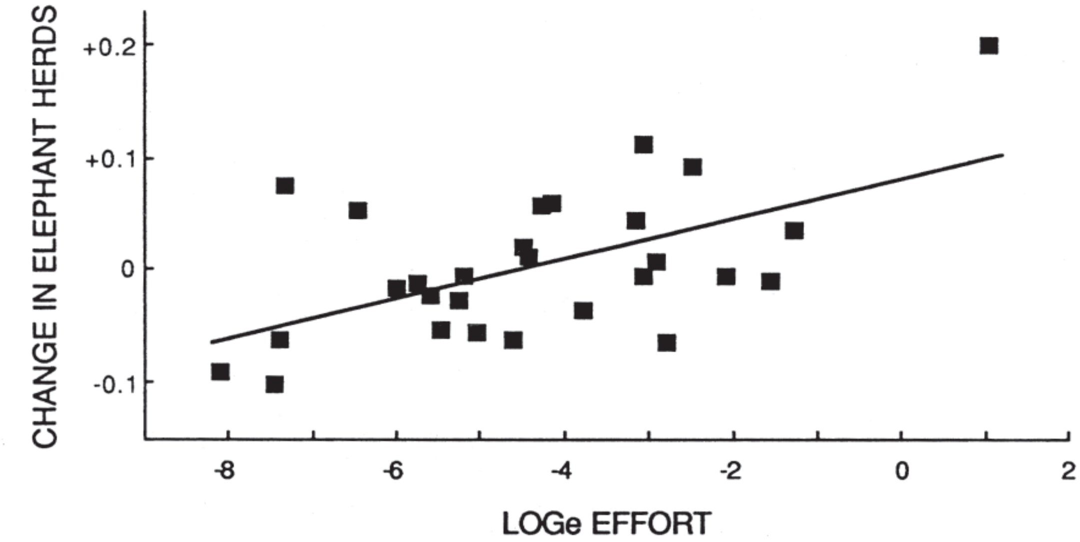

Fig. 16.10: Relationships between annual changes in sighting rates of elephant herds and in patrol effort in different areas during 1980-85 (from Leader-Williams et al. 1990).

On the other hand, the African elephant was put onto Appendix I of CITES in 1989; and the demand for ivory appears to have plummeted in Europe and America and to have fallen by 50% in Japan. This might have been expected to reduce the incentive of commercial poachers to kill elephants for their ivory within protected areas throughout their range. However, evidence from certain southern states suggests that there is still sufficient incentive to poach elephants (Dublin & Jachmann 1992). The fact that there appears to be no hard data to answer what effect the ivory ban has had remains a sad indictment upon the scientific community and national wildlife authorities, for exhortations to carry out research that is relevant to management have been made for many years (Bell 1986b; MacNab 1983). Indeed when such research is carried out it has proved to be of considerable practical importance, as well as being of interest to academics (Leader-Williams & Albon 1988; Leader-Williams et al. 1990).

The system described here could easily be adapted to different situations throughout Africa. In adapting it, the two basic requirements noted previously must be borne in mind, namely collecting the standadised categories of data and setting such measures against a standardised measure of effort. Thus, in rainforest with no established system of patrolling, it might be possible to establish a system of monitoring through the number of reports of poaching measured against the numbers of villagers interviewed in an informer network. The sooner that situation-specific methods of monitoring law enforcement and illegal activities are developed across Africa, the sooner will data become available with which to assess such important management actions as the implementation of the ivory ban.

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SECTION 6

HANDLING ELEPHANTS

CHAPTER 17

HOW TO IMMOBILISE ELEPHANTS

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17.1 INTRODUCTION

It is sometimes necessary to immobilise elephants for purposes such as fitting radio collars or carrying out veterinary procedures. These operations are dangerous because elephants may injure members of the darting team, or the immobilised elephant may die under anaesthesia. No matter how well planned and executed a darting operation may be, there will still be an element of risk, and this must be taken into consideration when deciding whether or not to carry out a particular immobilising exercise. No darting operation should be carried out unless it is understood by all concerned that there is a finite chance of elephant mortality.

Darting from a helicopter or a vehicle is safer than doing it on foot. However, budgetary considerations or the nature of the vegetation may make it necessary to carry out the operation on foot. In this case it is preferable to use a spotter aircraft and/or a back-up team in a vehicle. Operations carried out on foot without back-up, as will be necessary in forest areas, carry a high degree of risk. The risks are particularly high in areas of thick vegetation, when darting elephant family groups rather than bulls, and where elephant density is high.

17.2 PERSONNEL

17.2.1 Darting team.

a) On foot
The darting team should consist of the person doing the darting (usually a vet), and a tracker/ guard or back-up man armed with a heavy rifle at the minimum. If an elephant is to be radio collared, then a biologist should also be present. In this case it is best to have an additional guard. All members of the team must have cool heads, be able to run fast, and have experience of approaching elephants on foot. The most difficult job is that of the back-up man, who must always be aware of where all the members of the team are in relation to the elephants. He must be able to decide if, and when, to fire a warning shot, or to kill an elephant to protect other members of the team. It is advisable to have a back-up man who has previous experience of shooting elephants.

b) From helicopter
The darting team should consist of a pilot and darter at the minimum. Usually, the darter sits in a back seat, behind the pilot. The selection of animals can be difficult since one wants to reduce the time that the helicopter is in close proximity to elephants, and it is not easy to age and sex elephants from overhead, so it is best to have a third person who is positioned on the same side as the darter, to concentrate on the selection of a target animal. Headsets and intercoms are essential for these people to be in communication with the pilot. Shouting or signing is not effective.

17.2.2 Back-up team

The role of the back-up team is to carry heavy equipment, to assist in driving away the rest of the elephant family and to change the position of the anaesthetised elephant if necessary. If any observers, photographers, etc. are present, their place is with the back-up team. Radio communications between the back-up team and darting team are essential.

17.2.3 Spotting team

Ground operations can be made considerably safer if they are directed from a spotter plane, such as a Piper Supercub. The pilot should be able to do low tight turns at slow speed over a fixed point on the ground for a long time, allowing for the effects of wind, while observing an elephant on the ground. It also helps to have an observer with good eyes and a strong stomach. Ideally the spotting team should be able to communicate through an intercom to the ground team, rather than having to speak into a hand set.

