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The social structure, distribution and demographic status of the African elephant population in the Central Limpopo River Valley of Botswana, Zimbabwe and South Africa

by

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THE SOCIAL STRUCTURE, DISTRIBUTION AND DEMOGRAPHIC STATUS OF THE AFRICAN ELEPHANT POPULATION IN THE CENTRAL LIMPOPO RIVER VALLEY OF BOTSWANA, ZIMBABWE AND SOUTH AFRICA

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ABSTRACT

The Central Limpopo River Valley elephant population is a cross border population on which very little scientific data pertaining to numbers, distribution and demographic status is available. The total range was determined using published literature, reports, postal questionnaires and interviews. Numbers and dry season distribution were determined by means of three total aerial counts in 2000, 2001 and 2004 of the sections of the total range in which elephants were reported. Totals of 1388, 1424 and 1339 were recorded with the highest numbers in all counts in the Botswana section of the study area. Four sub groups within the population were identified. Human settlements and the distribution of rivers and fencing appeared to be the major factors influencing distribution and movement. The population is highly mobile within the total range, and numbers fluctuate markedly in any given section, but numbers in the total range appear to have been increasing slowly at below 2% per annum and the range expanding slightly over the last 30 years. Additional range is being provided by the creation of a Trans Frontier Conservation Area. Movements were determined through ground observations within the study area and seem to follow the major rivers namely the Shashe, Ramokgwabane, Simukwe, Shashani, Tuli, Umzingwane and Limpopo rivers. The social and demographic status of the population was determined through ground observations as well as total aerial counts conducted within the Northern Tuli Game Reserve from 1976 to 2004. The study has shown that group sizes increase with an increase in rainfall (average mean group size of 56.524, SDE 77.388) and decrease during low rainfall periods (mean group size of 24.157, SDE 22.223). The age structure was determined from aerial photographs during August 2000 and showed a high percentage of adults and sub adults, with infants estimated at 3%. The approximate birth rate (1.5%) calculated for 2000 is balanced by an average natural mortality determined between 1999 and 2004 of 1.8%. The inter calf interval determined from known herds observed in the Northern Tuli Game Reserve was estimated at 3.94% and suggests that the long-term birth rate for the population should be higher than that for the year 2000. The difference between the combined natural and human induced mortality rates (~4%) and the birth rate suggested by the age structure and the inter calf interval (~6%) gives the ~2% long-term increase observed in the numbers. Human elephant interactions within the study area were determined through published literature and interviews with local residents. Elephants and humans interact in both a positive and negative manor and interactions are related to human land use practices within the area. Elephants were indicated as the major problem animal in farming areas, but the major draw card within tourism operations.

Additional keywords: distribution, numbers, group sizes, Northern Tuli Game Reserve, Trans Frontier Conservation Area, range, mortality rate, birth rate, inter calf interval, rate of increase, age structure, human elephant conflict

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INTRODUCTION

The range of the African elephant continues to dwindle at an ever-accelerated rate with the inexorable increase in human population, which destroys elephant habitat, disrupts migratory pathways, changes distribution and alters behaviour patterns. The net effect is that an estimated 90% of Africa's elephants are crowded into parks and other sanctuaries where much of the habitat is overpopulated (Buss 1990).

The Central Limpopo Valley elephant population is an important population on which very little scientific data pertaining to numbers and movements have been collected. In the light of the proposed Shashe/Limpopo Trans Frontier Conservation Area research on the size, distribution and social structure is urgently required.

BACKGROUND TO THE STUDY

The Tuli elephant population is distributed over three different countries namely South Africa, Botswana and Zimbabwe (Figure 1).

Land use by people varies within the elephant range and the different conservation agencies manage the section of the population over which they have jurisdiction, differently. In Botswana the area along the Limpopo River consists of a number of adjoining farms, which form an area known as the Tuli Block (Figure 2). The Northern Tuli Conservation Area in Botswana consists of a number of privately owned farms bound by the Limpopo, Motloutse and Shashe rivers. It comprises about half of the area of a conserved ecosystem which consists of the Tuli Controlled Hunting area (Tuli Circle) and the Mlala Reserve in Zimbabwe, and two farms on the southern bank of the Limpopo River in South Africa (Page 1990). Several wildlife based tourist operations occur in the region and depend on the presence of elephants for their success. One farm within the Northern Tuli Game Reserve area is used for subsistence agriculture and stock farming. To the north west and east of the Northern Tuli Game Reserve is tribal land. The boundary between the farms and tribal land is fenced in most parts. Land use in the tribal land consists of subsistence agriculture and stock farming. The area to the east of the Shashe River in Zimbabwe consists of the Maramani and Masera communal lands. Subsistence agriculture and stock farming occur in these areas. Two privately owned ranches Sentinel Ranch and Nottingham Estate occur to the east of the tribal land in Zimbabwe. Approximately 57000 ha in total of these two ranches are used for wildlife. Irrigation agriculture occurs on the Limpopo River.

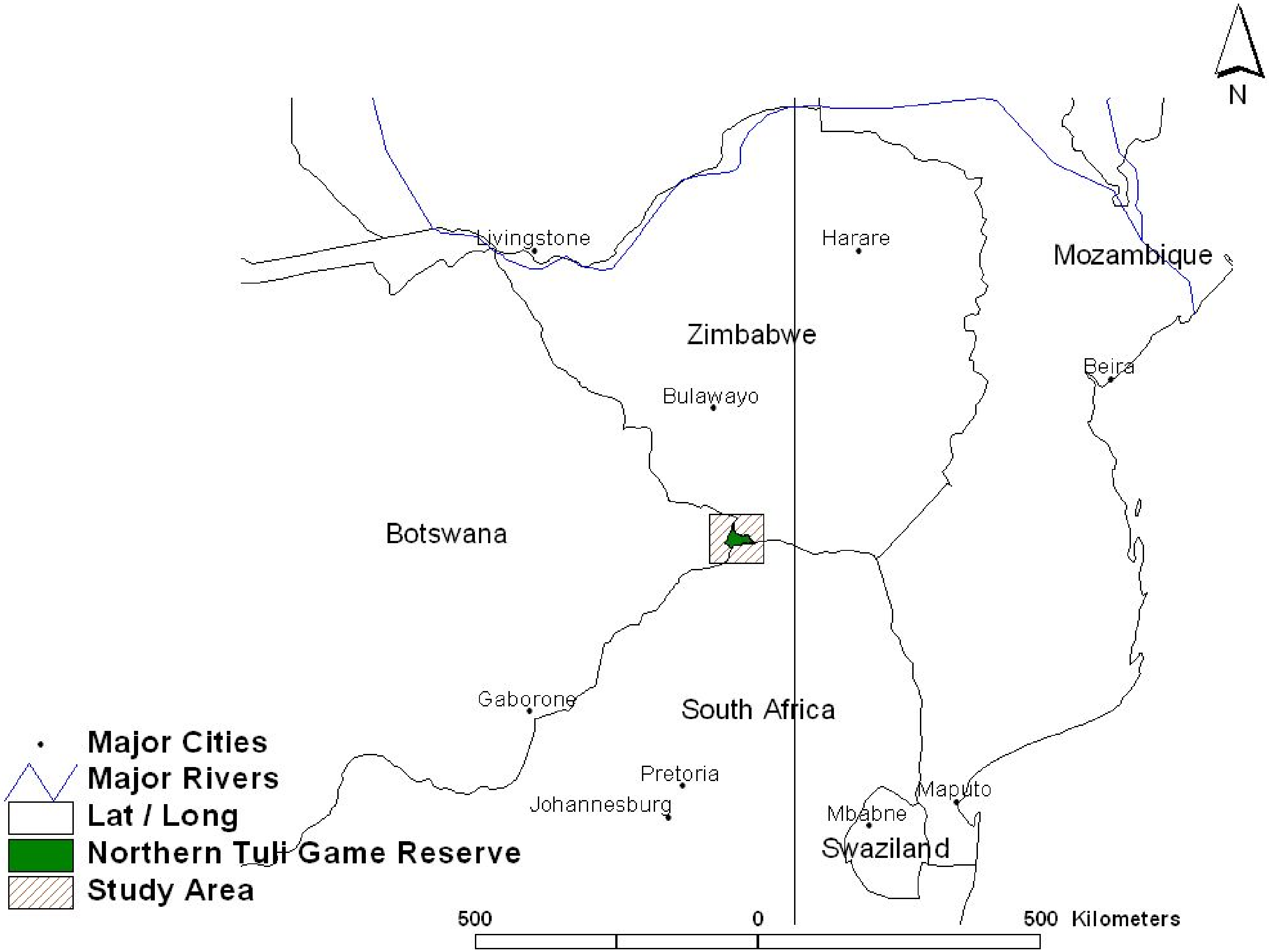

Figure 1: Location of the Central Limpopo River Valley study area

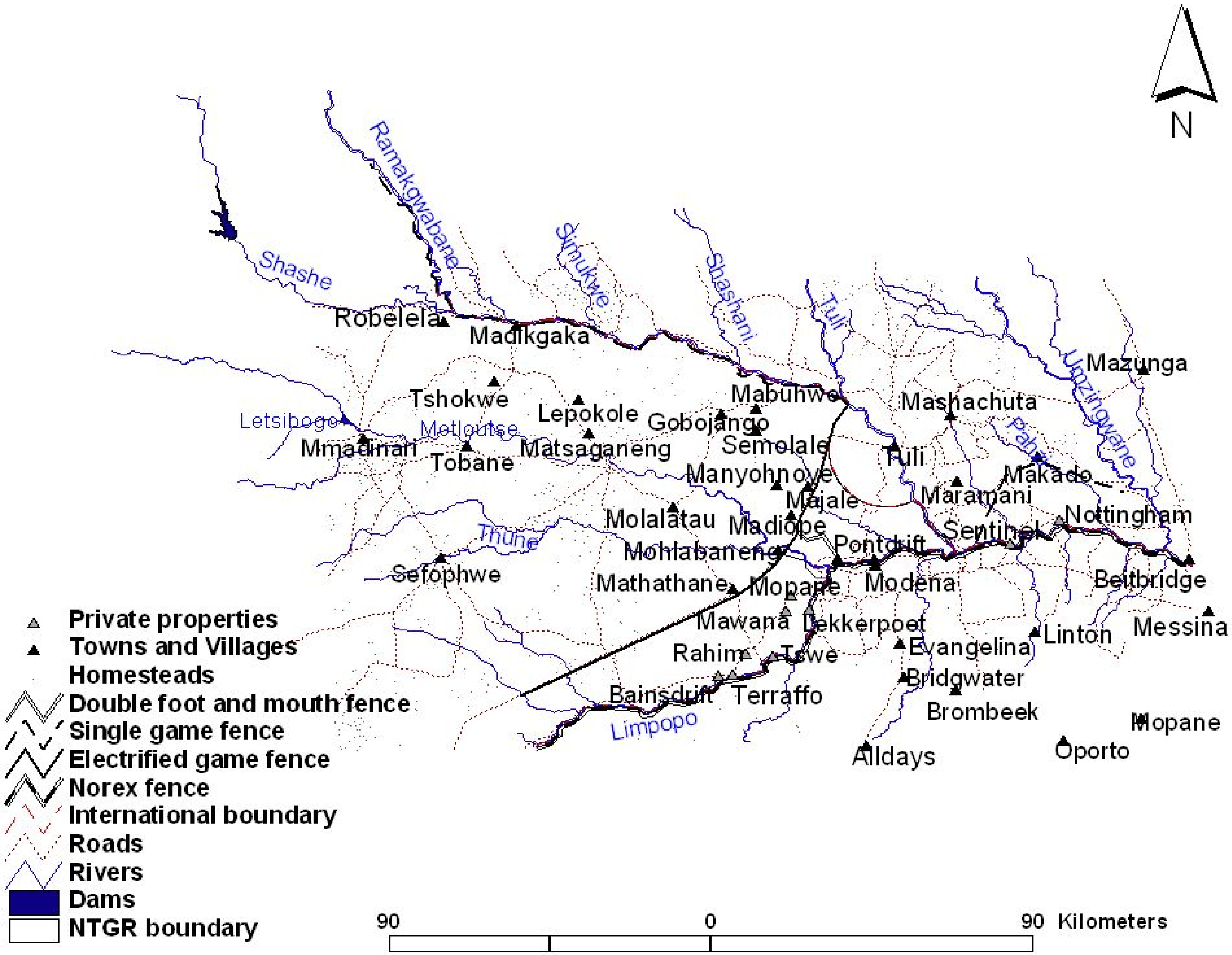

Figure 2: The Central Limpopo Valley study area

A resettled farm formerly known as River Ranch, which is now a subsistence settlement, is found on the east of Nottingham Estate. In South Africa there are several farms, which cultivate citrus and other crops under irrigation, and utilise part of the farms as wildlife areas.

When the first scientific counts of elephants were done in 1976, the civil war in Zimbabwe (then Rhodesia) prevented a count in the entire region. Walker (1971) attempted to define the range from interviews and the surveys conducted in Botswana.

In 1977 Page (1980) attempted to establish the range more precisely by using radio collars, but again because of the civil war in the then Rhodesia, this failed. Before the present study the precise range used by the population, their numbers, social structure, age structure and sex ratios have not been determined.

The elephants can move freely from the Northern Tuli Game Reserve into Zimbabwe in the east and north. Elephants can also move south west along the Limpopo River onto farms further up the Tuli Block. Movement across the Limpopo River onto farms in South Africa in the area between Platjan and Messina also frequently occur.

In 1991 reports were received of elephants moving onto farms in the central Tuli Block in areas in which they had been absent for at least the past 100 years (Page, pers. comm.)[1]. A group of about 80 was reported to be resident on Mawana in the Platjan area. A group of 200 was reported on Nottingham Estate in Zimbabwe and isolated small groups on several farms in South Africa. Spoor crossing the main Messina – Beitbridge road was reported (Page, pers. comm.)[1].

As stated earlier, management of the regional elephant population is different in the three countries. Hunting quotas and permits for control shooting and culling or capture are issued by the three different conservation agencies on the basis of incomplete information related to only a part of the elephant's range. Given the plans for a Trans Frontier Conservation Area in the region, that everyone in the region is affected by the presence of the elephant in some way, and the fact that elephants currently appear to be widespread and mobile, it is of critical importance to establish

[1] Page, B. R. School of Biological and Conservation Sciences, University of KwaZulu-Natal, Durban. Personal communication.

the following:

(i) what the current range is,

(ii) what the size, age structure and sex ratios of the population are,

(iii) what the social structure is,

(iv) what the movement patterns are and what determine these,

(v) what the population and social dynamics are, and the factors which determine them,

(vi) what the ecological densities are, and how these influence the structure and dynamics of the system, and

(vii) what interactions occur between people and elephants, what conflicts arise because of these interactions, and how to resolve these.

This study aims to address requirements (i) and (ii) in depth and obtain preliminary information on (iii) and (iv), and will form the basis for later in depth studies which addresses requirements (v), (vi) and (vii).

AIMS AND OBJECTIVES

Objective

The broad objective for this study is to determine the range, social structure, and demographic status of the African Elephant population in the Central Limpopo River Valley, and to relate their distribution and demographic structure, to the land use in the region.

Specific aims

1. Determine the past and present range of the population.
2. Determine the size and distribution of the Central Limpopo River Valley elephant population.
3. Determine preliminary estimates of the home ranges, daily and seasonal movements of the elephant groups within the study area.
4. Determine preliminary estimates of the numbers and range of mature bulls.
5. Identify possible factors that might be influencing movements.
6. Determine which areas / habitats are preferred by the elephants in different seasons, and attempt to identify possible factors that might be influencing area or habitat selection.
7. Determine the group size dynamics of the elephant groups within the study area
8. Determine the influence of rainfall on group sizes
9. Determine the age structure and sex ratio

10. Determine the birth rate and inter calf interval of the elephant population
11. Determine the mortality rate within the elephant population
12. Determine the intrinsic rate of increase for the elephant population
13. Determining the attitudes of the local communities to elephant.
14. Determine the different interactions occurring between elephants and humans within the study area as well as possible conflicts that might arise from these interactions and possible solutions to these conflicts.

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THE STUDY AREA

LOCATION

The study was undertaken in the Central Limpopo River Valley, between latitudes 21º00’ south and 22º40’ south and longitudes 27º15’ east and 30º00’ east, in south eastern Botswana, northern South Africa and south western Zimbabwe (Figure 3).

CLIMATE

The climate of the region is semi-arid sub-tropical. Summer maximum temperatures exceed 42ºC, while winter minimum temperatures are as low as -5ºC (Table 1 and Table 2). Frost is however, infrequent (Lind and Stephan 1974). As typical for the Limpopo Valley rainfall is low and unpredictable (Harrison 1984). The long-term average annual rainfall is 369.4 mm (1966 - 2001) with peak rainfall years receiving 916.7 mm (1999/2000) and low rainfall years receiving as little as 135.5 mm (1998) (Table 3). Most rain falls between November and February, usually in the form of thunderstorms (McKenzie 1990). There is an annual winter drought with only occasional rain at this time of the year (Lind and Stephan 1974). Permanent natural surface water is confined to a few small pools in the channels of the major rivers, although water can be obtained by sand abstraction from the sandy beds of the rivers (Voigt 1983). When not experiencing drought, the area is prone to flooding, as during Cyclone Eline in 2000 (CESVI 2001).

Table 1: Mean maximum monthly temperatures as measured at station [0809706 X] Messina – Macuville (Coordinates -22.2700S and 29.9000E) for 2000 to 2003

	2000	**2001**	**2002**	**2003**
January	29.9	34.8	35.8	35.7
February	29.3	30.3	34.7	36.1
March	30.0	29.9	34.1	32.0
April	27.6	30.4	31.2	31.1
May	25.8	27.0	29.0	28.7
June	24.2	25.4	24.8	24.5
July	23.6	24.1	25.8	25.4
August	26.7	29.1	28.3	28.6
September	29.5	29.3	29.0	31.7
October	31.5	32.0	31.9	32.8
November	32.8	31.4	32.2	34.0
December	34.3	32.0	34.9	33.0

Table 2: Mean minimum monthly temperatures as measured at station [0809706 X] Messina – Macuville (Coordinates -22.2700S and 29.9000E) for 2000 to 2003

	2000	**2001**	**2002**	**2003**
January	19.9	20.3	20.7	22.4
February	20.8	20.7	20.6	23.2
March	19.7	18.8	20.0	19.9
April	14.4	16.0	16.3	16.5
May	8.9	10.4	11.7	12.2
June	9.4	7.9	9.0	11.0
July	6.2	7.0	7.3	7.5
August	8.3	11.3	12.1	9.5
September	13.7	14.9	13.5	15.2
October	16.5	17.9	18.0	17.5
November	19.3	20.4	18.5	20.2
December	19.2	20.3	22.1	16.9

Table 3: Rainfall data from Station [0808253 3] Pontdrift (Coordinates –22.2200S and 29.1500E) from 1980 to 2003

(mm)	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
January	204.2	148.8	37.5	34.5	27.5	74.5	62.0	109.0	46.5	2.5	52.5	178.0	4.5	41.5	7.0	99.0	164.1	75.5	48.5	54.2	279.5	0.0	7.0	78
February	72.6	34.5	35.0	10.5	7.5	55.5	55.0	12.0	49.0	11.0	1.0	42.0	16.0	49.0	50.0	16.0	95.8	0.0	8.5	64.0	365.4	32.1	3.0	0.3
March	7.0	67.0	0.0	16.5	44.0	49.5	0.0	45.5	58.0	34.0	11.5	109.0	25.0	0.0	0.0	143.0	9.5	108.5	11.5	4.0	113.4	12.0	1.0	43.5
April	0.0	37.0	24.0	13.0	7.0	0.0	45.5	0.0	2.0	28.0	43.0	1.5	0.0	6.0	0.0	15.0	0.0	9.5	0.0	4.0	6.5	4.0	15.0	0
May	0.0	0.0	29.0	15.5	0.0	12.0	0.0	0.0	0.0	0.0	0.0	17.0	0.0	0.0	0.0	30.0	29.0	1.0	0.0	6.0	10.5	0.6	1.3	0
June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	65.0	13.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	0.0	6.5	23
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	22.0	0.0	0.0	48.0	0.0	0.0	4.5	13.7	0.0	0.0	0
August	0.0	0.0	0.0	9.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0
September	15.2	0.0	0.0	0.0	14.0	79.0	10.0	23.0	0.0	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0	29.0	1.3	0.0	0.0	17.5	23.5	2
October	6.5	10.5	72.0	8.0	46.5	148.5	22.0	4.0	31.5	18.0	7.0	0.0	30.0	4.0	20.0	3.0	0.0	6.0	67.5	3.0	2.4	19.8	32.0	51.6
November	117.7	102.5	26.0	32.5	73.0	22.0	42.0	0.0	6.0	61.0	47.0	77.5	41.0	134.0	32.0	22.0	66.7	29.0	100.2	79.0	48.0	37.9	11.3	28.7
December	0.0	38.5	0.0	98.0	30.0	130.0	43.0	102.0	14.5	8.0	101.0	13.5	114.0	67.5	35.0	25.0	61.0	2.0	126.5	42.0	55.4	220.5	7.2	25.7
	423.2	**438.8**	**223.5**	**237.5**	**249.5**	**571.0**	**279.5**	**298.5**	**272.5**	**180.0**	**263.0**	**452.5**	**232.5**	**324.0**	**144.0**	**353.0**	**474.1**	**261.5**	**364.0**	**260.7**	**907.7**	**344.4**	**107.8**	**252.8**

GEOLOGY AND SOILS

The area falls into the floor of the Limpopo Valley, a broad geological trough formed by the Limpopo mobile belt (Figure 3). Geologically this area is an outlier of the Karoo system. Sandstones, shales and mudstones of the Cave Sandstone Stage form the hills and valleys of the area (Voigt 1983). The geological units of the study area are part of the Tuli Syncline – an extensive trough-like structure. Geologically the Tuli Syncline is a westward continuation of the Nuanetsi Syncline, which is situated in the south eastern corner of Zimbabwe. The southern limb of the Nuanetsi Syncline swings southward to form the Lebombo Monocline in the Kruger National Park. Thus, a rather close relationship exists between the rocks of the study area and those of the Kruger National Park (Joubert 1984).