17.3 EQUIPMENT

17.3.1. Darting team

The darting team requires the following:

- Dart gun and aluminium darts with robust 70mm long needle. Appropriate guns are described in Bathmat (1989)
- Etorphine (‘Immobilon’ or M99)
- Antibiotic spray
- Antibiotic injection
- Respiratory stimulant
- Syringes, needles, etc.
- Syringes with narcotic antagonist Diprenorphine, ‘Revivion’) and preferably antagonist for human use (Naloxone)

Items listed below are for a ground-based team only:

- Binoculars
- Wind indicator (a sock or small fabric bag filled with ash)
- Signalling mirror
- Heavy rifle (.458, .470 or similar calibre)
- Hand held VHF radio (preferably with an ear plug) and spare batteries
- Dark clothing and suitable shoes
- Tape measure

17.3.2 Back-up team

The back-up team requires the following:

Essential:

- Water in jerry can
- Radio with spare battery (as many as possible)
- Sharp knife
- Notebook and pens
- VHF radio
- Stethoscope and thermometer

If the team has a vehicle:

- Heavy rope (minimum 40ft long)
- Winch

For radio collaring:

- Radio collars
- Bolts for collar attachment
- Wood block
- Drill
- Spanners
- Screwdriver
- Radio receiver

Optional:

- Camera and film
- Marking pen
- Blood tubes
- Sample bottles

17.3.3 Spotting team

The spotting team requires the following:

- Radio
- Fuel
- Fuel pump and filter
- Airsickness pills (Avomine taken the previous day)

17.4 OPERATIONAL PROCEDURES

17.4.1 Preparation

17.4.1.1 Briefing

Before an operation starts there should be a meeting to ensure that everyone is fully briefed. Make clear what sort of animal is to be darted, the general area of operations, the time limit, any special considerations, and the chain of command.

It is essential that everyone is clear about the procedures to be followed in the even of an emergency, especially those involving aggressive elephants and accidental injection of etorphine. At least one member of the darting team, apart from the vet, should know how to carry out artificial resuscitation and intravenous injection of the narcotic antagonist (preferably Naloxone) and know where the drugs and needles are kept.

Non-essential participants should be instructed to follow orders and should only get out of vehicles after permission is given. They should not go on foot with the darting team. It should be made clear who is in charge. It may be necessary to divide responsibility between vets and biologists, but human safety should be given priority and one person must be clearly responsible for taking decisions on this.

17.4.1.2 Radio test
Radios must be operational, and spare batteries charged overnight. Radio procedures and channels should be agreed upon. Radios have to be checked for their ability to be heard from the distance they will need to be used. If other people are operating on the same channel, they should be informed that the operation is taking place and asked to maintain radio silence. It is essential that radio communication is available between the aircraft, darting team and back-up team.

17.4.1.3 Check equipment
Go through the check-list; make sure that all the equipment is in the right place, and that relevant people know how to operate it. Ensure that there is sufficient fuel and flying time for the aircraft for any planned operation. If refuelling is necessary ensure that fuel, pump and filter are in a suitable location. The gun and darts should be checked thoroughly. Considerable time and resources can be wasted with distorted darts, damp cartridges, etc.

If the purpose of the darting exercise is to apply a radio collar, make sure that the collar is working and that its frequency does not overlap with other transmitters in the area. Ensure that you know how the collar attaches.

17.4.1.4 Load darts
Make sure that there are at least two darts loaded with the appropriate amount of drug for the target animal. It may also be useful to carry a top-up dart with a partial dose. The darts should be stored in a way that prevents accidental discharge. A combination of pure etorphine (8-15mg for adult female and 10-18mg for adult males) and hyaluronidase (3000iu) are recommended. Three ml darts are ideal and dose volume can be adjusted to suit if 4.9mg/ml or 9.8mg/mI etorphine solution is available. Immobilon (etorphine and acepromazine) can also be used, but the sedative component is unnecessary. In general, high doses will lead to a more rapid induction, recumbency (usually lateral) and longer down time (without reversal). Etorphine produces respiratory depression but there is little difference whether 10mg or 16mg is administered. Lower doses have relatively long induction or less rapid response to the drug, lead more frequently to sternal recumbency, hyperthermia and muscular stress, but they allow for better respiration. The actual dose used will vary with the circumstances, i.e., how easy it would be to reach an animal that moved 2km during the drug induction period, but in general high doses are preferable.

17.4.2 Reconnaissance

If operations are to be carried out with a spotter plane, the spotting team should check the wind direction before leaving. They should do a reconnaissance flight to select a suitable group and identify the best starting point for the darting team, making allowances for a herd that is moving. If feasible, it is best to land and discuss this with the darting team. It may be useful to have a member of the darting team as an observer for this initial flight.

17.4.3 Approach

The darting team should aim to walk in from a distance of between 200m to 1km, keeping close together and continually checking the state of the wind. Vehicles should not come close enough to the elephants to cause disturbance. At this stage an aircraft should be circling overhead, giving distance and direction about the target herd. It should fly high enough and in wide enough circles not to disturb the animals. As the aircraft passes behind the elephants in line with the darting team, the pilot should say “The line is now. distance is X metres”. One member of the darting team should carry a mirror and flash it towards the aircraft to ensure that the aircraft team knows where the ground team is.

On the final approach, radio volume should be kept low and communication between members of the darting team should, as far as possible, be by hand signals. Alert each other with neutral sounds (e.g. clicking fingers, soft whistling) rather than vocally. Keep checking the wind direction. When in sight of the elephant, the spotting team should only communicate in case of emergency.

Approaching without an aircraft requires skilled tracking. It is essential to remain vigilant, particularly if there is more than one group of elephants in the area.

17.4.4 Selection of animal and darting

a) On foot

It is essential not to rush when the elephants are in range. If darting females for radio-collaring, it is best to select ones that do not have young calves or matriarchs. A calf staying close to its mother may be crushed when she collapses, and accidental death of the female will result in an orphan too young to survive alone. If possible, it is best to select an elephant with distinguishing features to make the job of the spotting team easier. It can be surprisingly difficult to distinguish sexes and to see whether a cow has a young calf, since in thick bush one can often only see the backs of the elephants. In very dense vegetation it is often best to withdraw for a while and wait until the elephants move into a better area.

If the elephants start moving towards the darting team, the team should retire quietly, bearing in mind that if the elephants cross their tracks they are likely to become disturbed. The chief danger in darting operations is that an elephant will charge. This happens most often when a cow has seen the team. If she only detects human scent the herd will usually move away; if she sees suspicious movement without scent she will usually do nothing, but stay at a higher level of alertness and she may continue to watch in the direction of the people. When a matriarch alerted in this way detects human scent, perhaps because of a change in wind direction, she is likely to charge.

The best response to a serious charge by an elephant is to run away immediately. On most occasions, the elephant will probably stop after a short run and will return to the herd, but it is not worth taking any chances. There is no evidence that running away provides any additional encouragement to aggression, as is the case with lions. However, it is most important to ensure that everyone stays together, and the back-up man knows what is going on. Where the team consists of two armed and two unarmed people, each back-up man should watch one of the others. When running away, go downwind, do not run in a straight line, and get thick vegetation between you and the elephant. If you find yourself in imminent danger of being overtaken by an elephant, it is probably best to dive into the middle of the nearest patch of thick bush. If there are large enough trees and the elephant is not too close, climb one of the trees.

Most charges are bluffs and do not last longer than 50m; provided that one starts at a sufficient distance, it should be possible to keep away. If the charge goes on longer or the starting distance is too small, a gun may have to be used. It is fairly safe to use the first shot as warning. If this fails to stop the elephant or if he or she is too close, a heavy calibre shot into the chest or head is usually enough to turn a charging elephant, if not to kill it. If an elephant is shot but not killed, it is important to follow up immediately as soon as the entire team is accounted for, and unarmed individuals have been escorted to safety.

If everything goes well in the approach and selection of the target animal, a shot with the dart gun should be taken at a range of 20-30m. Darting should not be done less than two hours before dusk because of the risk of failing to locate an immobilised animal. The rifle propellant (cartridge or gas) should be appropriate for the weight of the dart and the range, in order to avoid the failure of the dart to penetrate or discharge. Aim for the haunch or shoulder and ensure that the animal is as square as possible to the shot and that there is no vegetation in the way. The haunch is better, since a shot at the shoulder runs the risk of being intercepted by the ear. If one misses, the animals will usually run away from the sound and the operation will have to be started again.

There is normally no problem with the hit animal, which will tend to run in the direction that it is facing, so it will usually run at right angles to the darting team. If the herd comes towards the darting team, evasive action will have to be taken.

b) From helicopter

It is more difficult to dart from a helicopter because there are bones close to the top of the rump, and a dart fired from directly overhead may bounce out or fail to inject intramuscularly. It is better to shoot slightly obliquely at the rump or shoulder, though this means that the aim will have to be compensated for down draught.

17.4.5 Drug induction period

a) Ground operations

It usually takes between five and fifteen minutes for an elephant to go down after being darted, although this depends on the drug combination, dosage and point of injection (i.e. intravenous or intramuscular). The distance the elephant moves can vary from less than 100m to more than 2km. The important objective at this stage of the operation is to ensure that both darting and support teams are close at hand when the elephant goes down. The spotting team plays a key role in keeping track of the drugged elephant and guiding the ground teams. Circumstances determine what should be done. Sometimes the darting team may follow the elephant directly on foot, or rejoin the back-up team with the vehicle. Following a darted elephant on foot without aircraft support is difficult and dangerous, and requires alertness and good tracking skills. Because of the risk of confusion, it may only be possible where there are small numbers of elephants in an area.

As soon as the elephant is darted, the darting team should communicate the time of darting and any distinguishing features of the target elephant. Sometimes the dart is visible but usually it falls out soon unless cuffed or barbed needles (which have considerable disadvantages) are used. The spotting team should bring the back-up team to the closest position on the road to where they expect the elephant to drop. Once the target animal shows signs of drugging and is unlikely to move further, they should bring the back-up team in on the easiest route. Constant communications from aircraft to ground team are necessary to tell them about the situation, the distance from other elephants and the level of urgency involved. This will allow the driver to decide how carefully to treat his vehicle, if one is available for the back-up team. For example, if the elephant has collapsed on its sternum, with the resulting risk of oxygen starvation, it may be necessary to make all speed to the spot. However, if it is surrounded by its family, they have to be driven off before people get too close.

Once the ground team has arrived in place, and the rest of the elephants are away, the aircraft can land. However, if the rest of the family is nearby it is essential for the aircraft to stay overhead until the end of the operation to inform the team of any change in the situation. This will be particularly important if it has not been possible to get the vehicle in close. If the elephants are around the darted animal, they will have to be driven away. It may be necessary to fire in the air.

Sometimes the elephant either fails to fall down or shows no sign of being drugged. The animal should be watched for 30 minutes and if it is still mobile after this time lapse, it can be safely left. If it is obviously drugged but has not fallen over, another partial dose may be administered.

b) Operations with helicopter

If a helicopter is used with an experienced pilot, it should be possible to get the elephant to drop in a spot that is easily accessible to the ground crew, by applying gentle pressure in the direction required. It is important for the helicopter not to come too close, to avoid causing stress to the animal.

17.4.6 Operations on the ground

17.4.6.1 General

As soon as the ground team arrives, it is essential to ensure that the immobilised animal is safe. Non-essential personnel should stay back until the person in charge has declared the situation safe.

Everyone on the team should know what his responsibilities are. Ideally, one should have a vet to keep checking vital signs such as breathing rate, and another to collect samples, ectoparasites, etc.; one person should put on the collar, another should take measurements and another should write down data, and the back-up man should keep watch for other elephants.

17.4.6.2 Veterinary

During the time that the elephant is recumbent, the vet’s primary responsibilities are to ensure that the elephant is moving air into its lungs adequately by monitoring the rate and depth of breathing. Once vital signs have been checked the vet should insert a syringe with Revivon in an ear vein, in case immediate reversal is needed. He should remove the dart, unless it has already fallen out, and treat the injection site with local antibiotic application. Injection of systemic antibiotics will prevent abscess formation later. If possible, both eyes should be covered with eye ointment to prevent the cornea from drying out, and in order to reduce vision briefly when the elephant gets up, and the team is still close. This also may reduce distress since narcotics are not true anaesthetics, and the animal probably retains a degree of sensory perception. Noise should be kept to a minimum. In hot conditions water should be poured over the body, especially the ears.