A bank of Karoo sandstone cuts through the centre of the area, straddling the Limpopo and Shashe channels (Voigt 1983). This provides a spectacular rugged landscape. A second wide band of rocky basalt ridges occupies most of the northern part of the area. The southern part of the area is made up of mixed geology forming a series of steeply undulating rocky hills and scarps. There are small pockets of fertile soils alongside the major river channels cutting through the area (CESVI 2001). The Tuli Circle consists mainly of poor basalt soils, which is heavily eroded (Walker 1971).

The geological substratum of the Northern Tuli Game Reserve comprise of a deep Clarens sandstone formation overlain by Letaba and Sabi River basalt formations (McKenzie 1990). Numerous east – west dolerite dykes intrude the abovementioned strata (McKenzie 1990). Sandstone is exposed along the Limpopo and Motloutse Rivers while the rest of the reserve is dominated by basalt formations.

Extensive accelerated erosion has followed over-utilisation of the herbaceous layer (Joubert 1984; Lind and Stephan 1974). Both sheet and donga erosion are evident in the reserve, giving rise to areas devoid of vegetation within the otherwise well vegetated river valley. Riverine soils are deep, while the basalt ridges have a thin layer of remaining topsoil (McKenzie 1990).

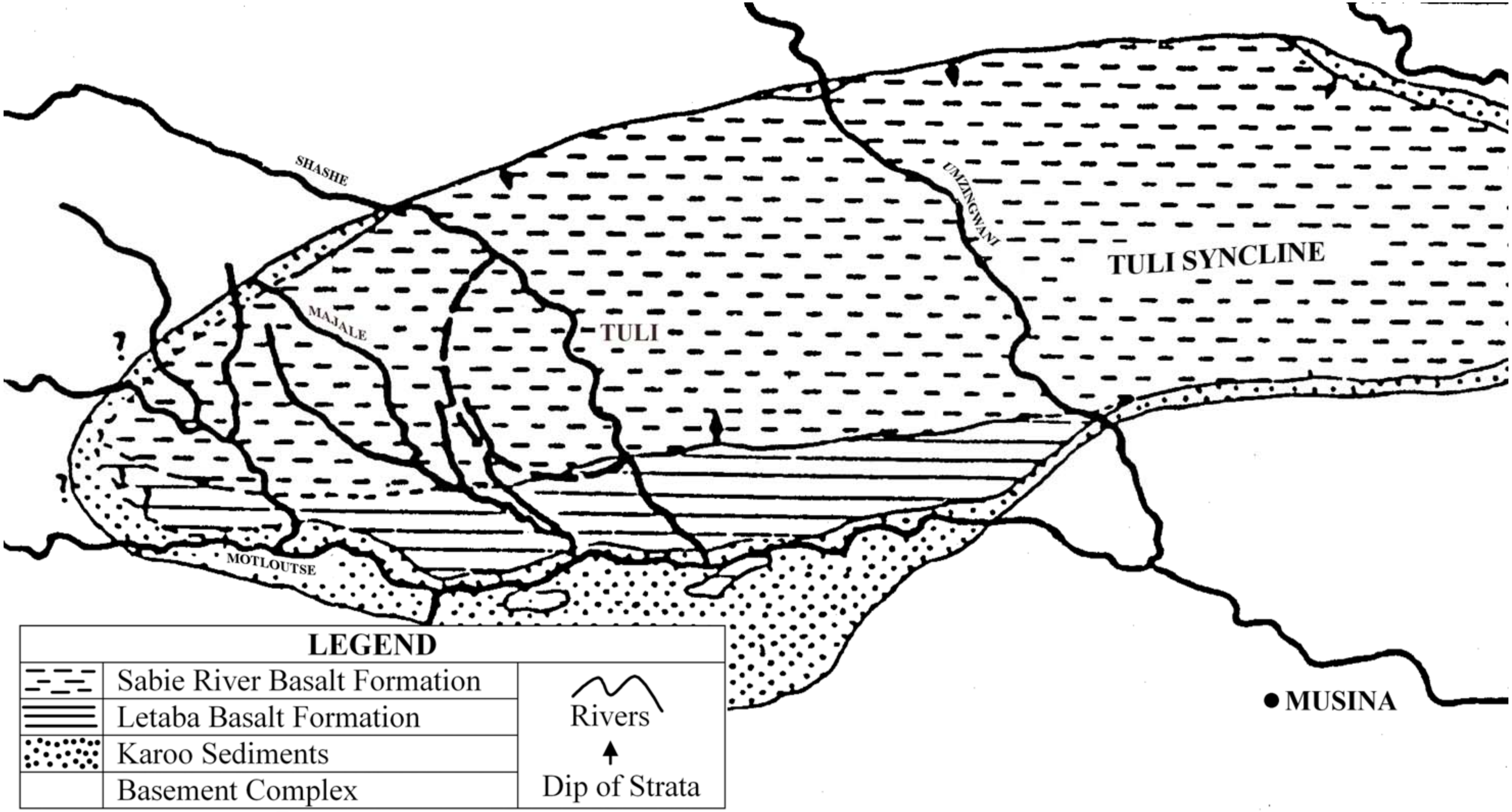

Figure 3: Map showing the major geological units in south eastern Botswana, southern Zimbabwe and a section of the Limpopo province south of the Limpopo River, South Africa (after Joubert 1984)

TOPOGRAPHY AND DRAINAGE

The area consists of a heavily dissected, basaltic plateau with successive east-west ridges (Bowden 1965 as quoted by King 1984). It varies from undulating to rugged country between 610 and 762 m above sea level, with smaller areas of flatter, low-lying ground in the wider valleys (King 1984). The north western section of the Tuli Circle is generally flat with isolated rocky outcrops becoming broken in the north closer to the Shashe River. The south and eastern sections are generally broken except where good alluvial deposits occur in the river valleys (Walker 1971).

Most of the Central Limpopo Valley drains into the Limpopo River, but neither this river nor its tributaries has a perennial flow. The other major rivers occurring in the area are the Motloutse, Majale, Shashe, Tuli, Pahzi and Umzingwani rivers (Figure 4). The Limpopo River, which rises in Gauteng in South Africa, carries large quantities of water during the rainy season. It frequently ceases to flow during the dry season although pools of water remain throughout the year and it is seldom completely dry. The Shashe and Motloutse rivers carry large quantities of water for periods of only a few days a year. During the rest of the year their courses are characterized by a wide expanse of sand. The period for flow of the Limpopo River is from four to six months while the Shashe River, having a porous sand bed, does not retain the surface flow of water for long after a flood. The Shashe River, however, has a large perennial subterranean flow (Nchunga 1978).

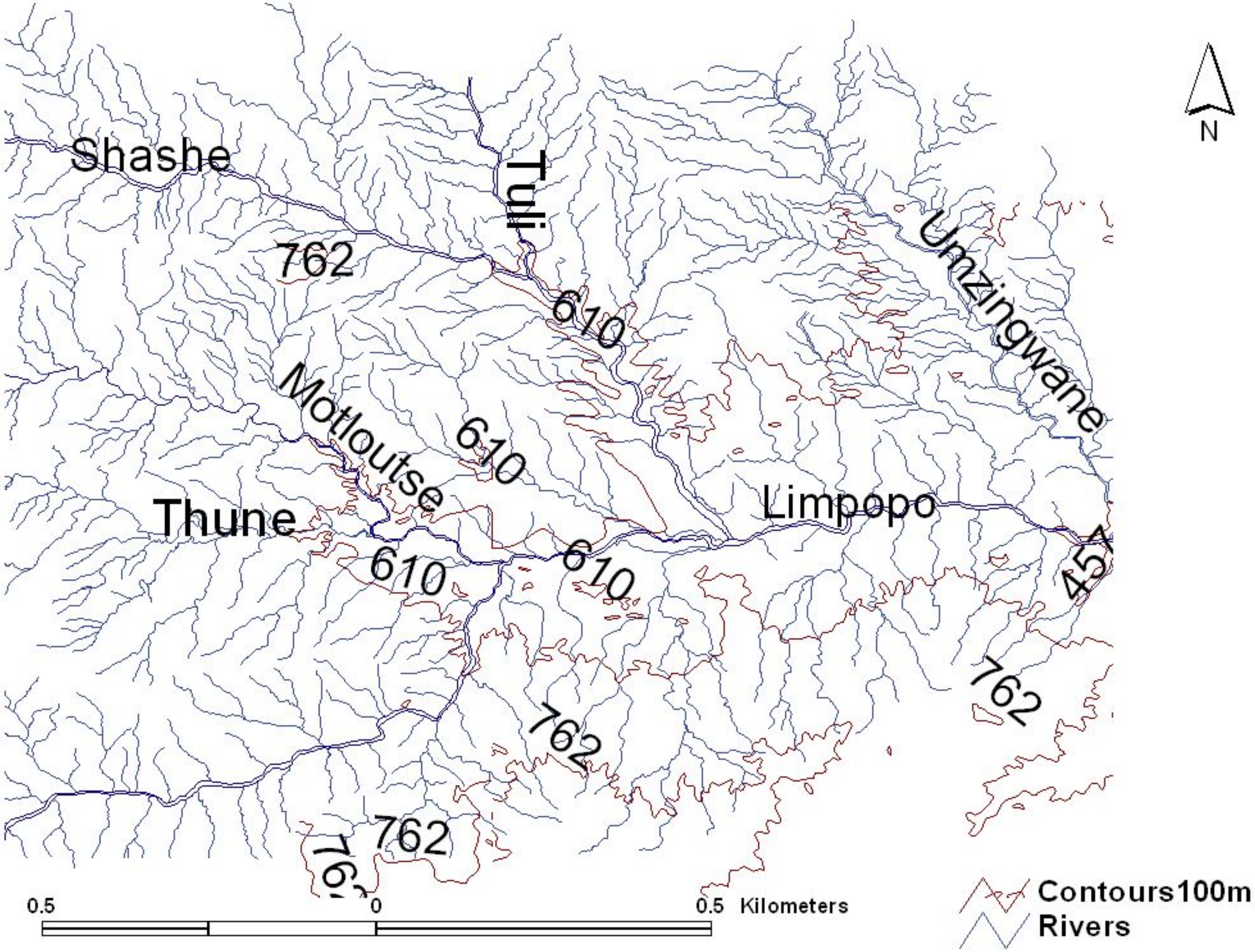

Figure 4: The Major rivers and topography within the Central Limpopo River Valley study area

VEGETATION

The vegetation of the study area falls within the broad classification of Mopane veld (Acocks 1988). The vegetation has not been mapped in detail for the whole study area. It varies slightly on the three different geological substrates south of the Limpopo River, north of the Limpopo River to roughly just north of the Tuli Circle (Figure 3).

In general the vegetation is varied and rich, including spectacular riverine forests along the main rivers, with majestic Mashatu trees (*Xanthocercis zambeziaca*), and groves of Fever trees (*Acacia xanthophloea*), and Mlala palms (*Hyphaene banguelensis*). The hilly areas away from the rivers support mixed woodland of *Acacias*, *Mopane*, *Terminalias* and *Combretums*.

There have been several attempts to classify the vegetation within the Northern Tuli Game Reserve (Lind 1973; Nchunga 1978; Walker 1982; Alexander 1984; Joubert 1984). The degree of classification differs greatly between these authors from Walker (1982) recognising three major vegetation types (Riverine, Acacia woodland and Shrubland), to Alexander (1984) that recognises 15 vegetation communities/types. Cheney (1998) and King (1984) recognised five broad vegetation types after Nchunga (1978). These are 1. Riparian woodland/forest, 2. Woodland, 3. Shrubland, 4. Shrub savannah, 5. Aquatic grassland (Figure 5). Joubert (1984) recognised three major landscapes in the Northern Tuli Game Reserve, in which different vegetation types were recognised. These are 1. Floodplains on alluvium, 2. *Colophospermum mopane/Terminalia prunoides* Rugged veld on Basalt and 3. Karoo Sandstone landscape. A landscape is defined as an area with a specific geomorphology, macro-climate, soil and vegetation pattern and associated fauna. These landscapes consist of a series of sub-components.

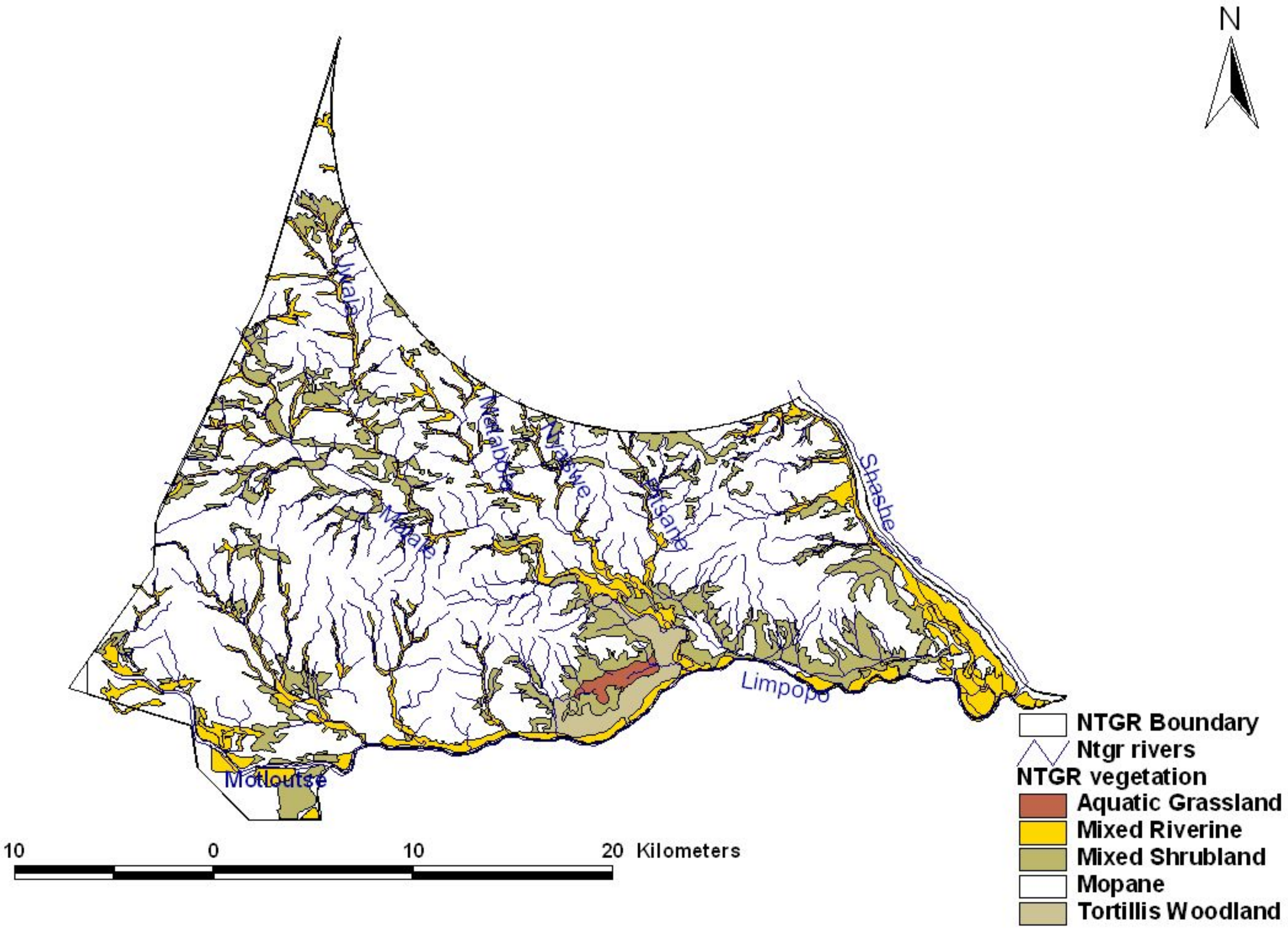

Figure 5: Major vegetation types of the Northern Tuli Game Reserve (after Nchunga 1978)

Floodplains on alluvium

This landscape is a flat plain on the alluvial soils along the Limpopo, Shashe and Motloutse rivers and is intersected from the north by the drainage channel of the Majale River. The rest of the tributaries from the north drain into streams that run parallel to the Limpopo and Shashe rivers and eventually drain into the Limpopo River. The soils are deep and belong mainly to the Oakleaf, Valsrivier and Rensburg forms. It is comprised of the following components:

Acacia albida gallery forest

The embankments of the Shashe, Limpopo and Motloutse rivers are made up of deep alluvial soils belonging mainly to the Oakleaf form. It is a dense tree veld of up to 15 m high with the canopies almost overlapping. The undercover is also dense but the grass cover is almost absent as a result of overgrazing and flooding.

The dominant woody plants are:

Acacia albida
Acacia xanthophloea
Lonchocarpus capassa
Xanthocercis zambesiaca
Acacia tortilis subsp. *heteracantha*
Ficus sycomorus
Combretum imberbe
Croton megalobotrys
Schotia brachypetala

The grasses that occur in this area are:

Panicum meyerianum
Panicum maximum
Sporobolus consimilis
Chloris gayana
Cenchrus ciliaris
Urochloa mosambicensis

This component of the landscape is at this stage badly overgrazed by cattle, which are in strong food competition with game such as waterbuck and elephant.

Sporobolus consimilis marshes

Decomposed material derived from basalts are carried down the rivers and deposited on the floodplains. The soils that developed on some of these alluviums are dark in colour and contain a lot of montmorilonite-type clays. The result is that these soils expand when wet and form big cracks when dry. Another characteristic of the soil is to granulate on the surface to form a loose layer. These soils are usually covered with water in the rainy season and the dominant soil form is Rensburg. Nels vlei is a typical example of these marshes but they also occur in isolated spots along the Limpopo and Shashe rivers.

The marshes are covered with *Sporobolus consimilis*, which can reach a height of 1.5 to 2 m. The reason why no woody vegetation occurs in these marshes is the expanding characteristic of the clays, which probably break the roots of trees. Secondly as a result of the temporary waterlogged conditions, the marshes are well maintained.

Hyphaene natalensis vleis

These vleis occur mainly along the Shashe River, but are also present along the Limpopo and Motloutse rivers. They usually occur as fringes around the *Sporobolus consimilis* marshes or as homogeneous stands of *Hyphaene natalensis* with *Sporobolus consimilis* as the dominant grass. The soils are deep alluvial soils and mainly belong to the Valsrivier and Oakleaf forms. The trees are usually stunted and larger trees are heavily used by man for making palm wine. This part of the landscape is one of the important habitats for elephant.

Salvadora angustifolia/Acacia stuhlmanni brushveld

Salvadora angustifolia in association with *Acacia stuhlmanni* occurs on the saline alluvial soils to the west of Nels vlei. Dominant soil forms are Valsrivier and Arcadia. The structure of the vegetation is a dense brushveld of up to 4 m high. Other woody species that occur are *Acacia tortilis* and *Acacia nebrownii*.

Salvadora angustifolia/Acacia torilis brushveld

The floodplains adjacent to the *Acacia albida* Gallery Forest are dominated by *Salvadora angustifolia* and *Acacia tortilis* subspecies *heteracantha* and resemble the *Salvadora angustifolia/Acacia stuhlmanni* brushveld. The soils are usually less vertic and the dominant soil forms are Valsrivier and Oakleaf.

The woody vegetation is dense to open and reaches a height of 6 m and higher. The grass cover is sparse to absent and *Tribulis terrestris* (dubbeltjie) is dominant after the rains. Other woody species that occur are:

Acacia nebrownii
Acacia Senegal var. *rostrata*
Boscia foetida subsp *rehmanniana*
Lycium austrinum
Hyphaene natalensis
Xanthocercis zambesiaca
Loncocarpus capassa

Acacia tortilis savannah

In some areas the above-mentioned component of the landscape (*Salvadora angustifolia/Acacia tortilis* brushveld) was bush-cleared and ploughed for the production of crops. These old lands are now covered with an almost homogeneous stand of *Acacia tortilis* subspecies *heteracantha*. The bush is open to dense and all the individual trees seem to be of almost uniform age. This is the case in the south/central areas of the reserve near Mashatu lodge. To the west, this component of the landscape is more natural but is still associated with human interference and overgrazing. In these areas *Acacia tortilis* trees of 8 m and higher are common with their canopies almost overlapping. The soils are clayey to a clayey-loam and the dominant soil form is Oakleaf. Associated woody species are the same as for the *Salvadora angustifolia*/*Acacia tortilis* brushveld.