A drugged elephant will usually have fallen over before the ground team gets to it, but when approaching a drugged elephant that is in standing sedation, one must be careful that the elephant does not fall on top of any of the team, and that people stay out of reach of the trunk.

Most elephants will fall onto their side (lateral recumbency), but some may fall on their sternum (sternal recumbency). If the elephants goes into sternal recumbency, or falls onto a tree trunk or rock, the animal should be pulled onto its side or away from the obstacle without delay. Use a rope around the neck or over the shoulder and around the base of the opposite foreleg, or over the neck and around the base of the opposite tusk. Ensuring that the rear legs are in a safe position, the animal can be pulled over, using a vehicle or a large team of people. Respiration in sternal recumbency will be adequate for up to 15-20 minutes but will become progressively more shallow, with difficulty in making deep inspiratory movements, evidenced by open-mouthed breathing. If it has been possible to get to the elephant as soon as it has fallen over, and operations on the immobilised animal can be restricted to less than ten minutes, turning the animal over may not be necessary. We have successfully collared three elephants in sternal recumbency, but did not take samples or measurements from them.

In lateral recumbency respiration may be as low as four breaths per minute, but if inspirations are deep and regular, with good capillary refill time and good colour of the mucous membranes, low respiration rate is not a cause for alarm. If respiratory problems do develop, application of the antidote may be life-saving for the elephant. It is important to ensure the trunk is not obstructed, for example by a tusk, leading to respiratory arrest, hypoxia and death. Two short sticks placed at the opening of the trunk will maintain open the air passages.

Body temperature should remain between 35^0C and 38C, and if it rises to over 40CC wetting the head and ears is essential. Rapid drug reversal is recommended in this case. Pulse rate should be between 40 and 60 per minute. If the rate rises rapidly or becomes markedly depressed, reversal of the narcotic should be considered. Easily accessible veins are on the posterior aspect of the ears and cranio-medial aspects of the forelegs. At least four times the etorphine dose (i.e., 10mg etorphine reversed with 40mg diprenorphine) is recommended for reversal, which should occur within 110 to 180 seconds. Less diprenorphine may cause problems as the halt life of the antagonist is shorter than the agonist. On occasion, entero-hepatic recycling can also be a problem.

17.4.6.3 Collaring

The radio collar should be put on just behind the ears. Sometimes it is difficult to get it around the elephant's head, so the head may have to be lifted up to provide room for the collar to go underneath. Usually the collar will seem tighter when the animal is recumbent than when it is standing up. Under some circumstances, folds of skin make the neck seem thicker than it actually is, so the head should be pulled forwards if possible. If the animal is an adult female, whose neck will not grow further, the collar should be moderately close fitting, but still with room for a fist to go between it and the neck when the animal is recumbent. For young animals and bulls, the degree of slack will be dependent on how long the collar is expected to stay on, but avoid collaring growing animals because too little slack may cause distress later, while too much may result in a front leg being trapped in the collar.

The transmitter should be activated and tested before the antidote is given. Collared animals have been allowed to recover with inactivated collars around their necks!

17.4.6.4 Measurements

There is no standard format for taking body measurements, and it is difficult to get accurate measurements from a recumbent elephant. However, we have generally measured shoulder height, back length, tusk length, tusk basal circumference and hind foot length.

For details on how to take these measurements see Chapter 18.

17.4.6.5 Reviving

When the elephant is ready to be revived, everyone except the vet should get back into the vehicle, or to a safe distance, and all the equipment should be out of the way.

Once the vet has injected the reviving dose, he should get back to a position from which he can safely observe. There should be a clear escape route for the vehicle and/or people on foot, ideally downwind and behind the elephant. It is Important to make certain that the elephant gets up but one must also keep out of the way. One of the best ways to wreck a car is to drive at speed through thick bush while being chased by an elephant!

The transmitter of the radio collar should be re-tested while the elephant is moving away, since the frequency of the transmitter may change slightly once it is on the elephant.

On several occasions, large old bulls have not responded well to being revived, and on one occasion an animal had to be raised with the aid of a winch after more than an hour of recumbency clearly adding to the trauma of the exercise. It is not clear what is the reason for this, but extra caution is recommended with these animals.

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CHAPTER 18

COLLECTING DATA FROM DEAD ELEPHANTS

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18.1 INTRODUCTION

A wealth of information can be collected from dead elephants. The data one is able to collect depend on the state of the dead elephant(s) and the circumstances of its/their death. The data fall into three basic categories:

i) Data from carcasses found where no fresh material is obtainable (poached animals or those having died of natural causes).

ii) Data from a single or a few animals killed where fresh material is obtainable (animals shot non-randomly for hunting, crop protection or other such purposes).

iii) Data from randomly culled elephants where many animals are shot simultaneously[1].

When carcasses are found with no fresh material on them (category (i)), the data which can be gathered are very limited. Usually only sex, age, and if they are still on the carcass, an estimate of the weight of the tusks can be recorded (see Chapter 14).

From category (ii) of dead elephants, more useful data can be recorded, but this still on a limited scale. Sex, age and reproductive status can be determined but these data can give no indication of the prevailing state of the dynamics of the parent population, unless such carcasses are regularly available and are of both sexes.

On the other hand, data which can be gathered from category (iii) are very useful for the study of the dynamics of the culled sample's parent population (population growth rate, inter-calving period, age structure, etc.), as well as life-history data which may differ spatially and/or temporally (breeding and calving seasons, age at puberty, growth rates, etc.). Elephants can be culled either randomly or non-randomly. In non-random culling, specific age and/or sex categories are removed from the population. This type of culling is rare and the data fall more into category (ii), and are of little use in providing information on the state of the elephant population. The second type of culling removes a random sample from the parent population and the data thus gathered are representative of the population to a lesser or greater degree, depending on the size of the Sample (culling is "random" when all animals in each group are culled regardless of age or sex). Obviously, a small sample is of less value, and the greater the proportion of the parent population that is sampled, the more representative of the parent population the results will be.

This chapter, therefore, concentrates on this third category as the discussion of the data which can be collected are of relevance to the other two categories as well. Excellent examples of the type of information that can be gained from unsophisticated data from a sample of randomly culled elephants were conducted by Ranks (1972), Sherry (1975) and Smuts (1975). Caughley (1977) has written an extremely useful and understandable book on the dynamics of populations, which goes into far more detail than can be given here.

This chapter assumes knowledge of elephant physiology and some basic veterinary skills. If you do not have the knowledge or skills yourself, you are advised to seek the assistance of someone who does when you collect data from dead elephants.

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[1] Strictly speaking, the term "culling" implies the removal of selected animals from a herd or population. "Culling" has been used here as a generic term implying the removal of a pre-determined proportion of the population by shooting, as this has become the term used and accepted in southern Africa.

18.2 DATA WHICH SHOULD BE COLLECTED

18.2.1 Age of culled animals

The determination of the age of each culled animal is fundamental to the study of the dynamics of a population. All aspects of a population dynamics study are relatable to age of individuals whether they be growth, age at puberty or age structure of the population.

Age of culled elephants is usually determined by the method of Laws (1966), revised by Jachmann (1988) which involves the examination of the molars in the mandible or lower jaw (see Chapter 7 - Box 7.1). As the molars are not easily visible while still *in situ* it is useful to wire a numbered metal tag securely to the jaw before the carcass is dismembered. (Attached to this metal tag should be a cardboard tag bearing the same number which can be stuck onto the wet surface of the uterus or testes when excised. This prevents subsequent confusion over which body parts belong to which animal). Age can be easily determined once the jaws have been excised. Preferably they should be stored (where scavengers cannot get access) and the ages of all the culled animals determined at the same time. This allows the worker to “get the feel” of the technique and thereby less errors will be made. Also, specific jaws can be re-examined should any possible anomalies arise.

18.2.2 Age class frequencies

Once the ages of all the culled animals have been determined, an idea of the age structure of the population can be gained by lumping the respective age classes and constructing a histogram of these

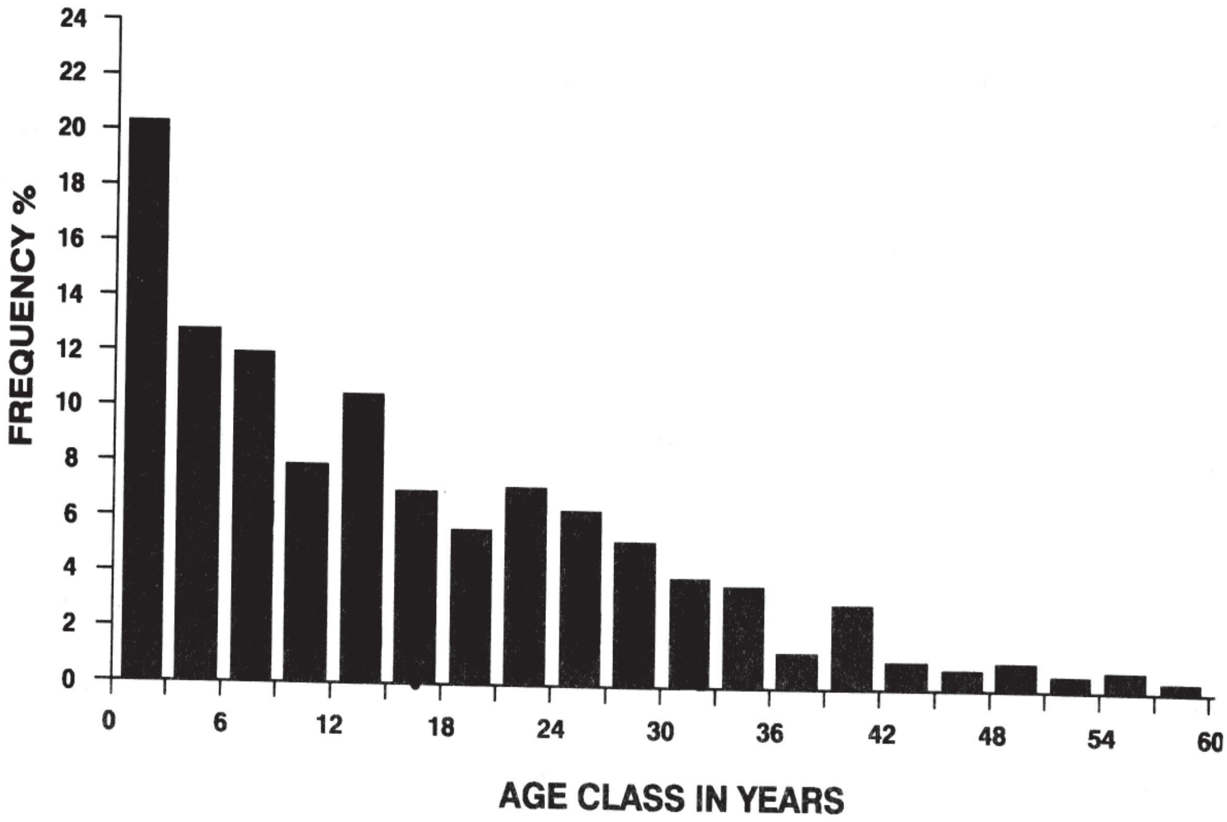

Fig. 18.1: Age frequency distribution of hypothetical elephant population.

according to their. respective proportions in the sample (Fig. 18.1). In a healthy population the age classes with the highest proportions will be the younger ones while there will be a steady decline in the proportions towards the older classes. Occasionally, one age class will be proportionately larger than those of the younger ones succeeding it. This may be due either to sample bias or be the result of a particularly good conception rate from the previous two years. As the gestation time for elephants is 22 months, they obviously cannot breed every year and after a period of protracted drought, the calf percentage of a particular year may suddenly be far higher than that of previous years.

Should the younger age-classes be consistently smaller than the older ones, there is the possibility of a problem with breeding and/or calf survival, and a strong likelihood that something is amiss in the elephants' habitat. Laws (1969) noted variations in annual recruitment among different elephant populations and suggested that they were related to variations in rainfall and therefore also to variations in habitat quality.

18.2.3 Sex ratio

Elephants are born at a sex ratio of approximately one male to one female. Young males leave their maternal groups soon after puberty and this is reflected in the sex ratios of the various age classes. The younger classes should have sex ratios of around 1:1 but from about 12 years on there is a bias towards females in the breeding herds. Age at puberty is dependent upon the attainment of a critical body mass, and elephants will achieve sexual maturity at older ages in habitats in poor condition. The age at which young males leave the herds can thus give an indication of the condition of the habitat for elephants. The relative proportions of animals culled will provide one with information on the sex ratio of the population.