Croton megalobotrys thickets

The lower floodplain of the Majale River is covered with a dense stand of *Croton megalobotrys*. The soils in this area are clayey and belong to the Oakleaf form. The woody vegetation is dense to very dense and grasses that occur are *Panicum maximum*, *Cenchrus ciliaris*, *Digitaria eriantha* and *Urochloa mosambicensis*.

Other woody species that occur in these thickets are:

Lonchocarpus capassa
Combretum hereroense
Combretum imberbe
Schotia brachypetala
Acacia nigrescens

Boscia foetida savannah

Old terraces occur on the contact zone between the floodplains and the basalt. These terraces consist of a calcareous, pebble-rich soil with Mispah and Glenrosa as the dominant forms. The component is differentiated by the presence of *Boscia foetida* subspecies *rehmanniana*. It is an open savannah with small trees of about 3 m high.

Other woody species that occur are:
Boscia albitrunca
Sesamothamnus lugardii
Commiphora pyracanthoides subsp. *glandulosa*
Commiphora mollis
Cordia ovalis

This component of the landscape is probably the driest and grasses that do occur are *Aristida* spp. and *Enneapogon cenchroides*. According to the staff a considerable number of *Commiphora trees* were removed by elephants over the years.

Colophospermum mopane/Terminalia prunioides **rugged veld on basalt**

The major central part of the reserve is made up of basalt and consists of a plateau, a middle slope, drainage lines and isolated outcrops. It is a dry landscape with shallow soils. The vegetation consists of a dense to moderate shrub to tree veld with a sparse grass cover. The major components of the landscape are described below.

Colophospermum mopane/Combretum apiculatum plateaux

The flat plateaux in the north and the north western parts of the reserve are typical examples of this component. Pans are common in the area and the vegetation is an open tree veld of up to 6 m high with *Colophospermum mopane* and *Combretum apiculatum* as the dominant woody species. The soils are shallow to moderate and Glenrosa, Mispah and Mayo are the dominant forms.

Other woody species that occur are:
Terminalia prunioides
Boscia albitrunca
Commiphora mollis
Commiphora merkeri
Commiphora pyrocanthoides subsp. *glandulosa*

Sterculia rogersii
Acacia nigrescens
Sesamothamnus lugardii

Cassia abbreviata trees serve as a useful differential species for this component.

As a result of the shallow soils, the grass cover is very sparse but nevertheless, this area has the best potential for a good grass cover in the reserve. Dominant species are:
Enneapogon cenchroides
Schmidtia pappophoroides
Urochloa mosambicensis
Aristida spp.
Eragrostis superba
Cenchrus ciliaris
Panicum maximum

Colophospermum mopane/Terminalia sericea middle slopes
The area between the plateaux and the floodplain landscape is slightly undulating and is intersected by a large number of streams. The soils on these middle slopes are shallow and usually eroded. Dominant forms are Glenrosa and Mispah and very often the soil consists of a high proportion of stones and gravel.

The dominant woody plants are *Colophospermum mopane* and *Terminalia prunioides* and the structure of the vegetation ranges from a shrubveld to a moderately dense tree veld. The slopes are gentle to steep and other woody species that occur are:
Sesamothamnus lugardii
Combretum apiculatum
Sterculia rogersii
Acacia nigresens
Albezia brevifolia
Commiphora pyrocanthoides subspecies *glandulosa*
Boscia albitrunca
Commiphora mollis
Commiphora merkeri
Adansonia digitata

Cordia ovalis

Grewia species

Catophractes alexandrii

The shrub *Rhigozum zambesiacum* is a good indicator of this component of the landscape. The grass cover is sparse with *Enneapogon cenchroides* and *Aristida* species as the dominants.

Basalt outcrops

Basalt koppies are common in the landscape. The vegetation cover is usually less dense and species that occur frequently are:

Adansonia digitata

Combretum apiculatum

Sterculia rogersii

Commiphora spp.

Boscia albitrunca

Valley bush

All the streams in the landscape have a narrow fringe of deeper alluvial soils. These Oakleaf soils are clayey and the riverine vegetation consists of species like:

Croton megalobotrys

Combretum imberbe

Combretum hereroense

Lonchocarpus capassa

Diospyros mespiliformis

Xanthocercis zambesiaca

Karoo sandstone landscape

Karoo sandstone outcrops occur locally in the south west of the reserve near the confluence of the Limpopo and Motloutse rivers. The area is very scenic with sharp sandstone cliffs and sandy bottomlands.

Sandstone outcrops

The sandstone forms small flat grassveld plateaux with steep cliffs and sandstone pediments. The vegetation cover is sparse with the following woody species:

Hexalobus monopetalus

Strychnos madagascariensis

Markhamia acuminata

Adansonia digitata

Ficus soldanella

Ficus tettensis

Ficus stuhlmanni

Sterculia Africana

Kirkia acuminata

Euphorbia cooperi

Ximenia Americana

Boscia albitrunca

Dichrostachys cinerea

Bridelia mollis

Pappea capensis

Grasses that occur on the plateaux are:

Panicum maximum

Schmidtia pappophoroides

Cenchrus ciliaris

Eragrostis species

This component of the landscape is unique and adds considerably to the diversity of the area.

Sandveld valleys

This component of the landscape has been ploughed in the past and serious wind erosion has taken place as a consequence. The soils, where still present, are sandy, and Clovelly and Hutton soils are the forms to be expected. The woody vegetation is secondary at this stage because a large number of *Acacia tortilis* trees have sprung up on the old lands. Woody species that can be present are:

Terminalia sericea

Strychnos madagascariensis

Hexalobus monopetalus

Peltophorum africanum

Dichrostachys cinerea

Boscia albitrunca

Acacia tortilis

The grass cover is sparse with the following species occurring:

Panicum maximum

Perotis patens

Eragrostis species

Schmidtia pappophoroides

Similar types are found within the rest of the study area.

FAUNA

The area is highly variable in terms of animal distribution. The highest concentration of wildlife species can be found within the Northern Tuli Game Reserve (Table 4). The Northern Tuli Game Reserve is not fenced in along the Tuli Circle boundary and movement in and out of the area, particularly by elephants, occurs (King 1984). Other areas with a healthy wildlife population are the remainder of the Tuli Block, Botswana, Sentinel Ranch and Nottingham Estate in Zimbabwe as well as game farms and the Mapungubwe National Park in South Africa.

Most of the previously abundant species in the southern African lowlands are still present in small numbers within the area. The principal exceptions are tsessebe (*Damaliscus lunatus*), roan antelope (*Hippotragus equines*), sable antelope (*Hippotragus niger*) and Cape buffalo (*Syncerus caffer*). Illegal hunting and drought eliminated the Cape buffalo in the 1970's and 1980's (CESVI 2001). Predator densities (mainly lion, *Panthera leo*) are low.

Table 4: Results of the total aerial counts of large mammals within the Northern Tuli Game Reserve from 1996 to 2001

Species	Totals			
	1996	**1997**	**1999**	**2001**
Impala (*Aepyceros melampus*)		13958	13034	15643
Blue Wildebeest (*Connochaetes taurinus*)	893	1735	1904	1626
Burchell's Zebra (*Equus burchellii*)		711	863	1031
Eland (*Taurotragus oryx*)		854	553	1154
Giraffe (*Giraffa camelopardalis*)		51	55	218
Kudu (*Tragelaphus strepsiceros*)		650	312	580
Waterbuck (*Kobus ellipsiprymnus*)		43	35	138
Warthog (*Phacochoerus aethiopicus*)		233	85	345
Ostrich (*Struthio camelus*)		275	194	202
Elephants (*Loxodonta africana africana*)	290	767	564	957

Presently lions are mainly confined to the west bank of the Shashe River, which is in the Tuli Circle Safari Area in Zimbabwe and the Northern Tuli Game Reserve in Botswana (CESVI 2001).

High numbers of livestock (cattle, goats, sheep and donkeys) can be observed within the communal areas in Botswana and Zimbabwe.

HISTORY

According to Voigt (1983) the Limpopo Valley has been occupied by iron-age people since 800 AD. Prior to this stone-age people were present in the area in smaller numbers (McKenzie 1986). The Babirwa intensively settled the area until 1926, with the densest settlement occurring in the south-central region (Molelu 1985 as quoted by McKenzie 1990). These settlements were accompanied by large numbers of domestic stock as evidenced by the remains of kraals, which can still be found in the reserve today (McKenzie 1987).

In 1891 Fort Tuli was established in what is today called the Tuli Circle in Zimbabwe. King Khama granted a concession to the Rhodes Charter Company. Native cattle were to be kept clear of the area within a radius of approximately 16 km from the Fort in order to protect the trek oxen from lung sickness, which was rife among the Bamangwato herds.

In 1896, a concession was granted to Cecil John Rhodes' British South African Company for a strip of land on the west bank of the Limpopo River, extending from Mafekeng to the Zimbabwean border. The proposed Cape to Cairo railway line was to run along the strip's western border, whilst the remainder was divided into farms to form a buffer against expansion of the then Transvaal Republic into Bechuanaland. The line was later rerouted further inland, but the farms remained freehold property (Lind 1973). The strip is today known as the Tuli Block.

Human numbers were low in the area from the turn of the century until about 1950 when they increased slowly in the area surrounding the Northern Tuli Game Reserve. In the late 1960's and early 1970's landholders in the Northern Tuli Game Reserve formed a consortium to conserve the wildlife in the area, and a number of commercial tourism ventures started (Feely 1975).

From the late 1880's to the 1960's periodic attempts at cattle ranching have been made in the area, with disastrous results on the vegetation (Lind 1973). According to Varty (1982), in the heyday of the Rhodesian Charter Company, 140 000 head of cattle used the North Eastern Tuli Block area, and today the devastating effects of those herds are being felt (King 1984). The once productive grasslands are gone, as well as the once numerous wild animal species such as sable antelope, roan antelope, reedbuck (*Redunca arundinum*), gemsbok (*Oryx gazella*), red hartebeest (*Alcelaphus buselaphus*), white rhinoceros (*Ceratotherium simum*), black rhinoceros (*Diceros bicornis*), cape buffalo (*Syncerus caffer*) and nyalas (*Tragelaphus angasii*) (King 1984).

LAND TENURE, SETTLEMENT AND LAND USE

In Botswana the area along the Limpopo River consists of a number of adjoining farms, which forms an area known as the Tuli Block. The whole block is about 320 km long and except for the Baines Drift and Seleka Government Reserves, the entire block is freehold land. There are 103 major divisions or farms of which some are further subdivided into portions (Nchunga 1978) (Figure 6 and 7). The Northern Tuli Game Reserve forms the most eastern section of the Tuli Block and covers an area of approximately 77 000 ha bounded by the Limpopo, Motloutse and Shashe rivers (Figure 7).

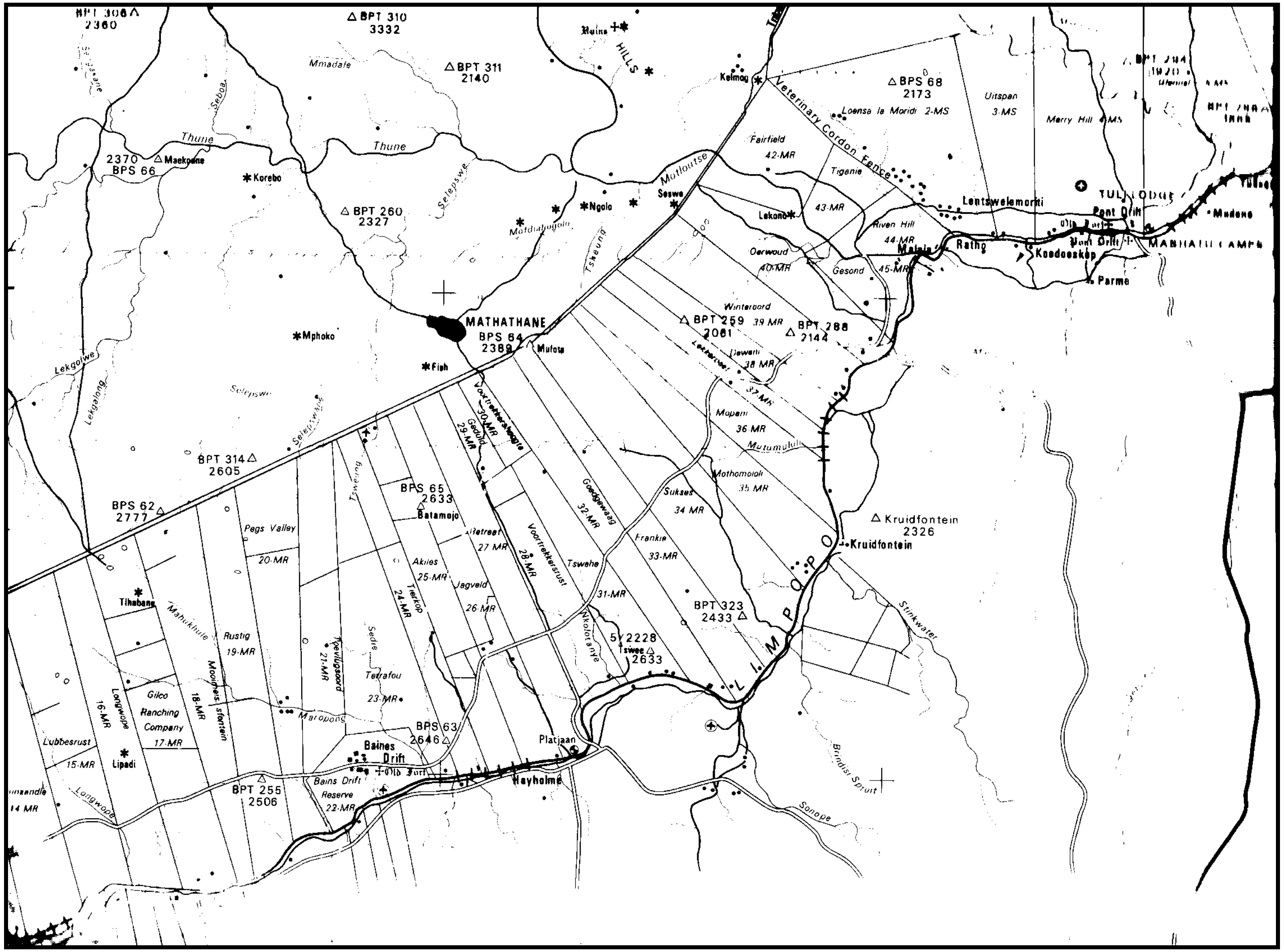

Figure 6: Central Tuli Block farm boundaries north east to the farms on the Motloutse River

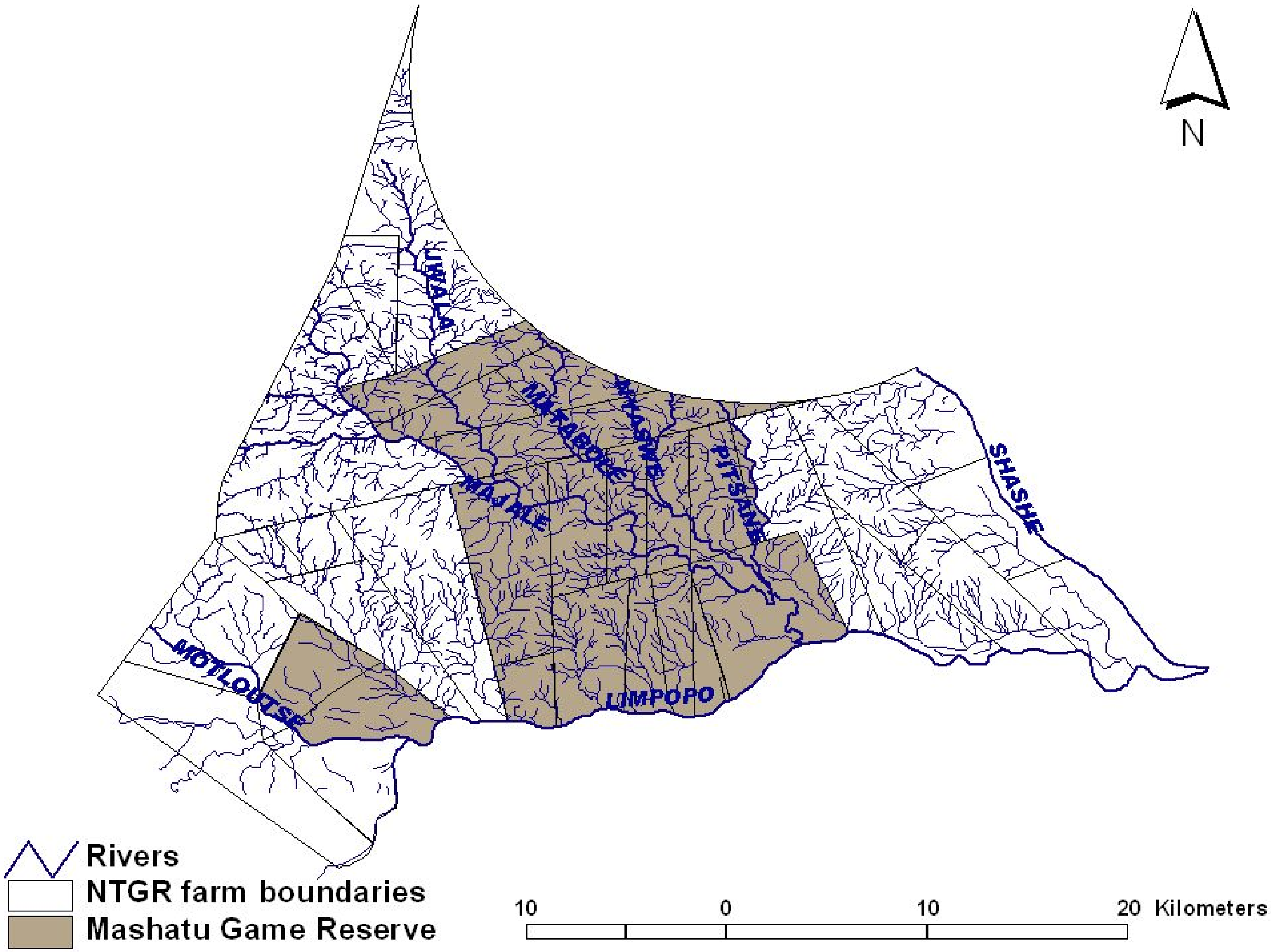

Figure 7: Farm boundaries in the Northern Tuli Game Reserve

The Eastern Tuli Block farms extend to the south west of the Northern Tuli Game Reserve. These farms are privately owned. Use ranges from game ranching and hunting to cattle and crop farming. Access to these farms is relatively unrestricted although there are cattle fences separating some of the properties. The cattle fences are however in disrepair. Terrafo, a property of 4 300 ha close to Baines Drift is completely fenced off with an electrified game fence. A section of approximately 400 ha along the Limpopo River are unfenced. An agricultural holding on the banks of the Motloutse River close to the Northern Tuli Game Reserve namely Talana Farm is also fenced with an electrified game fence.

North and north west of the Northern Tuli Game Reserve is communal land. The boundary between the reserve and communal land within Botswana is fenced. The fence along the western boundary of the Northern Tuli Game Reserve is an electrified game fence joined to a double veterinary fence along the Shashe River to the north and an electrified game fence along the northern boundary of the Tuli Block. This has been a recent development. Prior to 2002 a double veterinary fence extended along the western boundary of the Northern Tuli Game Reserve. Land use in the communal areas consists of subsistence agriculture and livestock farming. People densities within the communal areas in Botswana vary from as little as 20 people at cattle posts spread out through the area to as many as 10 000 people in the larger towns (Table 5). An electrified double foot-and-mouth veterinary fence runs along the Shashe River in the north of the study area in Botswana. Recently this fence has been upgraded to an electrified game fence. Several communities occur along the Shashe River within Botswana, while the section on the Zimbabwean side is scarcely populated.

Table 5: Towns and estimated people densities in the communal areas of Botswana and Zimbabwe in a radius of approximately 100 km surrounding the Northern Tuli Game Reserve (Lahmeyer 2004; CESVI 2001)

Town	People Density
Botswana	
Bobonong	>10000
Gobojango	1000-3000
Lentswe le Moriti	250-500
Lepokole	250-500
Mabuhwe	500-1000
Madikgaka	<100
Madiope Cattle Post	>100
Majale Cattle Post	>100
Manyohnoye Cattle Post	<100
Mathathane	3000-5000
Matsaganeng Cattle Post	<100
Mmadinari	5000-10000
Mohlabaneng	3000-5000
Molalatau	3000-5000
Robelela	1000-3000
Sefophwe	1000-3000
Selebi-Phikwe	50000
Semolale	3000-5000
Tobane	1000-3000
Tshokwe	500-1000
Zimbabwe	
Machuchuta	2000 - 3000
Maramani	5000-10000
Masera	2000 - 3000
River Ranch	200

The Tuli Circle area of Zimbabwe occurs to the north of the Northern Tuli Game Reserve (Figure 2). This is a semi-circle of 50 000 ha, managed by the Zimbabwean National Parks and Wildlife Department as a controlled hunting area for Zimbabwean citizens. The area is unfenced apart from the western boundary with Botswana where a double foot-and-mouth veterinary fence exists.

The area to the east of the Shashe River consists of communal land and privately owned hunting farms (Sentinel Ranch and Nottingham Estate) bounded in the south by the Limpopo River (Figure 2). The western and northern boundaries of Sentinel Ranch and Nottingham Estate are the Maramani and Masera communal lands and the eastern boundary is resettled state land that was formerly known as River Ranch. Subsistence and stock farming occurs in these areas. On the eastern side of the Shashe River is a 6 km strip of communal land called Maramani. The property is approximately 49 000 ha with approximately 5200 people occupying the area (CESVI 2001). An unknown number of livestock occur within the area. Several irrigation schemes occur along the Shashe River but none are currently operational (CESVI 2001). A game fence forms the boundary with Sentinel Ranch to the east of Maramani. North of Maramani lies another communal area named Machuchuta. This is an area of 76 000 ha with a frontage on the Shashe River opposite the Tuli Circle. A high density of people and livestock occur in the area. Two relatively efficient irrigation schemes are operational in the community. Masera is located east of Machuchuta and north of Sentinel Ranch and Nottingham Estate. This area is 34 000 ha in size with a high density of people and livestock. The boundary between Sentinel Ranch and Nottingham Estate with both Masera and Machuchuta are fenced with a cattle fence.

Sentinel Ranch to the east of Maramani is a privately owned game farm. Livestock has been removed from the farm in the 1980’s. A 2000 ha strip along the northern edge of the property is fenced and used for commercial cattle ranching. A section of 8000 ha to the south west of the property is used for eco tourism while the rest of the property is used for safari hunting. Sentinel Ranch adjoins Nottingham Estate to the east. This is a property of 25 000 ha of which 3000 ha along the Limpopo River is used for intensive irrigated farming of citrus and fenced off with an electrified game fence. A large dam was built on the north-centre section of the property as a means to irrigate. The rest of the property is used for safari hunting and livestock farming. Elephants are still hunted on both the properties.

River Ranch, an area of 17 000 ha adjoins Nottingham Estate to the east. It is resettled state land and allocated to two communities for livestock grazing (CESVI 2001). Currently 16 families have settled on the property (CESVI 2001). Elephant hunting continues in the communal areas to the north, east and west of Sentinel Ranch and Nottingham Estate as part of the Communal Areas management Programme for Indigenous Resources (CAMPFIRE).

From the southern boundary of the Northern Tuli Game Reserve and the remainder of the Tuli Block movement across the Limpopo River is restricted by a military and veterinary fence on the South African bank of the river (Figure 8). In addition the farms on the South African side are relatively well fenced. Opposite the confluence of the Shashe and Limpopo rivers the Mapungubwe National Park is found. The borders between Botswana, Zimbabwe and South Africa are fenced with a four strand electrified cattle fence in this section. Several hunting farms, game ranches and commercial crop farms occur along the Limpopo River on the South African side.

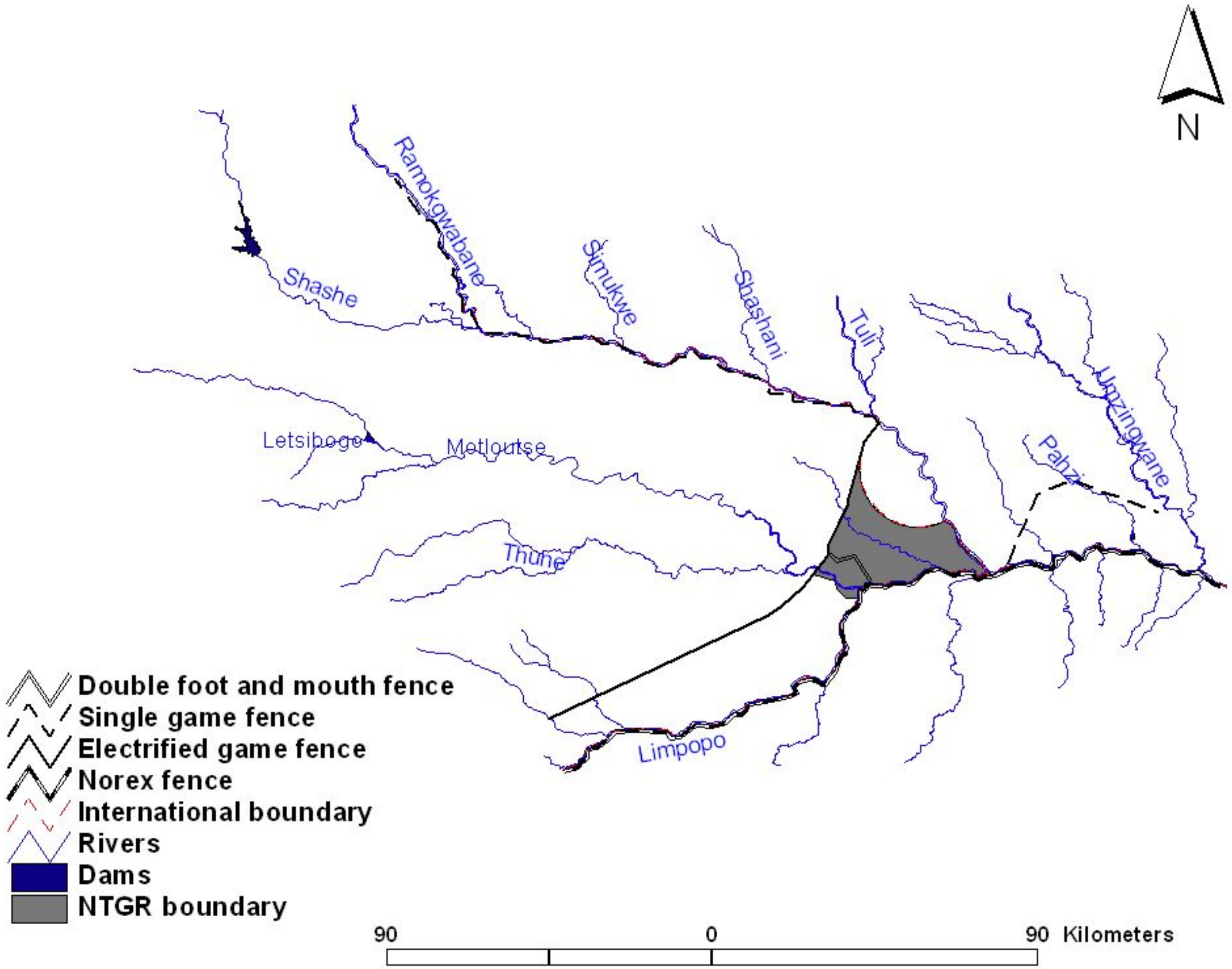

Figure 8: Location and types of fences within the Central Limpopo River Valley study area

ECONOMIC/COMMERCIAL ACTIVITIES

The environment in this area is generally hostile to conventional development based on farming. The only farming potential is through irrigated farming of the alluvial soil pockets lining the main rivers. Livestock farming is also marginal, the overall sustainable stocking rate being estimated at about one livestock unit per 30 hectares, but again liable to frequent losses due to drought. After decades of unsuccessful livestock ranching, the great majority of commercial estates in the area, in all three countries, have removed all livestock and turned the land over to commercial game ranching, although some retain arable pockets under irrigation (CESVI 2001).

The communal lands in western Beitbridge District, comprising Maramani, Machuchuta and Masera wards (Figure 9), are among the poorest in Zimbabwe. Rain-fed farming is highly unreliable, while three small scale irrigation schemes along the Shashe River support less than three hundred families, while the largest scheme is currently not operational due to flood damage and lack of maintenance. The grazing lands are overstocked and rely heavily on relief grazing elsewhere, while most of the livestock is concentrated in few hands. The principal sources of livelihood for these communities are illegal, including “border jumping” for employment in South Africa, brewing palm wine and stream bank cultivation (CESVI 2001).

The Northern Tuli Game Reserve is utilised for photographic safaris – both private and commercial. The most intensively utilised area is the south central region, which is utilised by the commercial enterprise Mashatu Game Reserve as well as by visitors to the Gilfillan properties in this area (McKenzie 1990). Utilisation is most exclusively in the form of game drives in open four-wheel-drive vehicles.

Hunting by Vira Safaris ceased in the Northern Tuli Game Reserve in 1987 (McKenzie 1990). The only remaining consumptive activity within the reserve is the utilisation of impala and kudu by the commercial lodges and for staff rations. Within the Central Tuli Block a number of private ranches are managed wholly or partially for wildlife. Bow hunting of plains game is undertaken on several of these farms.

Hunting of game is currently practised in the Tuli Safari Area, Nottingham Estate and Sentinel Ranch in Zimbabwe as well as on certain farms on the Limpopo River in South Africa.

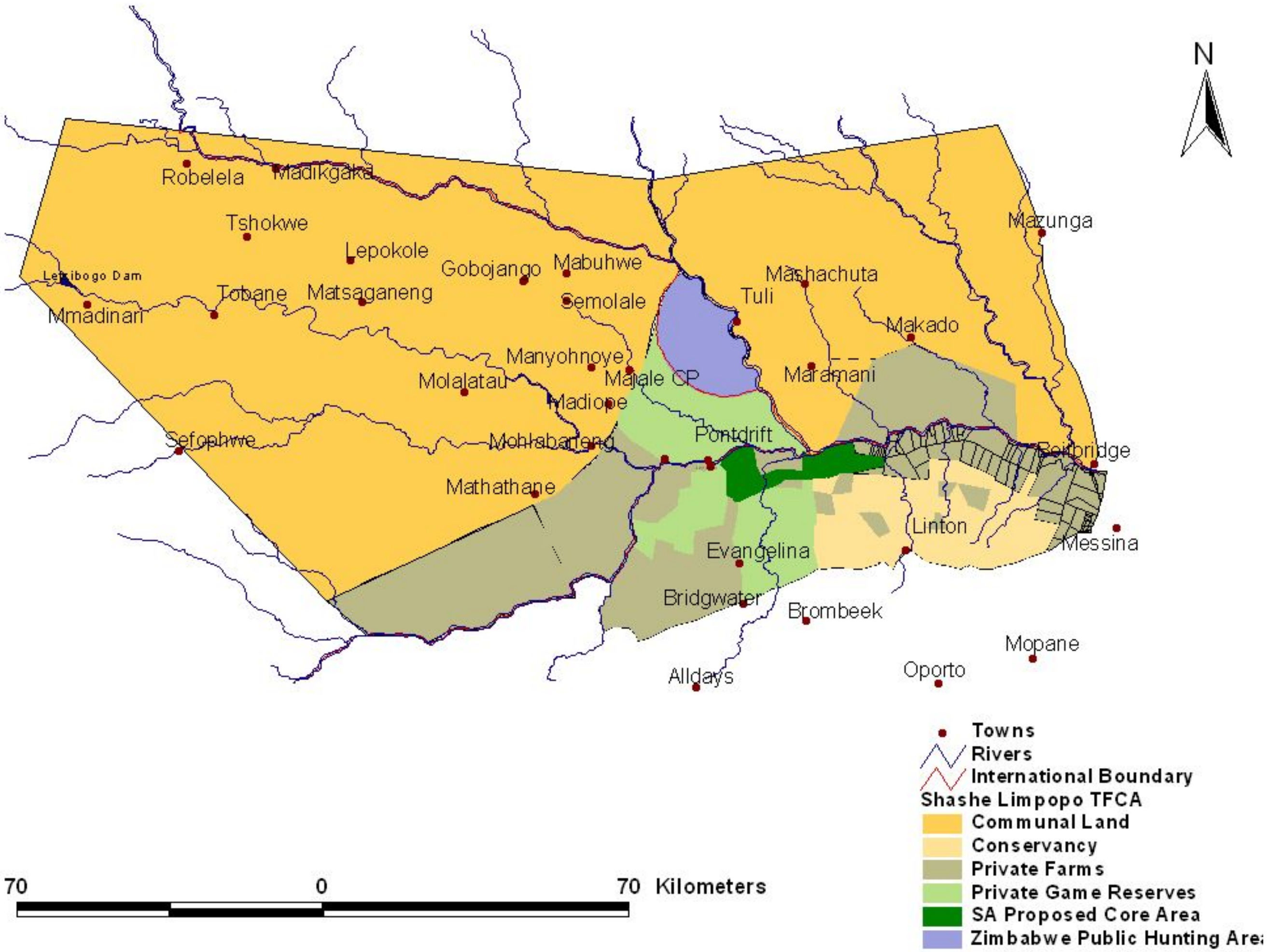

Figure 9: Land use within the Central Limpopo River Valley study area

In addition to wildlife and scenery, the area has a great wealth in terms of archaeology and cultural tourism. The sandstones near the Limpopo River have yielded rich deposits of fossils, dating to the age of reptiles and amphibian. Secondly there are large numbers of pre-iron age rock painting sites, also mainly in the sandstones. There are also important sites belonging to the civilisations of the Early Iron Age. Prior to about 1100 AD, the area evidently had a much wetter climate than it has today, was the centre of a developed culture, with a of stone walled structures and important artefacts in iron and gold (Voigt 1983).

The Mapungubwe National Park is situated on the South African side of the confluence of the Shashe and Limpopo Rivers. The cultural importance of the archaeological treasures of the park resulted in it being declared a World Heritage Site in 2003. The artefacts found at this site rank amongst the most important pieces of ancient art yet found in sub-Saharan Africa (Maphasa and Bester 2001). The National Park is utilised for eco tourism purposes and is ear marked as the core area for the proposed Shashe/Limpopo Trans Frontier Conservation Area (Maphasa and Bester 2001).

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DETERMINATION OF THE RANGE AND NUMBERS OF THE CENTRAL LIMPOPO RIVER VALLEY ELEPHANT POPULATION

INTRODUCTION

The Central Limpopo River Valley elephant *Loxodonta africana* population is the last free ranging, flourishing elephant population on private land south of the Zambezi River.

Regular aerial censuses of the elephant population in the Northern Tuli Game Reserve have been undertaken since 1976. Data from the aerial counts show that in the Northern Tuli Game Reserve area elephant numbers fluctuate between different months in the same year as well as between different years (Table 6). The elephant numbers fluctuated between zero (though this is very unusual and only recorded once in November 1979) and 767 (September 1997). Clearly fluctuations of this magnitude were a consequence of movement into and out of the Northern Tuli Game Reserve and not birth and mortality, but it was unknown where the animals went to or came from.

OBJECTIVES

The objectives of this study was to determine

1. The past and present range of the population
2. The size and distribution of the Central Limpopo Valley elephant population
3. Preliminary estimates of the range and numbers of mature bulls

LITERATURE STUDY

Historically the African elephant was distributed widely over the African continent from Cape Town to the fringe of the Sahara (Ebedes, *et al.* 1991). The elephant is still represented today through much of this region, although its distribution has become somewhat fragmented.

It is only due to the interference of man that the elephant's distribution range became restricted (Viljoen 1991). Up to 1982 the distribution of elephants in the then Transvaal province was confined to the Kruger National Park and a small population on the border of the Transvaal, Zimbabwe and Botswana at the confluence of the Limpopo and Shashe Rivers (Rautenbach 1982).

Table 6: Aerial census data of the Northern Tuli Game Reserve from 1976-2004. Data from 1976 – 1997 obtained from Le Roux (1997). A 10% correction factor was used.

Date	**2004** Oct	**2001** 27-29 Jul	**2000** 3-6 Aug	**1999** May	**1997** Sep	**1996** Sep	**1995** Aug	**1993** 23-26 Jul	**1991** 30-Jul	**1989** 30-Jul	**1988** 18-19 Sep	**1988**	**1987** 2-3 Dec	**1986** 10-11 Oct	**1984** Sep	**1983** Jul	**1978** Jun	**1977** Mar	**1976** Oct	**1976** Jun	**AVE**
Total Counted	291	877	512	508	690	264	392	680	627	406	617	598	258	576	567	327	277	190	590	443	485
Corrected Total	320	965	563	559	766	290	431	748	696	451	685	658	284	634	625	400	311	213	663	498	538

Elephant distribution is governed by the distribution of both past and present human settlement, even in the remotest and least disturbed forests of equatorial Africa (Barnes *et al.* 1991). There is one general feature having a more pervasive influence on animal populations. This is the presence of a boundary demarcating the area within the sanctuary from the land without. The division may be in the form of a physical barrier, such as the fences enclosing Kruger National Park (Owen-Smith 1983). In other parts of Africa, the demarcation may be little more than a line drawn on a map. But, vague though such lines may have been in the past, their effects are becoming increasingly apparent through the contrast in the human activities conducted within and outside these boundaries: expanding human settlements and uncontrolled hunting on the one side, more or less limited poaching on the other. Thus, even where there is no physical barrier, the effects on animal movements are similar; excursions beyond the sanctuary area are inhibited or deflected back (Owen-Smith 1983). Looking ahead, all wildlife reserves are destined to become ecological islands in a sea of man-modified landscapes (Owen-Smith 1983).

There are no records of the occurrence of elephants in the Central Limpopo Valley region from about 100 years ago until about 1945 (Page, pers. comm.)[2]. Archaeological evidence from the Mapungubwe site suggests that they occurred in the region at the time that Mapungubwe was active from 950 to 1150 AD (Voigt 1983). It is probable however, that elephants occurred in the region, but were shot out between the early 1800's and the 1940's as was the case in almost all of Southern Africa (Pienaar *et al.* 1966; Hall-Martin 1987). From the 1940's onwards the region that is now the Northern Tuli Game Reserve appear to have formed the core of the elephant population range (Walker 1971).

At this time the first estimates of the number of elephants in the Northern Tuli Game Reserve were made. Peacock (undated), Lind and Stephan (1974), and Lind Undated as quoted by Page (1980) reported 1200 elephants in the area. No details were given on how widely these elephants ranged. The first aerial surveys of the Northern Tuli Game Reserve were conducted in June 1976, which counted 498 elephant in the area (Walker (1976a) as quoted by Page 1980).

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[2] Page, B. R. School of Biological and Conservation Sciences, University of KwaZulu-Natal, Durban. Personal communication.

In 1976 a study on the determinants of the carrying capacity of the Northern Tuli Game Reserve for elephants was initiated. Several reports emanated from this study, which quantified the impact of elephants on the woody vegetation (Page 1980).

Data from fourteen counts carried out in the Northern Tuli Game Reserve show that elephant numbers fluctuate between different months in the same year as well as between different years of the same month (Table 6). Analysis by Cheney (1998) suggests that the changes in numbers were a consequence of movements that appeared to be related to rainfall in the region, but the trends were not clear.

Feely (1975) defined the home range of the Central Limpopo Valley elephant population as bounded by the Shashe River on the north-east, Limpopo River on the south, a line some 50 km west of and parallel to the Shashe River and in the north a line approximately 21º30' S latitude. Joubert (1984) described the Northern Tuli Game Reserve as an area that represents a relative small relict of what was once a vast ecosystem. It would appear that the elephants of the Northern Tuli Game Reserve largely represent a "compressed" population that has found a sanctuary in this area from harassments suffered in surrounding areas.

Page (1980) suggested that there was a marked skew in the adult male: adult female ratio (1:3.9). Hall-Martin (1987) calculated a ratio of 1:3. Elephants have been shot in the area regularly since they first appeared. Where crop raiding occurred both males and females were shot, but more frequently males. There has been regular hunting of bulls in the Tuli controlled hunting area in Zimbabwe (Walker 1971). The annual increment of the elephants is estimated to be 5%, with an average inter-calving period of 4 years, depending on habitat and climatic conditions (Garaï, pers. comm.)[3]. This would imply that the population should be growing by that percentage, however it appears that in general the number of elephants utilising the Northern Tuli Game Reserve are mainly stable, with seasonal variation (Garaï, pers. comm.)[2].

This indicates that elephants move out of the Northern Tuli Game Reserve and most likely settle into new areas, as is supported by reports from Zimbabwe (Le Roux, pers. comm.) [4], where elephants are now seen in areas where they were absent in the past. However, reportedly elephants also move into the Northern Tuli Game

[3] Dr. Marion Garaï, Chairman, Elephant Management and Owners Association, Vaalwater 0530. Personal communication.
[4] Mr. Pete Le Roux, Operations Director, Mashatu Game Reserve, Eastern Tuli Block, Botswana. Personal communication.

Reserve from across the Shashe River in Zimbabwe.

The numbers of animals and their occupancy is of fundamental importance to wildlife management (Ottichilo 1999). Elephant census techniques fall into two classes. The first comprises of those surveys where the elephants themselves are counted. These are "direct counts". Indirect counts include surveys where signs of elephants (dung piles, tracks, feeding signs) are counted (Kangwana 1996).