18.2.4 Age at puberty

a) Males
In males, puberty is regarded to have occurred once sperm production begins. From culled males, the age at which this begins can be determined in two ways:

i) Sperm smears
In contrast to most other mammal males, elephants' testes are carried intra-abdominally near the kidneys. There is no epididymis but there is a Wolffian duct present. This should be excised with the testes once the animal has been'eviscerated. By cutting through this Wolffian duct using a sharp blade, a milky white fluid can be expressed, and by picking up a drop of this fluid on the edge of a microscope slide glass and then making a thick smear on another, the presence or absence of spermatozoa can be determined under a microscope after the smear has been stained. This can be done as follows:

1. Air dry the smear after it has been made (it can be stored for a week or more before fixing).
2. Fix in methanol (MeOH) for 5 minutes.
3. Pour off MeOH and stain in 5-6% Giemsa (preheated to 60^0C) for one hour at 60^0C.
4. Pour off Giemsa and in tap water.
5. Allow to dry.

It must be said that it is not easy to cut the Wolffian duct at the right place and some experience is necessary. Fluid in the ducts of younger animals (if obtainable at all) may be clear, not milky.

ii) Histological specimens
A small specimen of approximately 10mm X 10mm X 10mm should be cut from the inside of the testis, avoiding the larger tubes. This should be preserved in Bouin's Fluid for 48 hours and then transferred into 70% ethyl alcohol. The sample can later be cut for histological examination for the presence or absence of spermatozoa in the seminiferous tubules.

This is a far more sophisticated method which requires specialised laboratory equipment for the preparation of the histological specimens, and should only be attempted when the necessary laboratory facilities are available.

Mean age at puberty can then be determined from the proportion of animals that have achieved puberty in each pubertal age class.

b) Females
The uterus of the female elephant is also situated in the abdomen, the ovaries being located near the kidneys. The ovaries and uterus should be excised intact once the animal has been eviscerated. Ovaries can be examined macroscopically. Immature females' ovaries contain small (<5mm) developing follicles, while ovaries of sexually mature females will contain one or more corpora lutea (CL) and/or corpora albicantia (CA). ACL is an accessory organ which develops on the ovary at the ovulation point. It is variable in size and can be

as large as a golf ball. The CL produces hormones which are important in the maintenance of pregnancy and is yellow in colour when dissected. A CA is a CL which is degenerating after the birth of a calf and is dark brown in colour.

A pubertal female will have no CLs or CAs but will have at least one follicle greater than 5mm.

Mean age at puberty can also be determined from the proportion of animals that have achieved puberty in each pubertal age class.

18.2.5 Pregnant adult females

The data that can be collected from adult females are the most important with respect to understanding the dynamics of the parent population. Nearly all this information comes from the uterus, which should be excised intact. A pregnant uterus is fairly obvious except in the early stages of pregnancy In most mammals, the presence of a CL is indicative of pregnancy as it develops at the ovulation point and its function is to maintain the pregnancy. Elephants, however, may have several oestrus cycles which may not necessarily result in pregnancy. Each one has an ovulation point and subsequent CL. Elephant ovaries may therefore have several CLs present which have not yet resulted in a pregnancy. Each uterus must therefore be opened using a sharp knife to make sure that there is no small foetus in the early stages of development. Both of the uterine horns should be opened even if a small foetus is found in the first, as twins have been (rarely) recorded.

Once the uterus has been excised, it should be cut transversely just above the cervix. This exposes the two horns of the uterus, and a sharp knife can then be inserted into the opening (lumen) so made and each horn can be cut open right up to the top. Any evidence of pregnancy is soon revealed-clear watery fluid and filamentous white membranes. If these are the only evidence of pregnancy, the foetus will be too small for the sex to be determined or to weigh.

i) Foetal sex ratio
From an early stage in the development of an elephant foetus, the sex can be determined. In a large enough sample, the ratio between foetal males and females can be determined. Any significant deviation from a 1:1 ratio may be indicative of habitat quality. This has not yet been demonstrated for elephants but has been for other species such as Red deer (Clutton-Brock *et al.* 1982) and buffalo (Whyte in prep.) when females in poor condition are more likely to conceive a female foetus.

ii) Foetal age
Foetal age can be calculated for any mammal species according to the method of Huggett & Widdas (1951). Their formula was revised for elephants by Craig (1984) and is the one more widely accepted today:

$\text{age} = 3\surd\ \text{mass } 0.0945) + 138$
(The formula gives age in days when foetal mass in grams is used).

A limitation of the method is that Craig estimates that an elephant foetus is 138 days old before it is large enough to be "weighable". This means that there is a four-month period between conception and weighable size, which cannot be covered by the equation.

iii) Conception and birth dates
From the equation above, the foetal age (in days) on the date of collection can be calculated, and the conception date can therefore be determined by counting back from the date of collection.

The expected birth date can also be estimated by adding the gestation time (22 months or 660 days) to the conception date. Such calculations are time consuming and prone to error unless a computer with date arithmetic is available, but a simple device to assist with such calculations was developed by Whyte (1986).

By lumping the data for respective months, a histogram can be drawn showing the breeding and calving peaks for the population under study Fig. 18.2 shows the conceptions for a hypothetical elephant population showing a peak in the summer months.

iv) Inter-calving period
The inter-calving period (i.e., the mean period between calves for adult females in the sample) can be calculated in two ways. The first is to make an estimate from the number of placental scars, which will be covered in the next section (non≠pregnant females). The other is to calculate the mean duration of anoestrus (DA) as follows (Hanks 1972):

$$DA = \frac{\text{gestation time x (number not pregnant)}}{\text{number pregnant}}$$

Data from the Kruger National Park (Smuts 1975) gave an estimate of:

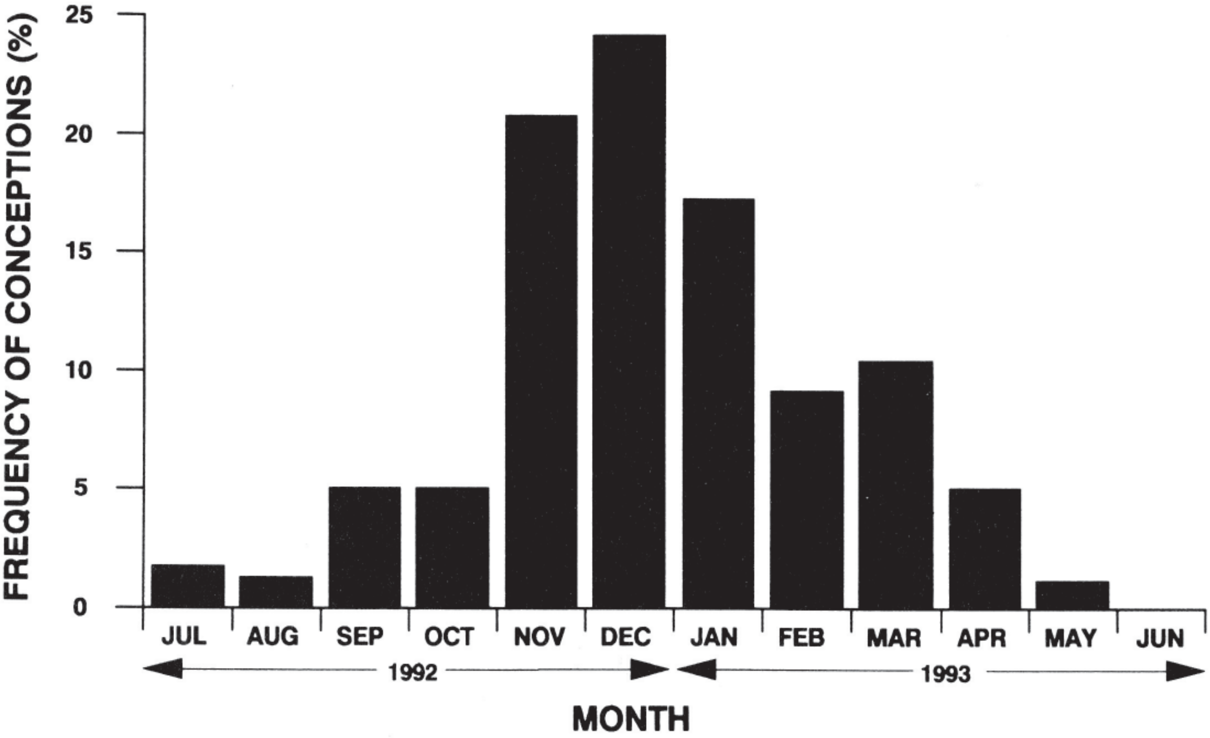

Fig 18.2: Distribution of mating activity in a hypothetical elephant population.

$$DA = \frac{22 \times 430}{292} = 32.4 \text{ months}$$

The inter-calving period (ICP) is then calculated from this by simply adding the gestation time.
ICP = 32.4 + 22 = 54.4 months.

This is a measure of the inter-calving period prevailing at the time that the culling took place as it is based on the proportion of females currently pregnant and non-pregnant respectively. This can vary within a population temporally (from year to year).

18.2.6 Non-pregnant adult females

The other method of estimating the ICP, involving the counting of placental scars, is an estimate of the long-term performance of the population as it includes all the calves which have been born to all the adult females in the sample over their whole lives. This may show only minor differences from year to year depending mainly on the sample but comparisons with similar data from populations in other habitats may indicate clear differences.

Elephants have what is known as a zonary placenta. This means that the placenta is connected to the uterus at only one place or “zone”. The connection is circular”- like a collar around the inside of one of the horns of the uterus. At birth the placenta tears away from the uterine wall in a traumatic process which leaves a clear scar once it has healed. When the lumen of the excised uterus has been opened, these scars lie horizontal to the direction of the cut made. They form shallow “troughs” across the uterus which, when fresh, can be clearly seen. They tend to fade with age but careful inspection can reveal them all. This is best done by placing the opened uterus on a flat surface and, while pressing down fairly hard, sliding the fingers slowly up and down the exposed length of the uterine horn. The troughs made by the scars can thus be felt. The placentas of successive pregnancies do not connect to the uterine wall in the same place and therefore these scars can be counted to determine the number of calves a female elephant may have had during her life.

Scars cannot be counted when the female is pregnant as they are not visible, and there are also two other conditions of the uterus which may be encountered which make the counting of scars difficult. The first is when the endometrium (the inside surface of the uterine wall) becomes “haemorrhagic” (bloody and jelly-like). The second is when the uterine lumen becomes “occluded” or blocked. The lumen contracts very tightly, and it is extremely difficult even to get a knife into the lumen to open it up. The endometrium takes on a whitish jelly-like texture. The scars are almost invisible when the uterus is in either of these conditions, but by feeling for them with care, using the method described above, they can usually still be counted. These two conditions are clearly part of the oestrus cycle but their significance or function has not yet been described.

The number of scars counted for each female can be plotted against her age as in Fig. 18.3. A least squares regression line can then be fitted mathematically to the data and the slope of the line gives the inter-calving period. That is, the interval equivalent to one scar on the vertical axis indicates the calving interval on the horizontal axis. The data in the figure are for a hypothetical population, used only to show the method.

18.2.7 Lactation

It is reasonable to assume that every lactating female has a calf that is still suckling from her. If this is so, then there must be the same number of suckling calves as lactating females. It is also reasonable to assume that the suckling calves will be from the youngest age classes. An estimate of mean age at weaning can thus be obtained.