Direct counts of elephants can either be carried out from the air or from the ground. In savannah habitats aerial counts remain the most effective means of elephant census (Douglas-Hamilton, Hillman and Moss 1981). There are two kinds of aerial counts: total counts and sample counts. With total counts the assumptions are made that the whole area is searched, that all groups of animals are located and that all groups are counted correctly (Norton-Griffiths 1978; Sutherland 1996). With sample counts only a sample of the designated area is searched and counted, and the number of animals in the whole area is then estimated from the number counted in the sample area. The same three assumptions are made about searching, locating and counting all the animals in the sampled area, and an additional assumption is made that if, for example, 25% of the total area is counted then it will contain exactly 25% of the animals (Norton-Griffiths 1978).

Ground counts from vehicles are practical and give excellent and consistent results in small to medium sized areas where the area can be traversed by vehicles, and where the vegetation is reasonably open and the animals used to vehicles (Norton-Griffiths 1978). Ground counts are also beneficial for obtaining data on seasonal patterns of distribution within different vegetation types, and much additional information can be obtained on the behaviour and condition of the animals that cannot be obtained from an aeroplane (Norton-Griffiths 1978). Ground observations, however, in a survey requiring data on many elephants at the same time, may be unreliable in the light of visibility problems (Croze 1972; Eltringham 1972; Norton-Griffiths 1978) and subjectivity in assigning ages to animals (Croze 1972).

The light aeroplane is now widely used for wildlife censuses and surveys. Reliable and consistent results can be obtained as long as some straightforward precautions are taken and as long as qualified crews carry out the census. It can cover large areas quickly and economically, and it is the only method for censusing in areas where access on the ground is difficult or impossible (Bothma 1995; Norton-Griffiths

1978). Its use only becomes limited when the vegetation is so thick that the animals cannot be seen from the air, or if the animals concerned are very small (Norton-Griffiths 1978).

Total aerial counts are expensive (Croze 1972; Norton-Griffiths 1978; Sutherland 1996), cumbersome and give only a minimum estimate with no limits of accuracy (Croze 1972; Norton-Griffiths 1978). Although the use of sample plots, or strips, provide statistically reliable counts at relatively low cost, such techniques allow for no observations on distribution and migration (Buss, 1990; Croze 1972). Problems have been partially solved by the advent of growth curves (Croze 1972).

Populations of the elephant *Loxodonta africana* are regularly counted from the air (Field 1971) and indeed this method is often the only practical one for obtaining an estimate of numbers (Eltringham 1972; Ricciuti 1980). Several causes of error are apparent including the movement of animals between successive flights from a counted area into an uncounted one or *vice versa* (Norton-Griffiths 1978; Sutherland 1996). However, another source of error results from inaccuracies in counting (Eltringham 1972). Even so Eltringham (1972) concluded that aerial survey is the most efficient way of counting elephants in the Queen Elizabeth National Park.

A typical method for counting elephants over large expanses of savannah is to fly back and forth in straight, regularly spaced transects. The elephants are easy to spot from a low-flying aeroplane (Douglas-Hamilton 1972; Norton-Griffiths 1978; Ricciuti 1980). Observers in the rear of the aeroplane note the animals only when seen within strips of ground demarcated by rods fixed to the aeroplane's struts (Norton-Griffiths 1978; Ricciuti 1980). From these totals the densities of elephant populations in different areas can be calculated (Ricciuti 1980).

METHODS

At the start of this study no information was available regarding the range of the elephants that occurred in the Central Limpopo Valley. The distribution and size of the population was determined using three approaches. (i) A literature review, postal survey (Appendix A) and interviews with people (Appendix B) to determine where elephants occurred in the study area, the region between 21º 00' and 22º 30' south and 27º 15' and 30º 00 east. (ii) The recording of signs such as broken branches, spoor and elephant dung whilst driving through or flying over the study area. (iii) Three aerial counts of the range of the population identified in (i) and (ii). In addition the numbers of free ranging bulls was estimated using a capture recapture technique.

Determination of the range of the Central Limpopo River Valley elephant population from literature, postal surveys and interviews

A questionnaire (Appendix A) was sent out to all the landowners in the Tuli area while interviews were conducted with local communities in Botswana, South Africa and Zimbabwe using a similar questionnaire (Appendix B).

Aerial counts of the Central Limpopo River Valley elephant population

Three total aerial counts were conducted, over the range previously identified. The counts were carried out during August 2000, July 2001 and October 2004.

Three aeroplanes were used to carry out a simultaneous count of the previously identified range in the three different countries. Each country, which was censused sequentially over two days, was divided into several blocks. Adjacent blocks in the different countries were flown simultaneously to prevent double counting of elephants moving from one block to another. One aeroplane was responsible for counting the Zimbabwean component, one the South African component and one the Botswana component.

In Botswana the entire Tuli Block from the Shashe River in the east to Baines Drift in the west was surveyed. This included the bed of the Limpopo River. In the vicinity of the Northern Tuli Game Reserve the survey extended to about 1 km west of the back-line fence. East of the Motloutse River it extended to a line about 10 km north of and parallel to the back-line fence. In Zimbabwe the entire area bounded by the Shashe River to the west, the Umzingwane River in the east, the Limpopo River in the south and the 22º 00’ S latitude line in the north was covered. In South Africa a 10 km belt parallel to the Limpopo River was surveyed from Beitbridge to Baines Drift. In addition the portions of the major rivers (Motloutse and Shashe) not covered in the above sections, were surveyed to a distance of 2 km either side of the river.

Within the communal areas of Botswana transects were flown on both banks of the Motloutse River to the Letsibogo Dam. On these transects spoor in the riverbed was recorded. Within the vicinity of the Letsibogo Dam several transects of about 4 km long were flown north to south. In addition one transect was flown up from Letsibogo dam to the Shashe River close to the Shashe Dam. Three transects were flown along the Shashe River, one on the Botswana bank and two on the Zimbabwe bank from the Tuli Circle to the Shashe Dam. The Tuli River was flown from the confluence with the Shashe River to some 25 km upstream. On transects along the major rivers spoor in the riverbed was recorded.

Flight strips of 1km in width (500 m each side) were used in open vegetation, but in riverine areas the width was decreased to 250 m on each side. Each transect was systematically searched at a height of 100 m to 150 m. The flight lines ran roughly parallel to the Shashe River (roughly north – south) in Botswana and Zimbabwe and parallel to the Limpopo River (roughly east – west) in South Africa. The counting team, all with previous experience in animal counting, consisted of the pilot, a navigator and four counters. Flying was restricted to early morning from 07h00 to 10h00 and late afternoon from 16h00 to 18h30. Flight times, altitude and speed were recorded for each block. Observers were instructed to count all groups and the numbers, locations, habitat of all elephants was recorded and plotted on a 1:250 000 Geographical interface system's map of the area.

Data obtained from the total aerial counts conducted within the Northern Tuli Game Reserve were digitised using the computer program ArcView 3.2. A Kernel analysis was performed on the data to determine the distribution of the elephants within the Northern Tuli Game Reserve.

Three separate counts of Mapungubwe National Park and the South African National Parks properties within South Africa was conducted by the South African National Parks during 2001, 2002 and 2003 respectively. The count in 2001 was a ground count, while the counts in 2002 and 2003 were aerial counts conducted from a helicopter.

Estimation of bull numbers within the Central Limpopo River Valley elephant population

The ear-print identification technique enables one to estimate the numbers of bulls using a multiple capture-recapture technique (Croze 1974). Once an animal's ear-prints are recorded through photographing the elephant it may be considered to have been "captured" and "marked", and when resighted the elephant is "recaptured" (Croze 1974). It was assumed for the purposes of this study that bulls ranged freely over the entire range. This postulate was tested as part of the study.

RESULTS AND DISCUSSION

Range of the Central Limpopo River Valley elephant population

The literature survey indicated that elephants were present in a region bounded by 21°00’ to 22°40’ south latitude and 27°15’ to 30°00’ east longitude.

The distributions encountered during the three aerial surveys of the region identified from the initial surveys were very similar. Figure 10 indicating that, for the midwinter season at least, distribution appears to be reasonably constant.

Comparison of the distribution of rural households, villages, farmsteads, with the distribution of the elephants indicate that elephants are avoiding areas with high human densities (Figure 11). Fencing and the presence of steep riverbanks further appear to be influencing the elephant distribution (Figure 11).

Numbers and population distribution of the Central Limpopo River Valley elephant population

The distribution of the elephants between all counts was similar, with the bulk of the elephants concentrated in areas with low human densities (Figure 11). The total number of elephants counted in the study area was 1388 in 2000, 1424 in 2001 and 1339 in 2004. A 10% correction factor was used based on a comparison of aerial photographs and the count from the aircraft of the photographed group.

Kernel analysis applied to the distributions suggests that there are at least three and possibly four sub groups within the population, at least during the dry season (Figure 12). The distributions in the Tuli Block farms west of the Motloutse River to Baines Drift (BDMRF) and the Northern Tuli Game Reserve (NTGR) suggest that this may be a continuous group that is closely linked. However for the reasons outlined below it is thought that at least some family units might be permanently resident in this locality.

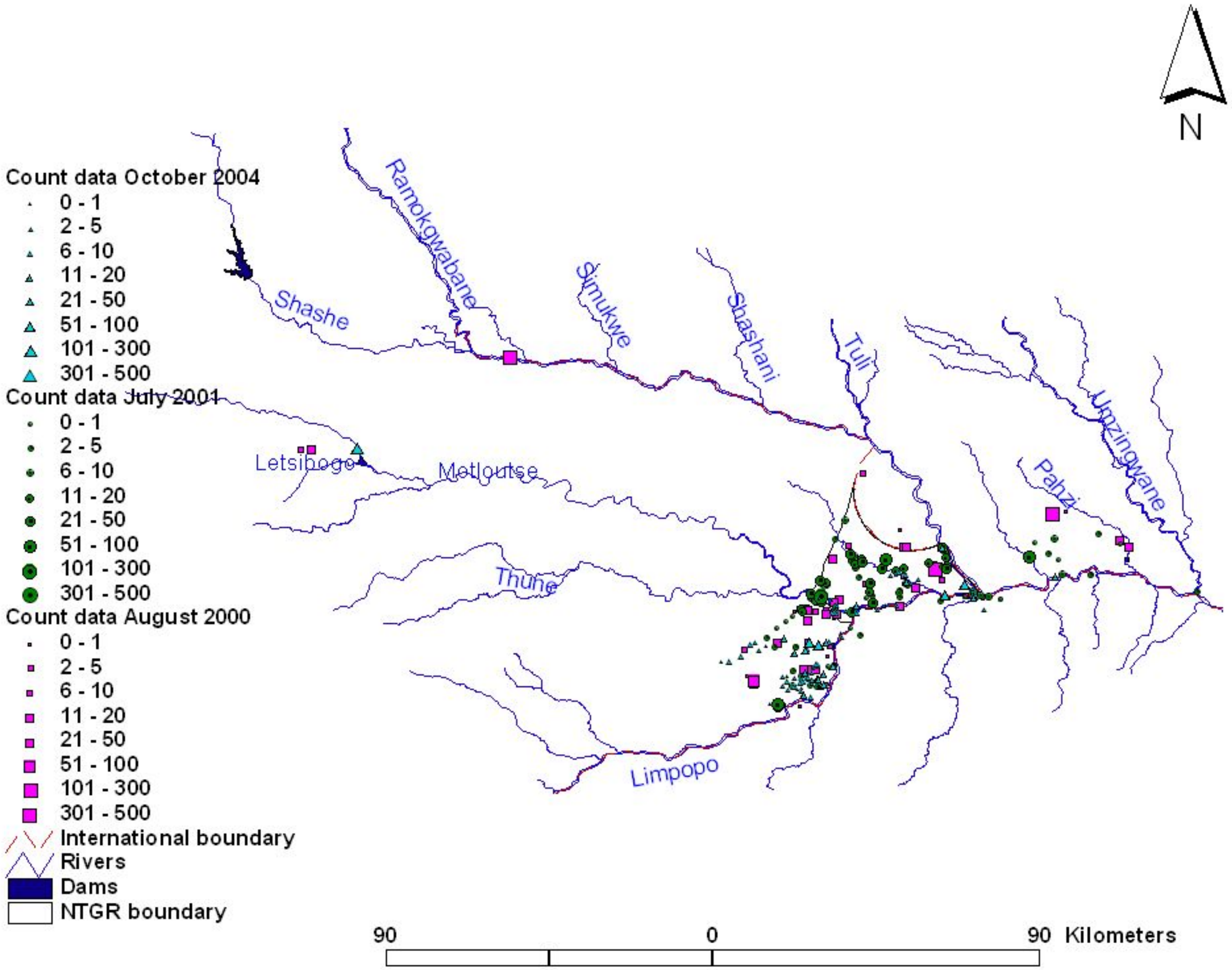

Figure 10: Comparison of elephant distribution between three total aerial counts conducted in the Central Limpopo River Valley

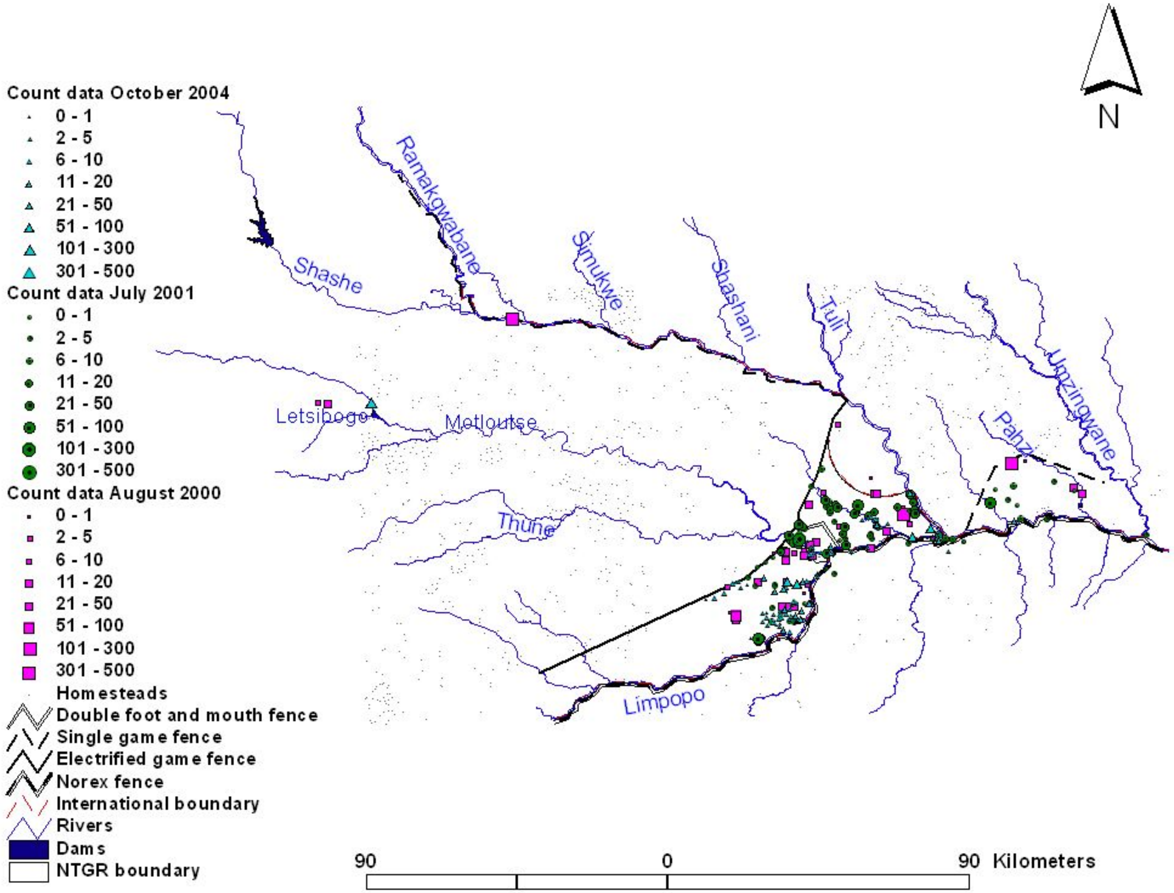

Figure 11: Comparison of the human distribution to the elephant distribution for the three total aerial counts conducted in the Central Limpopo River Valley

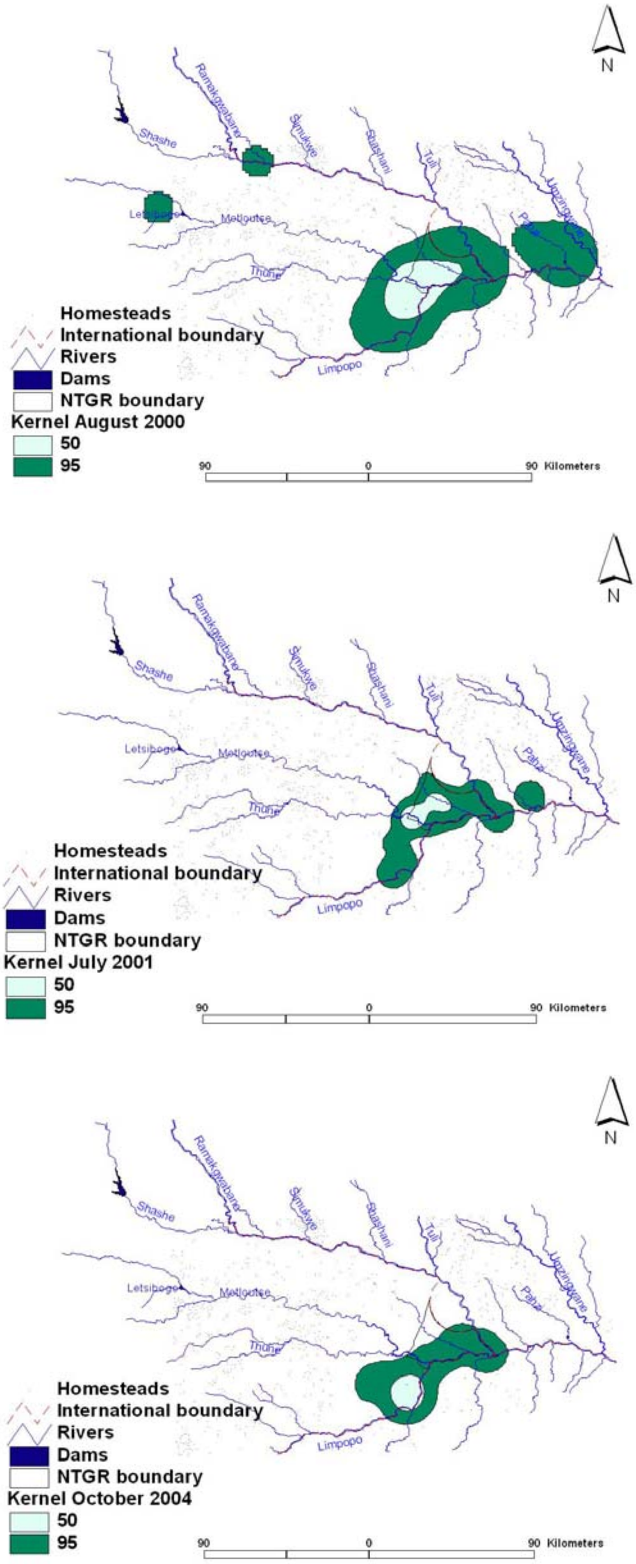

Figure 12: Kernel analysis of the three total aerial counts indicating the different sub groups in the population

Figure 12 indicates that there are at least three and possibly four regions with high elephant densities separated by areas with lower densities that are constant between the three years. These are 1. A grouping between the Motloutse and the Shashe rivers that occurs north of the Limpopo River in the Northern Tuli Game Reserve (NTGR) and into the Tuli Safari Area (TSA), as well as south of the Limpopo River in the Mapungubwe National Park (MNP) and on other farms on the South African bank opposite the NTGR. 2. A grouping in an area referred to as the Baines Drift – Motloutse River Farms (BDMRF) made up of farms in the Tuli Block, Botswana, west of the Motloutse River to Baines Drift. 3. A grouping around the Letsibogo Dam and northern Shashe River (LDNS). 4. A grouping on Sentinel Ranch, Nottingham Estate and River Ranch in Zimbabwe referred to as the Sentinel-Nottingham-River Ranch Complex (SNRC).

Table 7 gives the numbers involved in each of the sub groups. Whilst core areas are suggested by the kernel method, the difference in numbers in the four regions suggests that there is considerable movement of animals between the four core areas (Figure 12 and Table 7).

Numbers in the Northern Tuli Game Reserve (NTGR) increased by 350 animals in 2001, while the number in the Baines Drift – Motloutse River Farms (BDMRF) decreased by 93 elephants. In all of the other localities the numbers decreased in the July 2001 count. This suggests that there is at least some movement of animals between the Northern Tuli Game Reserve and the surrounding area.

During the 2000 count the highest number of elephants counted within the Northern Tuli Game Reserve was along the Motloutse River area, while the highest number of elephants in 2004 were counted higher up in the Tuli Block close to Platjan. The Northern Tuli Game Reserve joins onto the rest of the Tuli Block and probably forms one unit due to movement of the elephants between the two sections, suggested by the differences in the three counts.

Table 7: Comparison of the results of the three total aerial counts of the Central Limpopo Valley elephant population

Subgroup	Locality	Total (Corrected)		
		Aug 00	Jul 01	Oct 04
Northern Tuli Game Reserve	Botswana - NTGR	**563**	**965**	**320**
	RSA - Mapungubwe - Greeffswald	0	11	2
	RSA - Mapungubwe - Schroda	0	0	0
	South Africa - Ratho	0	3	6
	South Africa - Den Staat	0	2	0
	South Africa - Samaria II	6	1	0
	Zimbabwe - Tuli Safari Area	63	0	0
		632	982	328
Baines Drift - Motlotuse River Tuli Block Farms	Botswana - Tuli Block	410	317	574
Sentinel-Nottingham - River Ranch Complex	Zimbabwe - Sentinel Ranch	165	101	22
	Zimbabwe - Nottingham Estate	22	13	0
	Zimbabwe - River Ranch	0	0	0
	Zimbabwe - Zhove Dam	0	0	250
		187	114	272
Letsibogo Dam - Northern Shashe	Shashe Riverine	132	11	0
	Botswna - Letsibogo Dam	28	0	165
	Botswana Communal Area	0	0	0
		160	11	165
TOTAL		**1388**	**1424**	**1339**

Movement between the Sentinel – Nottingham groups and the Northern Tuli Game Reserve is likely to be limited, as there is a fence on the western boundary of Sentinel Ranch and a high density of people in the Maramani area. There does however appear to be some movement. During the 2004 count only 22 elephants were counted within the area. After a ground survey by the Nottingham Estate scouts it was reported that a herd of between 200 and 300 elephants was seen at Zhove Dam approximately 50 km up the Umzingwane River. A week after the count the elephants were observed moving back towards Nottingham Estate (Ambler-Smith, pers. comm.)[5].

The low numbers of elephant in the South African section of the range is surprising as there are many reports of intensive damage to trees in the area of Mapungubwe National Park. Only bulls were encountered during the aerial surveys. However there are reports of female groups using the Mapungubwe National Park (Van Lente, pers. comm.)[6]. During the interviews local residents reported regular movement across the Limpopo River from both Zimbabwe and Botswana. The fence along most of the border between the Northern Tuli Game Reserve and South Africa is in a state of disrepair and in places e.g. on the boundary of the Mapungubwe National Park the military fence has been replaced by an electrified cattle fence. The riverbanks in most places are high (5 m +) and more or less vertical, with few cuttings or slides, which elephants could use. Human activity surrounding the National Park is also relatively high. This might account for the lack of elephants in the South African part of the range. A higher number of elephants were observed within the Limpopo riverine vegetation on the South African section in 2001 compared to the 2000 and 2004 (Table 7).

During two ground counts conducted on the 24th and 27th of July 2001, in Mapungubwe National Park, 52 and 46 elephants respectively were observed (Table 8). During the total aerial count (July 2001) nine elephants were counted on Greefswald. The results obtained for Greefswald during the ground counts indicated 18 and 22 bulls respectively. The results given for Kruitfontein are estimates.

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[5] Mr. C. Ambler-Smith. Manager Nottingham Estate, Zimbabwe. Personal communication November 2004.
[6] Mr. B. van Lente 2001. Warden Mapungubwe National Park, Limpopo Province, South African National Parks.

Table 8: Results of the ground count done by the South African National Parks on the 24th and 27th of July 2001

Area	24/07/01		27/07/01	
	Number	**Sex**	**Number**	**Sex**
Messina to Weipe	0		0	
Schroda	2	M	0	
Greefswald	22	M	18	M
Samaria	9	M	9	M
Den Staat	2	M	2	M
Tuscanen to Pontdrift	0		0	
Ratho	2	M	2	M
Kruitfontein*	15-25	F	15-25	F
Total	**52**		**46**	

* This figure is an estimate by farm manager and resident ranger

It is likely that at the time of the aerial count the herd had moved back across the Limpopo River into the Central Tuli Block in Botswana. This supports the argument of frequent movements of elephants across the Limpopo River in and out of South Africa. During 2002 the area known as the Vhembe gap and up to this point open to Botswana was closed off with a four-strand electrified fence preventing further elephant movements into South Africa from Botswana. During 2002 and 2003 two respective aerial counts were conducted on the South African National Parks properties. The results of the counts are presented in Table 9. The results indicate once again a low number of elephants within the South African section of the study area, most of which are bulls visiting the South African side.

The fact that no elephants were counted within the Tuli Circle during the 2001 and 2004 counts can probably be explained by disturbance from hunting.

Lind (1971) suggested that elephants used the Northern Tuli Game Reserve as a summer home range and moved into the communal areas to the west in Botswana [in winter] from the end of May to early December when large herds returned to the reserve. At this time (summer) elephants were seen mostly along the lower reaches of the Majale River and the junction of the Majale and Limpopo rivers. However, Feely (1975) claims the opposite, suggesting that herds moved to the Shashe – Limpopo River floodplains on the south eastern section of the reserve during March to October [winter]. He suggested that with the onset of the rains the concentrations of elephant dispersed northwest and was spread mainly throughout the Bamangwato area during November to February [summer]. The elephants then migrated to the Tribal areas north of the reserve and then back down the Motloutse River. A few herds were observed moving east crossing the Shashe River north of the Circle and were not seen returning to the reserve. Feely also suggested that hunting disturbances within the tribal areas increased since the 1970's, which resulted in much higher proportions of the population moving into the Tuli Block in winter (Feely 1975). This is in agreement with the present study.

Table 9: Results from the two aerial counts conducted in 2002 and 2003 in the South African National Parks properties

Date	Area 1 VDNP east (Schroda/Riedel/Greefswald)	Area 2 VDNP west (Samaria/Den Staat)
Sep 2002	24	26*
Sep 2003	25	12

* 25 elephants were walking in the Limpopo River on the Botswana side of the boundary fence. This means Area 2 only had one elephant.

From the postal surveys and interviews it appears that the elephants may have been absent from the area between the Lotsane and Motloutse Rivers from the late 1970's to the early 1990's when they started recolonising these areas. Elephants have only been utilising Mawana Nature Reserve (some 15 km down the Tuli Block from the Motloutse River) since 1992/3 (Baytopp, pers. comm.)[7]. Elephants are now seen all the way to Baines Drift and reports of elephants as far as the Zanzibar Border Post have been received.

The interviews also revealed that in 1991/2 a herd of approximately 200 elephants moved across the Shashe River from the Northern Tuli Game Reserve onto Sentinel Ranch (Bristow, pers. comm.)[8]. However elephants have been resident in the Sentinel Ranch – Nottingham Estate area, the original Dongola National Park in South Africa, since at least the early 1940's. Elephants have also been observed ranging northwest and northeast of Beitbridge for the last two to three years. Reports of elephant movements east of Beitbridge have also been received. This area however overlaps with the movements of elephants outside the Gona-re-Zhou National Park and the Kruger National Park.

There are elephant pathways that enter the communal areas of Machuchuta, Masera, Maramani and River Ranch from the Sentinel-Nottingham Estate area. Local residents reported crop raiding by elephants (CESVI 2001). Interviews revealed that elephants only enter these areas at night and return to the safety of the game farms in the early mornings (CESVI 2001). There seems to be no elephant movement through the Maramani Trust area to the Northern Tuli Game Reserve from Sentinel Ranch. Whilst elephants cross into the Maramani Trust Area from Sentinel Ranch no reports of crop raiding or elephant movements have been received from the central Maramani area. Also a fence runs along the western boundary of Sentinel Ranch separating Sentinel from the Maramani communal land. The fence, however is currently in disrepair. It seems likely that elephants cross from the Northern Tuli Game Reserve across the Shashe River into the Maramani Irrigation Scheme at night and return to the reserve the following morning. Movement along the Limpopo River between Sentinel Ranch and the Northern Tuli Game Reserve has been observed (pers. obs.).

[7] Mr. S Baytopp 2000. Manager Mawana Game Reserve, Tuli Block, Botswana.
[8] Mr. C Bristow 2000. Sentinel Ranch, Beitbridge District, Zimbabwe.

Elephants range freely into the Tuli Safari Area from the Northern Tuli Game Reserve. Elephant movements have been noted along the Shashe and Tuli rivers. Patterson (1999) reported that 180 – 200 elephants utilise the area along the Shashe, Tuli, Simukwe and Shashani rivers during the winter months from June onwards.

Regular reports of elephant crop raiding have been received from the communal areas along the Shashe River and around Letsibogo Dam north of Mmadinari in Botswana. The areas mainly affected are Robelela, Polometsi, Dikgatong and Madikgaka. During the 2004 count 165 elephants were counted in the vicinity of the dam. It seems likely that the elephants observed at Letsibogo Dam utilise an area around the dam and to the north, crossing into Zimbabwe on a regular basis. During the 2000 count only 28 elephants were counted in the vicinity of the dam, but 132 were counted to the northeast on the Shashe River. The Veterinary Department in Botswana indicated that elephants regularly break the veterinary fence along the Shashe River in the vicinity of the Shashe and Ramokgwabane river confluence (Nuru, pers. comm.)[9]. Even though some elephant paths were observed in along the Motloutse River is seems unlikely that the elephants seen at Letisbogo dam currently move between the Northern Tuli Game Reserve and the dam. Elephants can however travel from the Northern Tuli Game Reserve via the Tuli Circle along the Shashe River and eventually end up at the confluence of the Shashe and Ramokgwabane rivers.

A kernel analysis applied to the Northern Tuli Game Reserve aerial count data from 1986 to 2001 indicated that the distribution of elephants within the Northern Tuli Game Reserve appears to be consistent year after year (Figures 13a-l) even though the numbers counted were not. Elephants seem to be mainly distributed along the major rivers within the Northern Tuli Game Reserve. This might be applicable to the entire study area.

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[9] Dr. Nuru, 2003. Veterinarian, Veterinary Services, Department of Agricultural and Animal Health, Botswana.

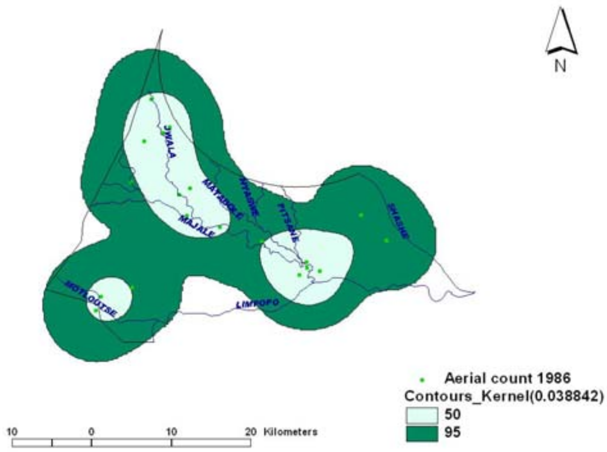

Figure 13a: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during October 1986

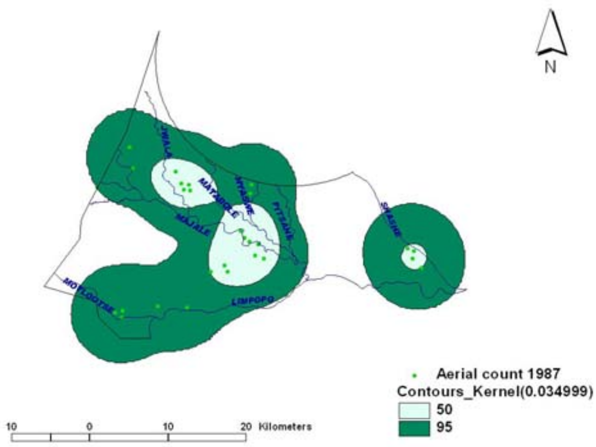

Figure 13b: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during December 1987

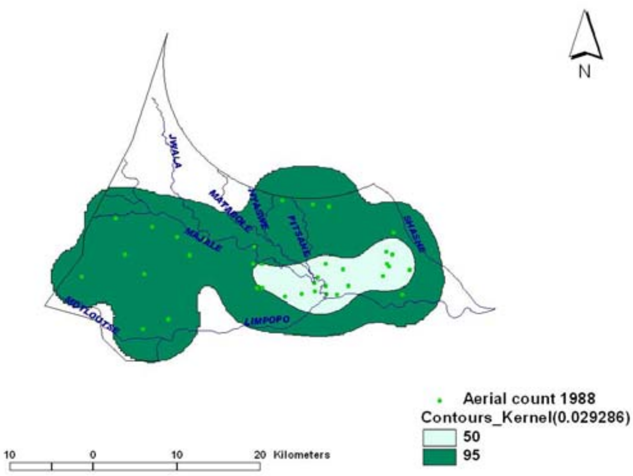

Figure 13c: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during September 1988

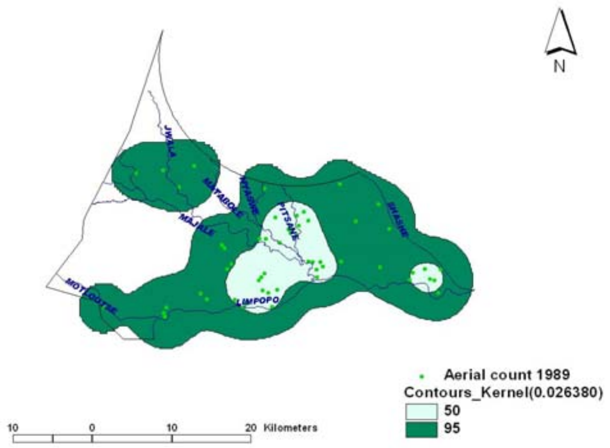

Figure 13d: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during July 1989

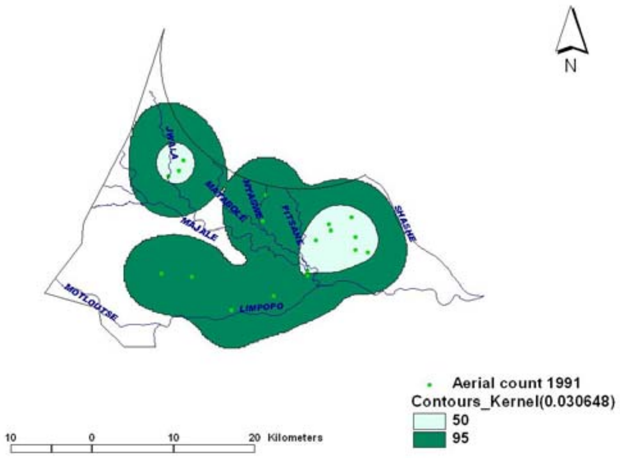

Figure 13e: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during July 1991

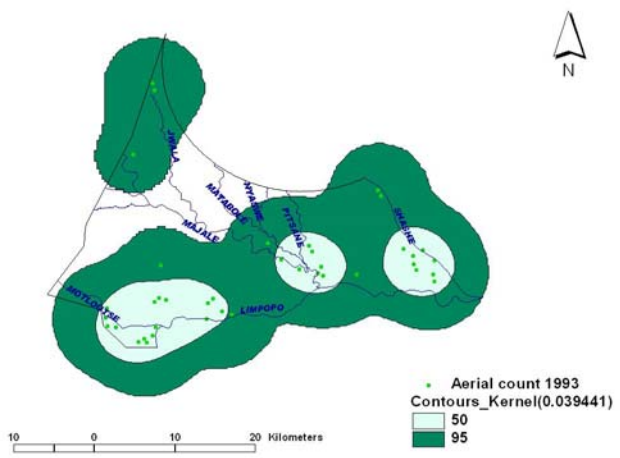

Figure 13f: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during July 1993

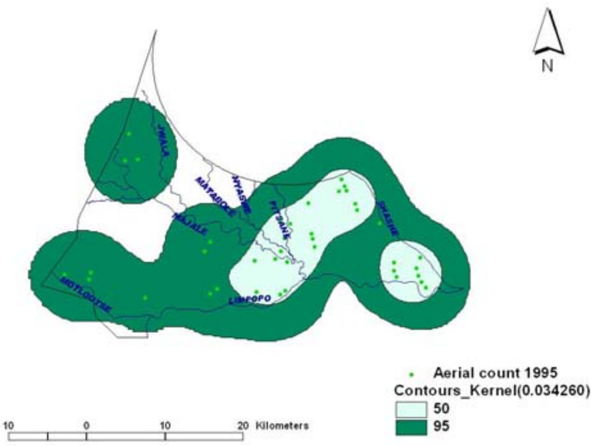

Figure 13g: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during August 1995

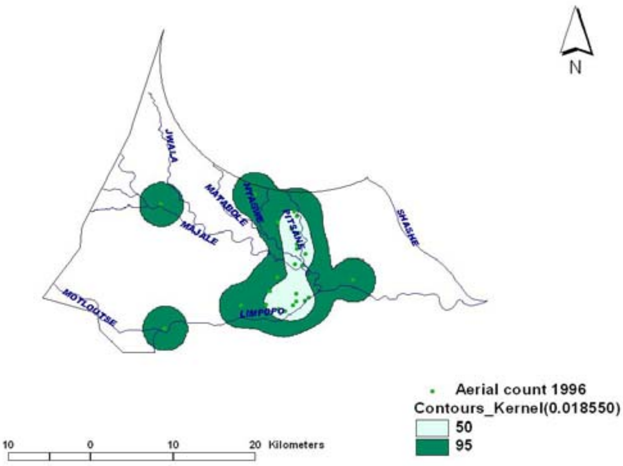

Figure 13h: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during September 1996

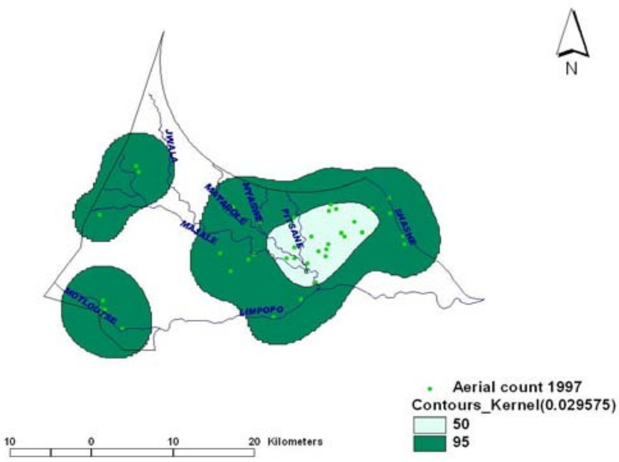

Figure 13i: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during September 1997

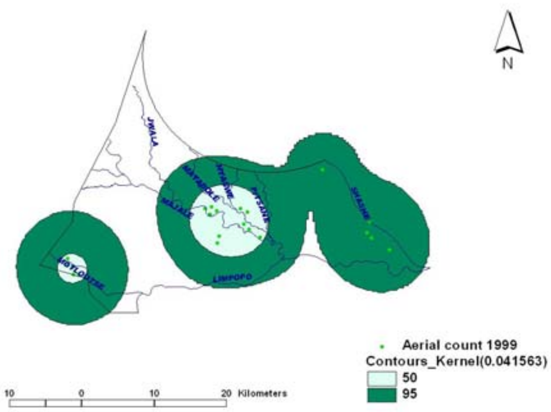

Figure 13j: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during May 1999

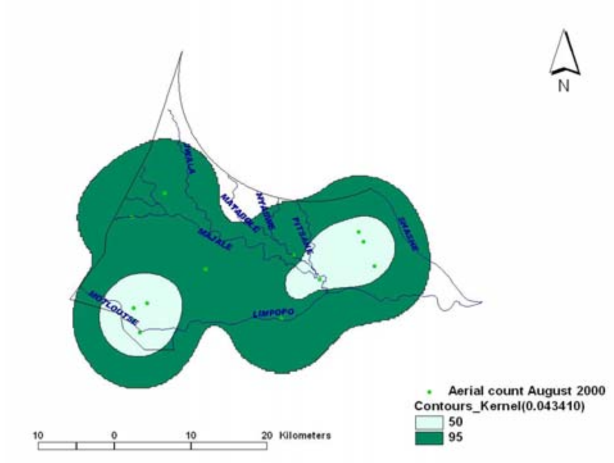

Figure 13k: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during August 2000

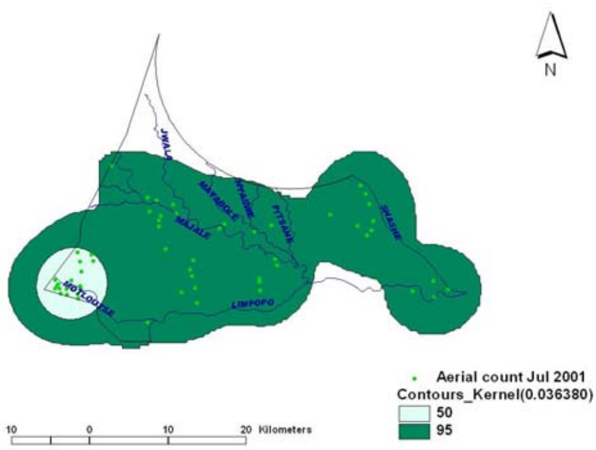

Figure 13l: Kernel analysis of the total aerial count conducted within the Northern Tuli Game Reserve during July 2001

Figure 13 (a-l): Kernel analysis of the total aerial counts conducted within the Northern Tuli Game Reserve from October 1986 to July 2001

Estimation of the mature bull range and numbers in the Central Limpopo River Valley

The assumption was made that all groups counted during the aerial counts of three or less are most likely bulls. Using this method there appear to be very few mature bulls within the study area (Table 10). The same method was used on the Northern Tuli Game Reserve counts (Figure 14). Fifty percent of the all the counts had 5% or fewer bulls. This was further substantiated by the ground observations. Within the Northern Tuli Game Reserve bulls are more frequently found associated with breeding herds than on their own (pers. obs.). The bulls are however not bound to specific breeding herds but move between different groups. It appears further that bulls range wider than the breeding herds and might be traversing between the three countries on a regular basis. This made it difficult in identifying individual bulls and using the capture recapture technique of Croze (1974). The few mature bulls within the Central Limpopo Valley are a point of concern.