In a sample of culled elephants examined by the author between 1989 and 1992, there were 344 lactating females which means there should also have been the equivalent number (344) of suckling calves. The sample also included 88 calves of less than one year old (nought-year olds), 88 one-year-olds. 84 two-year-olds and 90 three-year-olds. This means that all of the nought, one- and two-year-olds would still have been suckling. The remainder of the 344 would have come from the three-year-olds (84 of the 90 in the sample). Therefore the mean age at weaning under the conditions prevailing during the sampling period can be estimated as:

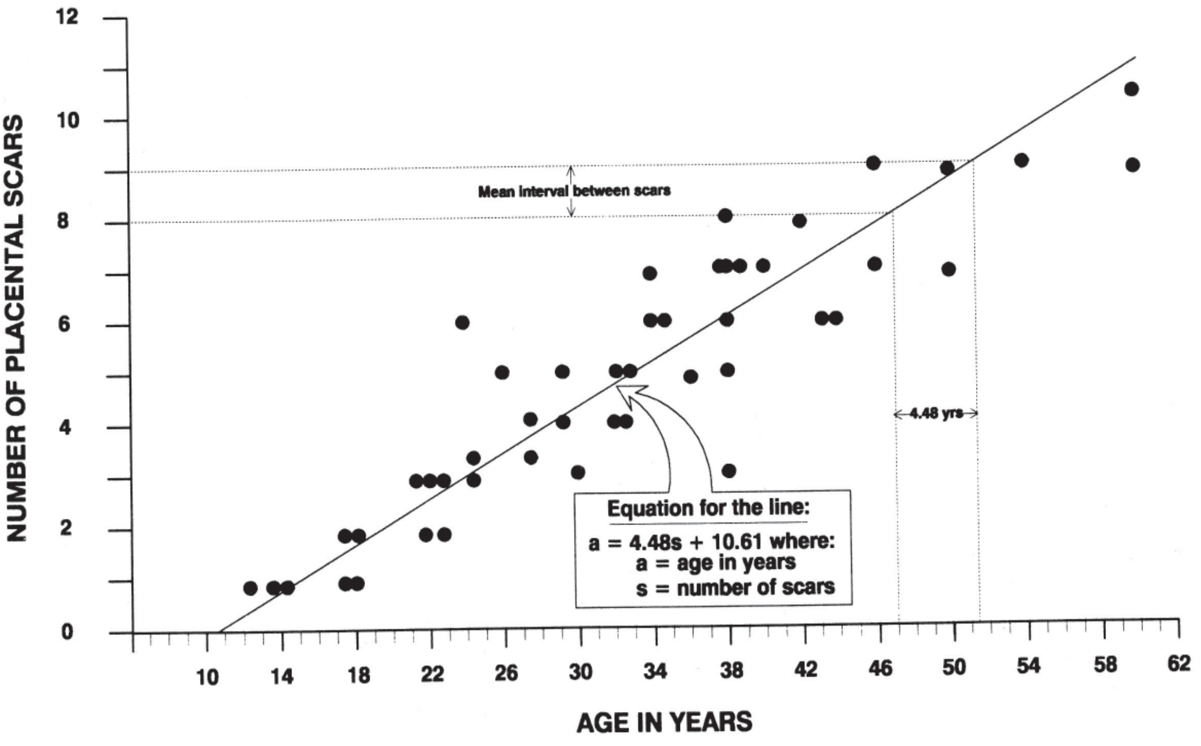

Fig 18.3: The relationship between the number of placental scars and age in adult elephant cows.

2 + (84+90) = 2.93 years.

18.2.8 Measuring dead elephants

a) Shoulder height
Many of the measurements that can be taken from an animal are prone to variation and therefore error, but a technique for measuring shoulder height can be standardised. The freshly dead elephant is rolled onto its side before rigor mortis sets in. The two front legs are then straightened and the top front leg is placed on top of the bottom one. As this is done, the top leg "locks" itself in this straight position and two stakes can then be driven vertically into the ground- one touching the top of the scapulars (shoulder blades) and the other touching the soles of the feet and an accurate, standardised measurement can then be taken between the stakes.

From these data, growth curves can be calculated (Tomlinson & Abramson, 1961) but these complicated mathematical procedures will not receive further attention here.

b) Back length
The elephant should be measured from directly behind the ears to the start of the tail.

c) Tusk length
Tusks should be measured from the point where the tusk emerges from the skin along the tusk to the tip of the tusk; both left and right tusks should be measured.

d) Tusk circumference
This should be measured around the point where the tusk emerges from the skin; both left and right tusks should be measured.

18.3 OTHER INFORMATION

In circumstances where the dead elephant falls into categories (i) or (ii) (see Section 18.1), that is, the elephant was not culled, additional information can be collected about the circumstances of the elephant's death, to develop a database on elephant mortality in an area. One could note down the date and time of finding the carcass. Location, habitat type and the cause of death including whether or not the elephant was poached, should also be recorded, along with any other observations concerning the elephant that may interest you.

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BOX 18.1: APPLICATION OF EVOLUTIONARY GENETICS TO ELEPHANT CONSERVATION USING TISSUE SAMPLES

The long-term goal of elephant conservation is not just to conserve individual elephants, or local populations, but also to sustain and exploit natural processes that have been operating at regional or continental levels over evolutionary time. Within this long-term context, the questions invariably arise: What were those natural processes? And when are issues of historical continuity important in elephant conservation? For example, we will increasingly have the option of restoring populations that have gone extinct locally, sometimes by pooling individuals from distant locations. Current conservation policies implicitly assume that all elephant populations are phylogenetically equivalent, but recent studies have shown that this is far from true. For example, although they hybridise, forest and savanna elephants are not only genetically distinct, they are genealogically different as well. Powerful evolutionary forces, not yet identified, appear to be limiting gene flow between forest and savanna elephants.

Recent advances in genetics now permit us to address these issues explicitly, to discover exactly what we are conserving in an evolutionary context. These methods require samples of DNA from elephants in precisely known locations. DNA exists in all nucleated cells of all individuals, and thus any tissue (e.g. skin, blood, muscle) is suitable for DNA analysis. However, for genetic studies at the population level, samples from more than one individual are required from a given location, and more than thirty samples from unrelated individuals are ideal. I have collected over 400 samples from elephants in eastern, southern and western Africa, primarily using a ‘biopsy dart’ (Georgiadis et al. 1994). This is simply a tranquilising dart modified to bounce out of the target with a small skin biopsy, without tranquilising or harming the donor elephant. While this is a simple and very efficient device that provides fresh samples, it is also relatively expensive. Genetic analysis can be done not only on fresh tissue samples, but also on samples that have been dried, salted or preserved in alcohol. Many researchers who work with elephants in the field are interested to know the genetic identity and distinctness of the elephants in their study area, and are in a position to accumulate tissue samples from elephants on an opportunistic basis which will enable them to do this.

If you are interested in collecting tissue samples and would like to have them analysed you can contact Nicholas Georgiadis at the address below for details on how to collect the samples and transport them to a laboratory where genetic analysis is carried out.

Nicholas Georgiadis, Mpala Ranch, P.O. Box 92, Nanyuki, Kenya.

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