Table 10: Comparison of free roaming male and female herd numbers in three different years counted

	Aug-00	01-Jul	04-Oct
Total	1262	1294	990
Number of Observations	54	105	82
Number of Breeding herds	36	72	59
Number in Breeding herds	1237	1251	957
Number of Bull Groups	18	33	23
Number of Bulls	25	43	33

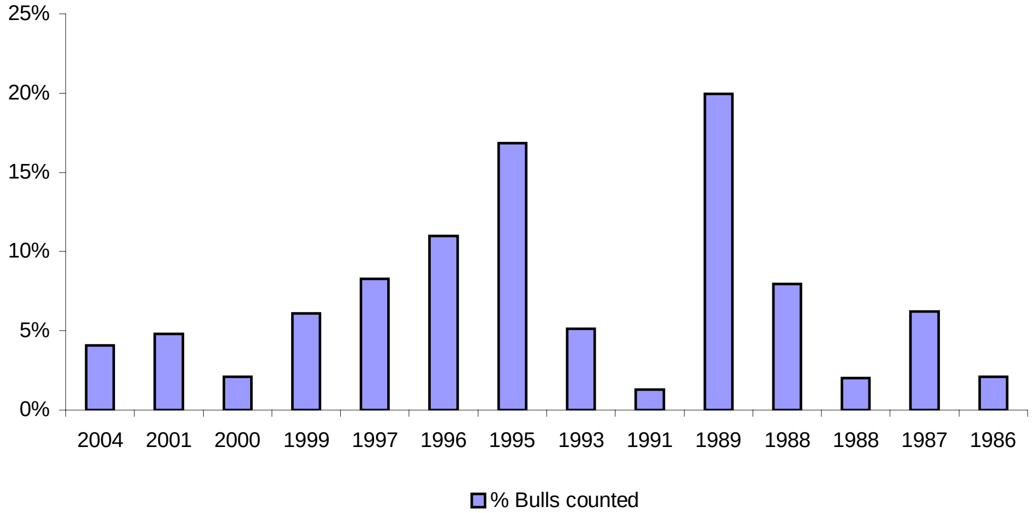

Figure 14: The number of bulls counted within the Northern Tuli Game Reserve during the total game counts as a percentage of the total number of elephants counted

Area specific elephant densities

The question of how many elephants the Central Limpopo Valley should carry on a sustainable basis has been asked many times. Recommended stocking rates for elephants vary from 0.24 elephants/km^2 (Van Wyk and Farall 1969) suggested for the Kruger National Park, 0.4 elephants/km^2 as suggested by Glover (1963) for Tsavo National Park, Kenya to a mean carrying capacity of 4.7 elephants/km^2 (De Villiers 1992) suggested for the Klaserie and Timbavati based on the quantitative daily intake of key feeding plants in the area.

Kruger National Park prefers to maintain their elephant population at a density of 0.35 elephants/km^2 (Van Aarde *et al*. 1999), while the Addo Elephant Park currently have a density of 1.84 elephants/km^2. The mean density for elephants within South Africa's National Parks is currently believed to be 0.33 elephants/km^2.

Recent research suggested that both mortality and reproductive rates are density dependent at densities higher than 0.36 elephants/km^2. The estimated equilibrium density as suggested by Armsbuster and Lande (1993) for semi-arid areas of 1.2 elephants/km^2 seem to be more relevant for the Central Limpopo Valley. The calculated densities for the Central Limpopo Valley lie within the range suggested for the Kruger National Park (0.34 elephants/km^2) and the equilibrium density suggested by Armsbuster and Lande (1993) (Table 11).

Table 11: The area specific densities within the study area as calculated from the three total aerial counts

		Aug-00		Jul-01		Oct-04	
	Area km^2	Total	Density	Total	Density	Total	Density
Northern Tuli Game Reserve - Botswana	770	563	0.73	965	1.25	320	0.42
Tuli Safari Area - Zimbabwe	500	63	0.13	0	0.00	0	0.00
Baines Drift - Motloutse River Farms - Botswana	600	410	0.68	317	0.53	574	0.96
Mapungubwe & Other Farms - South Africa	280	6	0.02	17	0.06	8	0.03
Nottingham & Sentinel - Zimbabwe	760	187	0.25	114	0.15	272	0.36
	2910	**1229**	0.42	**1413**	0.49	**1174**	0.40

CONCLUSIONS

The boundaries of the elephant range within the study area seem to be well defined but movement of groups out of the area is likely. Movements are mainly along the major rivers within the study area. These are the Shashe, Ramokgwabane, Limpopo, Motloutse and Umzingwane rivers. The percentage of elephants migrating in or out of the study area is as yet unknown.

Elephants are mainly distributed within areas of low human densities. Factors like rainfall, water availability and food distribution may influence the distribution and movements of elephants within these areas. These aspects however need further investigation and will be addressed in a follow-up study.

The Central Limpopo River Valley elephant population is estimated at about 1400 elephants. Within this region the highest density of elephants were found to be in the Northern Tuli Game Reserve (NTGR) and the Tuli Block farms west of the Motloutse River to Baines Drift (BDMRF), Botswana. It appears that four sub populations have established themselves within the study area. A more or less resident group of between 200 and 300 elephants have established themselves on Sentinel Ranch and Nottingham Estate (SNRC), Zimbabwe. Another group of between 100 and 200 seems to be utilising the Shashe River in the northern section of the study area (LDNS). This area however needs further investigation.

A mostly resident group of between 300 and 400 elephants is estimated within the southern extension of the Tuli Block (BDMRF). Within the Northern Tuli Game Reserve the more or less resident population is estimated to be between 500 and 600 elephants. The high density of elephants in this area is a matter of great concern to the landowners within the area. High densities of elephant together with a decrease in rainfall have resulted in a dramatic change in the vegetation of the area.

Elephants within the Northern Tuli Game Reserve appear to be mainly distributed along the major rivers. This seems to apply to the entire study area.

Prior to this study no scientific data pertaining to the numbers and distribution of the elephant population within the Central Limpopo Valley were available. Through the study we are now able to start on a strategy for managing the elephants in the region.

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APPENDIX A: POSTAL SURVEY QUESTIONNAIRE

DISTRIBUTION OF THE ELEPHANT POPULATION IN THE CENTRAL LIMPOPO VALLEY.

1. Respondent no. ____________________
2. How big is the farm? ________________
3. How long have you been resident on the farm?_____________
4. Main farming activities on your farm. Mark all the applicable activities.

Citrus	
Crops	
Eco-tourism	
Game	
Livestock	

5. Do elephants stay or pass through your farm?

Yes	No

6. Do you have a resident elephant herd on your farm?

Yes	No

7. How long have the elephants been resident or passing through your farm?____________________

8. How big is the herd?

	Bulls	Cows
0 – 2		
3 – 5		
6 – 10		
11 – 50		
51 – 100		
> 100		

9. Do you allow the hunting of elephants on your farm?

Yes	No

10. If yes please indicate which of the following you allow to be hunted.

Solitaire Bulls	Yes	No
Bulls in the vicinity of breeding herds	Yes	No
Cows	Yes	No

11. During which of the following seasons do you observe **BULLS** on your property? (Mark how regularly and how many bulls are observed at any one time).

Summer (1 November – 31 March)

	Frequent				**Seldom**				**Never**
	15-29 days/month				**1-14 days per month**				**0 days**
Nr. of Bulls	0-2	3-5	6-10	>10	0-2	3-5	6-10	>10	
1999/2000									
1998/1999									
1997/1998									
1996/1997									

Winter (1 April – 31 October)

	Frequent				**Seldom**				**Never**
	15-29 days/month				**1-14 days per month**				**0 days**
Nr. of Bulls	0-2	3-5	6-10	>10	0-2	3-5	6-10	>10	
1999/2000									
1998/1999									
1997/1998									
1996/1997									

12. During which of the following seasons do you observe **Breeding herds** on your property? (Mark how regularly and how many animals are observed at any one time).

Summer (1 November – 31 March)

	Frequent				**Seldom**				**Never**
	15-29 days/month				**1-14 days/month**				**0 days**
Nr. Cows	**0-10**	**11-50**	**51-100**	**>100**	**0-10**	**11-50**	**51-100**	**>100**	
1999/2000									
1998/1999									
1997/1998									
1996/1997									

Winter (1 April – 31 October)

	Frequent				**Seldom**				**Never**
	15-29 days/month				**1-14 days/month**				**0 days**
Nr. Cows	0-10	11-50	51-100	>100	0-10	11-50	51-100	>100	
1999/2000									
1998/1999									
1997/1998									
1996/1997									

13. Why do you think elephants come onto your property?

Mark the appropriate ones.

Drinking	
Grazing	
Browsing	
Passing through	
Citrus and Other Crops	

14. What is your attitude towards elephant on your property?

I like to have elephant on my property	
I tolerate elephant on my property	
I don't want elephant on my property	

15. What type of vegetation do the elephants prefer on your property?

____

16. What tree species is most utilised by elephant on your property?

1.
2.
3.
4.
5.

17. How large an area of your farm do the elephant utilise?

____

18. What proportion is this of your farm?

____

19. Do you approve of the following?

Hunting of solitary bulls	Approve	Don't Approve
Hunting of breeding herds	Approve	Don't Approve
Hunting of bulls in vicinity of breeding herds	Approve	Don't Approve

20. Do you experience any problems with poaching on your farm?

Yes	No

21. What is elephant's usual behaviour towards people on your property?

Aggressive	
Placid	
Scared/shy	

22. How much damage do elephant cause to trees on your property?

None	
Some Damage	
Tremendous	

23. How much damage is caused by elephants on your main farming activity?

None	
Some Damage	
Tremendous	

THANK YOU FOR YOUR PARTICIPATION.

JEANETTA

APPENDIX B: VILLAGE QUESTIONNAIRE

VILLAGE INTERVIEWS

1. Respondent no.____________________
2. Village name:___________________________________
3. Area:____
4. Longitude:_____________________
5. Latitude:_______________________
6. Vegetation of area:_______________________________
7. Main tree species observed with signs of utilisation:

____

____

____

8. Respondent name:______________________________
9. Title:_____________________

10. How long have you lived in this area? ___________________________

11. How many people depend on this piece of land?__________________

12. Main farming practises of the village?

Cattle	
Crops	
Both	

13. What type of crops is farmed?

Maize	
Sorghum	
Watermelon	

14. Do elephants come into your agricultural plots?

Yes	No

15. Do they eat the crops you grow?

Yes	No

16. During what season do you see the most elephant?

Summer (Nov.-Feb)	
Winter (May-Aug)	
Autumn (Mar-Apr)	
Spring (Sep-Oct)	

17. At what time of day do the elephants cause most problems?

Day Time	
Night Time	

18. How do you chase the elephant away?___________________________________

19. Have you or any of your villagers been hurt/killed by elephant in the last year?

Hurt	Yes	No
Killed	Yes	No

20. Have any of your livestock been injured or killed by elephant?

Hurt	Yes	No
Killed	Yes	No

21. How do you feel about elephant around the village?

I like to have elephant around	
I tolerate the elephant	
I don't want elephant around	

22. Do the elephants drink at the bore holes/wells?

Yes	No

23. Do they cause damage at the bore holes/wells?

Yes	No

24. What area does the elephants mostly use? ________________________________

25. How many elephant do you see in

	Bulls	**Cows/Calves**
Winter		
Summer		
Autumn		
Spring		

26. What is elephant's usual behaviour towards people on your property?

Aggressive	
Placid	
Scared/shy	

27. How much damage do elephant cause to trees around the village?

None	
Some Damage	
Tremendous	

28. How much damage is caused by elephants on your main farming activity?

None	
Some Damage	
Tremendous	

29. Do you approve of the following?

Hunting of solitary bulls	Approve	Don't Approve
Hunting of breeding herds	Approve	Don't Approve
Hunting of bulls in vicinity of breeding herds	Approve	Don't Approve

30. Would you like to hunt elephant?

Yes	No

Comments:

HABITAT SELECTION AND SEASONAL AND DAILY MOVEMENTS OF THE CENTRAL LIMPOPO RIVER VALLEY ELEPHANT POPULATION

INTRODUCTION

There has been much speculation on the subject of the African elephant, *Loxodonta africana* (Blumenbach) movement patterns. Early accounts suggest that whole populations migrated over distances of hundreds of kilometres (Sikes 1971). Laws *et al.* (1975) were critical of these reports and concluded that elephants generally had rather small home ranges. There is now increasing evidence that elephants can move large distances, but that there is a great deal of variation, with some populations being very sedentary (Douglas-Hamilton 1972). Others are nomadic or disperse in the wet season (Leuthold 1977 as quoted by Poole 1996; Lindeque and Lindeque 1991; Viljoen 1989), as might be expected in a species occurring over such a wide geographical and habitat range (Thouless 1995).

The conservation and management of elephant populations, which move over long distances, are particularly problematic. It is these elephants which will be most vulnerable to conflict arising from pressure from increasing human populations, since there are few areas remaining in Africa with large continuous and undisturbed patches of elephant habitat. In particular, it has been suggested that erection of game control fencing or other developments, which interfere with traditional movement patterns may have a disastrous impact on mobile elephant populations (Thouless 1995).

To be able to manage elephants and the habitats in which they occur effectively information on both the elephants and the habitat is needed. The distribution of elephants within the area and the nature of their distribution are important in the management of an area. 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 (Dublin and Taylor 1996). An understanding of the movements across the international boundaries would contribute greatly to the development of a conservation plan for the population as a whole (Whyte 1996).

The movements and migratory routes of the Central Limpopo Valley elephant population have interested people for several years. Very little information is currently available but is was speculated by Wilson and Stephan (1972) that the Northern Tuli Game Reserve may form a resting area on an elephant migration route between Wankie (Hwange National Park, Zimbabwe) and surrounding area in Zimbabwe and the Kruger National Park, Pafuri District and Mozambique (via Beitbridge). In order to manage the elephant population effectively it is necessary to determine the extent of their movements and the factors that determine these movements.

OBJECTIVES

The objectives of this study were to

1. Determine preliminary estimates of the home ranges, daily and seasonal movements of the different breeding groups. Also determine which groups use the Northern Tuli Game Reserve as part of their range for which part of the year, and which use other areas in Botswana, Zimbabwe and South Africa.
2. Identify possible factors that might be influencing movements.
3. Determine which areas / habitats are preferred by the elephants in different seasons, and attempt to identify possible factors that might be influencing area or habitat selection.

LITERATURE STUDY

The African elephant lives in a dynamic system of spatial use and grouping patterns. As with other parameters elephant home ranges vary from population to population and habitat to habitat. Individual home ranges vary from 15 to 3 700 km^2 (Douglas-Hamilton 1972; Leuthold 1977 as quoted by Poole 1996). In most areas it seems that females live in predictable dry season home ranges, but migrate over large areas during the wet season (Leuthold and Sale 1973; Leuthold 1977 as quoted by Poole 1996; Western and Lindsay 1984). The size of the group in which an individual may find itself can change from day to day and season to season, with small scattered groups typical in the dry season and large aggregations more common in the wet season (Western and Lindsay 1984). Moving singly or in groups of up to several thousand, elephants may travel as far as 75 km in a few days (Leuthold 1977 as quoted by Poole 1996). They may live at densities as low as 0.024 per km^2 (Poché 1974) or as high as 5 per km^2 (Douglas-Hamilton 1972).

Elephants are extremely adaptable, occupying a variety of habitats from desert to savannah to gallery forest (Lausen and 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 (Poole 1996).

In many respects, the size of an elephants 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 (Whyte 1996). Where water and food are abundant and disturbance is minimal, it can be expected that the home ranges will be small.

The seasonal movements of elephants are most probably related to the availability of food and water (Buss 1990). Food is the proximal factor governing movements and distribution of elephants. Food availability, in turn, is determined largely by the spatial and temporal pattern of rainfall (Leuthold and Sale 1973). In Etosha National Park it was found that the seasonal movements of the elephant were characterised by concentrating around watering points in the dry season, while daily activities were influenced to a large extent by the availability of sufficient shade (De Villiers and Kok 1984).

Elephants in Botswana roam unrestricted. Most of the parks or reserves are unfenced (Ebedes *et al*. 1991). An aerial sample counted conducted in 1999 showed that there are approximately 120 604 elephants in the water-rich area of northern Botswana (Blanc *et al*. 2005). The patterns for dry and wet season distribution vary considerably. Elephants concentrate along the perennial rivers during the dry season causing considerable damage to the vegetation (Ebedes *et al*. 1991; Mosugelo *et al*. 2002). The density of elephant population is four per km^2 in the dry season and two per km^2 in the wet season according to Craig (1991). Gibson *et al.* (1998) indicated an average density for elephants in the Chobe National Park as 7.6 elephants per Km^2, with the elephant population increasing at an annual rate of 6% since the early 1980's.

Seasonal changes in distribution and habitat selection by elephants, which coincide with seasonal climatic changes and the corresponding changes in food and water availability, are well documented (Barnes 1983; Short 1983). This seasonal use of habitat is probably an important mechanism of survival and optimum utilisation of the resource, while at the same time reducing the impact on the dry season habitats

(Viljoen 1989). According to Viljoen (1989) the optimum habitat for elephant would consist of a large area with mixed woodland and grassland and an adequate supply of fresh water together with large trees for shade.

The study of foraging behaviour is dependent 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 water points (Whyte 1996).

The differential use of habitats by elephants can significantly alter the structure of affected plant communities (Laws 1970; Field 1971). Utilisation patterns are influenced by forage preference and availability (Thouless 1995 as quoted by Dublin 1996) as well as by external factors such as extreme weather conditions (Corfield 1973 as quoted by Dublin 1996), human settlement and cultivation (Lamprey *et al*. 1967; Laws 1970) and poaching activity (Dublin 1996). It is necessary to know the habitat utilisation patterns of elephants within parks and reserves in order to understand their impact and to make decisions on local management.

The African elephant is a bulk and mixed feeder, that utilises a wide variety of species and whose feeding habits and preferences are well documented for vast open areas (Barnes 1982; Ishwaran 1983; Viljoen 1989; Waytt and Eltringham 1974). According to Page (1980) it was found that *Colophospermun mopane* made up the bulk of the elephant's diet in the north-eastern Tuli Block Conservation Area but six other species - *Terminalia prunioides*, *Commiphora tenuipetiolata*, *Commiphora pyracanthioides* and *Commiphora merkerii*, *Acacia tortillis* and *Croton megalobotrys* were well used.

METHODS

Determination of elephant movements from literature, postal surveys and interviews

A literature review, postal survey and interviews with people within the study area was conducted to determine the past and present elephant movement patterns in the study area i.e. the region between 21º 00' and 22º 30' south and 27º 15' and 30º 00 east.

Geographic Information System analysis of area and habitat selection and movements

Whenever elephants were located or their signs observed between August 1999 and December 2003, the precise location of the site was obtained using a Geographical Positioning System (GPS). The distributions of the elephants within the different seasons were related to the distance from the rivers and surface water, the proximity of vegetation of different types, proximity to human settlements, and topography using a Geographic Information System (ArcView 3.2). The two seasons were classified as the wet season extending from the 1st of November to the 31st of March and the dry season extending from the 1st of April through to 31st of October.

Recording movements and activity patterns of known groups

When a group of elephants were sighted the group was identified using a photograph and sketch identity kit. The location was determined using a geographical positioning system (GPS). The position of the elephants were then plotted on a 1: 50 000 Geographic Information Systems map of the area using ArcView 3.2. The movements of the different breeding herds were determined. Elephant activities were noted whenever a group of elephants were observed and classified into one of seven categories according to the overall activity of the group, namely browsing, grazing, feeding/walking, drinking, resting, walking and other.

Both data obtained through this study as well as rangers data obtained from rangers traversing the Mashatu Game Reserve area were used in the analyses.

Several herds were identified by known individuals. Locations of these herds were recorded whenever they were seen between August 1999 and December 2003. The wet season (summer) was defined as starting 1st November and the dry season (winter) as starting 1st April .The home ranges of these herds were calculated using the minimum convex polygon (MCP).

RESULTS AND DISCUSSION

Cross border elephant movements

Currently the Central Limpopo Valley elephant population can be divided into three or four different sub populations. These are the Northern Tuli sub population, the Baines Drift to Motloutse River Tuli Block Farms sub population, the Zimbabwean Sentinel-Nottingham Estate – River Ranch Complex sub population and a fourth group around the Letsibogo Dam and northern Shashe River.

It is likely that the sub populations originated mostly from the original population found within the Northern Tuli Game Reserve prior to the 1990's. It can be speculated that these groups are closely related. This would explain the regular intermixing of the sub populations at different times during the year. In a study conducted by Thouless (1996) in northern Kenya several sub populations could be distinguished. The ranges of these sub populations overlapped and elephants from different sub populations were occasionally seen in the same groups. The groups, however, had different movement patterns.

Cross border movements of elephants between Zimbabwe and Botswana via the Northern Tuli Game Reserve occur regularly and seem to be mainly at night. Elephants were observed to move from the Northern Tuli Game Reserve across the Shashe River into Zimbabwe at sunset to return back to the reserve early the following morning. Several small-scale irrigation schemes exist along the Shashe River within Zimbabwe but at present all are non-operational (CESVI 2001). Elephants are known to crop raid within the communities living along the Shashe River in Zimbabwe and from a survey conducted within these communities it was shown that elephants and hyenas are considered the main problem animals in the area (CESVI 2001).

Elephants were found to move along the Shashe River onto the island situated at the confluence of the Shashe and Limpopo rivers. From the island tracks indicate elephants crossing into the Limpopo riverine on the South African side. From the island the elephants cross into Zimbabwe in areas with low human densities to eventually end up on Sentinel Ranch further down along the Limpopo River in Zimbabwe. Tracks in the Shashe and Limpopo rivers indicate that both breeding herds and bull groups venture into Zimbabwe. Local residents of Maramani at the confluence of the Limpopo and Shashe rivers indicated that bulls were more frequently observed than breeding herds in this area.

Elephants were frequently seen moving between the Northern Tuli Game Reserve and the Tuli Circle. A large influx of elephants into the Northern Tuli Game Reserve from the Tuli Circle was observed at the onset of the hunting season in the Tuli Circle during May. The herds can be identified by their nervous and aggressive behaviour in the reserve. During the aerial counts (August 2000, July 2001 and October 2004) very few elephants were counted within the Tuli Circle (63, 0 and 0 respectively).

Walker (1971) notes that the distribution pattern of elephants within the Tuli Circle has been greatly modified over the years by the control and hunting of elephants within the Tuli Circle.

The numbers of elephants counted on the South African side of the study area are less than expected. During the three total aerial counts conducted in August 2000, July 2001 and October 2004 a total of six, 16 and eight elephants were respectively counted on the South African side. Two ground counts were conducted by the South African National Parks on the 24th and 27th July 2001 on the South African side. During these counts a total of 52 and 46 elephants were counted respectively. Only one breeding herd of between 15 and 25 elephants was counted on Kruitfontein. Bull groups made up the remainder. During two consecutive counts in the Mapungubwe National Park during September 2002 and September 2003 a total of 50 and 37 elephants were counted respectively. Of the 50 elephants counted in September 2002, 25 were walking in the Limpopo River on the Botswana side of the boundary fence. A total of 30 bulls are estimated to be resident within the Mapungubwe National Park, South Africa (Van't Foort, pers. comm.)[10]

Elephant movements into South Africa were regularly noted and were found to be both bull groups as well as breeding herds. These movements occur in areas where the military fence (Norex fence) has been removed or is out of order. From the farm Tuscanen to Schroda a four strand electrified fence was erected in 2003 together with a cattle fence in order to prevent the movement of elephants into this area. This area is commonly referred to as the Vhembe gap and was the main entry point for elephants from the Northern Tuli Game Reserve into South Africa prior to the erection of the four-strand electrified fence. The fence, however, is only a partial barrier to elephants and is often broken by elephants crossing in or out of the park.

The movements of breeding herds into South Africa are mainly during the dry season when the Limpopo River is dry. Bulls however were seen crossing the Limpopo River at all times of the year except at times when the Limpopo River was in flood. Due to the flood damage of 2000/2001 to the Norex fence elephants could freely move into South Africa. During late December 2000 a small breeding herd of 12 elephants was seen crossing the Limpopo River and onto a South African farm named Kruitfontein. This caused some controversy. It was believed that the elephants would be hunted

[10] Van't Foort, W. Senior Ranger, Vhembe Dongola National Park, P.O. Box 383, Musina South Africa. Personal Communication 23 January 2004.

on Kruitfontein (Macleod 2001). Since the erection of the four-stranded veterinary fence less movement of elephants to and from the Northern Tuli Game Reserve into South Africa has been observed (Van Lente, pers. comm.)[11].

Seasonal movements and habitat selection

Northern Tuli sub population

According to Lind (1971) the elephants are spread out over the whole Northern Tuli Game Reserve area in fairly large numbers in the beginning of the year with numbers increasing until May. At the end of May the elephants move out of the area completely returning to the area only in late July utilising mainly along the lower reaches of the Majale River and the Majale/Limpopo river confluence until the first rains in September – October when the herds move off again. During the middle of December a herd of approximately 500 elephants were spotted along the Motloutse River. During late December herds move back into the area in several small groups. Lind (1971) noted the migration of elephants into the tribal trust area north of the reserve during the wet season and back down the Motloutse River.

There seem to be a lot of movement between the Northern Tuli Game Reserve sub population and the Baines Drift - Motloutse River - Tuli Block Farms sub population. During the dry season herds from the Northern Tuli Game Reserve and the Tuli Block congregate along the Motloutse River and during the peak of the dry season (June to August) congregations of up to 400 elephants were seen along the Motloutse River on the farms Fairfield, Helena, Gesond, Oerwoud, Talana and Redshields (pers. obs.). During the rainy season some herds frequenting the Motloutse area can be seen entering the Northern Tuli Game Reserve and spending a part of the rainy season in the central section of the reserve (Figure 15). One such group, herd CRI, was observed every dry season along the Motloutse River. During March 2001 herd CRI was seen in a group of over 200 elephants early morning at Well-shaped Mashatu, while during the late afternoon the same group was seen crossing to the west of the reserve through Elephant Valley (Figure 16).

[11] Van Lente, B. Manager, Vhembe Dongola National Park, P.O. Box 383 Musina, South Africa. Personal communication, January 2004.

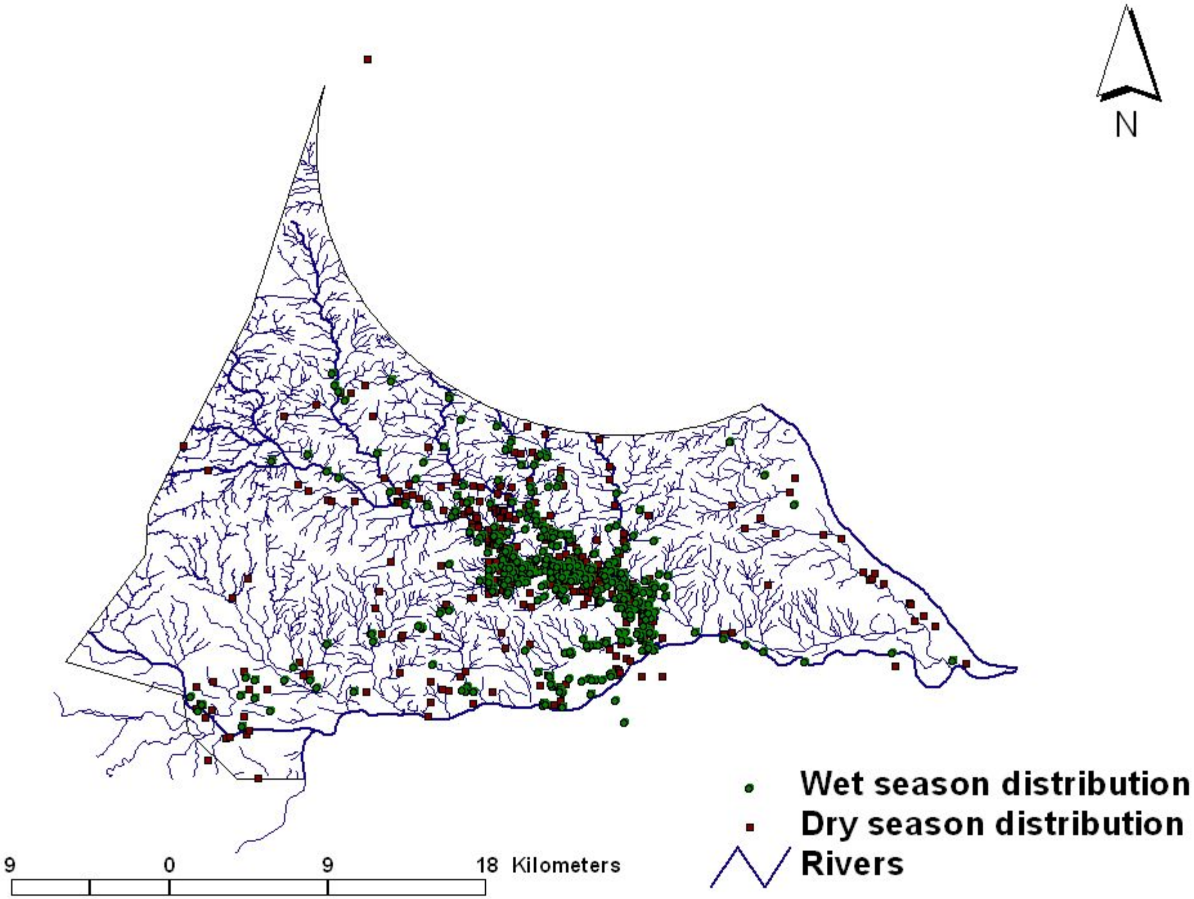

Figure 15: Location of opportunistic sightings of elephants over the period August 1999 to December 2003 in the Northern Tuli Game Reserve, Botswana. Circles are wet season (01 November to 31 March) locations and squares are dry season (1 April to 31 October) locations

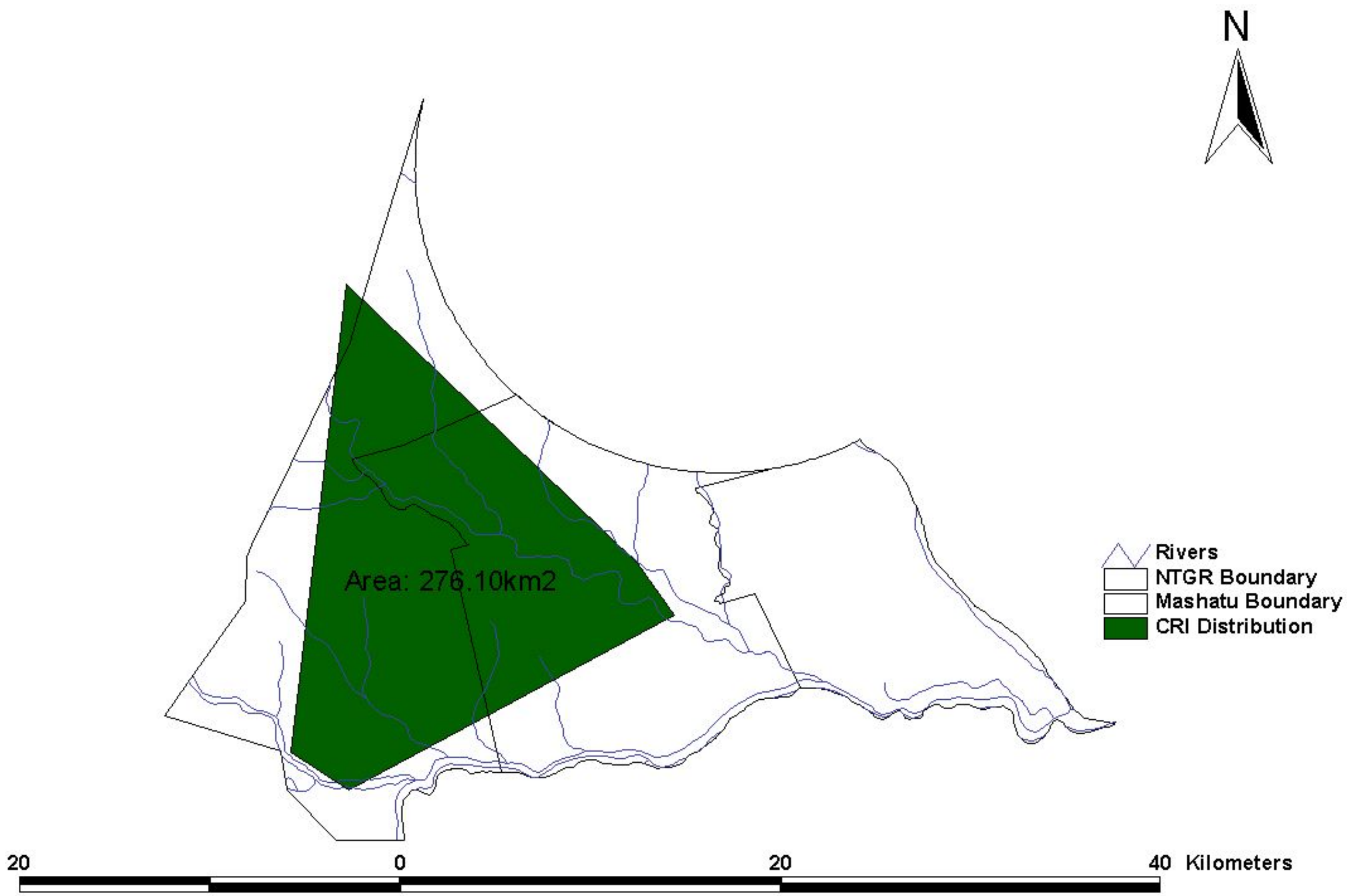

Figure 16: Distribution of herd CRI within the Northern Tuli Game Reserve

During the dry season elephants concentrate along the three major rivers namely the Limpopo, Shashe and Motloutse rivers. This corresponds with observations by Page (1980). Several studies have shown that the seasonal movements of elephants are characterised by elephants concentrating in the vicinity of perennial waterholes during the dry season when no natural water is available and disperse during the wet season (De Boer *et al*. 2000; Osborn and Parker, 2003; Owen-Smith, 1988; Wittemyer, 2001). This pattern holds for Etosha National Park (De Villiers and Kok, 1984; Lindeque and Lindeque, 1991) where elephants preferred to use areas within 4 km of water throughout the year (De Beer *et al.* 2006). Relative to the dry season, ranging during the wet season seems less dependent of distance from perennial water sources, as seasonal water sources are widely available (De Beer *et al.* 2006).

Herds within the Northern Tuli Game Reserve move out from the Majale River complex where most of the rainy season and early dry season are spend towards the Shashe River during the dry season. According to Page (1980) the Uitspan area is infrequently utilised from May to October with the Shashe and Majale riverine vegetation heavily utilised over this time period. This corresponds with the data from this study (Figure 17). Page (1980) further noted that the Motloutse riverine vegetation was more heavily utilised than the Uitspan area but less frequented than the Majale and Shashe systems. According to Lind (1971) the Shashe riverine vegetation and the Mopane veld west to Santhata and the Majale/Pitsane complex were a favoured winter-feeding area of the Tuli elephants.

The central section of the reserve along the Majale and Matabole rivers, apart from resident herds, is void of elephants during September and October. Large herds of elephants spend most of the dry season moving up and down the Shashe riverine vegetation (Petty, pers. comm.)[12]. During September and October large herds can be seen concentrating at the Shashe/Limpopo river confluence. This corresponds with the ranger reports (Santhata 1982 - 1984) where elephants move into the Shashe area during July with large numbers of elephants moving into the Shashe riverine vegetation during August. Other herds like herd FLE can be seen moving along the Limpopo River for most of the dry season, while up to 300 elephants can be seen concentrating on the area along the Motloutse River during the dry season.

[12] Petty, B. Manager, Charter Game Reserve, North Eastern Tuli Block, Botswana. Personal communication 2003.

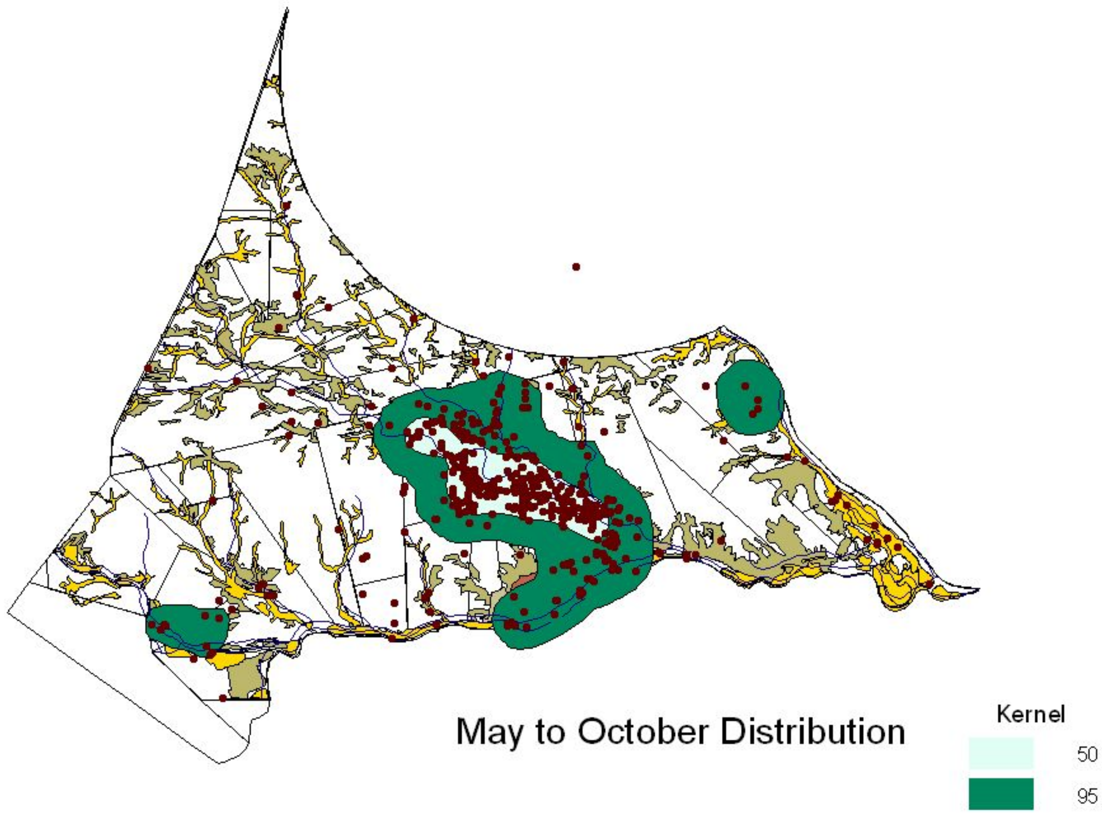

Figure 17: The May to October distribution of elephants within the Northern Tuli Game Reserve

With the onset of the rains in November/December large groups of elephants can be seen moving back into the central section of the reserve from the Shashe (Charter Reserve) area in the early mornings crossing back into the Charter reserve in the late afternoon. Herds from the Motloutse River area were also observed moving into the Northern Tuli Game Reserve along the Limpopo River and via Elephant Valley. During the wet season little elephant activity can be seen along the Motloutse River. Herds were found to be more spread out over the reserve during the peak of the wet season than during the dry season or early in the wet season.

Lind (1971) describe the Mopane veld area between the Pitsane, Shashe and Majale river flats from McNiels pool on the Majale River north, Uitspan, Elephant Valley, Naledi, Safari Ranches and the northern section of the Tuli Circle, as favoured summer feeding areas. Lind (1971) also describes elephant migrations to the Tribal Trust areas north of the reserve during the wet season moving back down along the Motloutse River. Recent movements into the communal areas during January can be explained by the readiness of crops in the communities over this time period.

According to Page (1980) the reason for the infrequent occupation of the Shashe River can possibly be ascribed to the difficulty elephants have walking in the wet clay and alluvial soils found along the Shashe River during the wet season. This might also explains the reason why the higher lying stonier soils on Uitspan, Safari and the upper reaches of the Nyaswe and Matabole rivers and the Tuli Circle are more frequented during the wet season.

Several factors determine the distribution and movements of elephants within a specific area. According to Jachmann (1986) the distribution of the elephants within the Kasungu National Park is very uneven with elephants mostly concentrated in the South eastern part of the park due to a combination of habitat preference and illegal activity. Weir (1972) indicated that the sodium content in the water could be a determining factor in elephant movements. According to De Villiers and Kok (1984) the distribution of large mammals in natural environments can be correlated to the occurrence of rainfall.

Some migrants congregate around permanent water sources in the dry season and disperse to drier habitats in the wet season. Others travel along rainfall gradients, concentrating in areas of low annual rainfall in the wet season and moving to areas of higher rainfall as the dry season advances (McNoughton 1990). Migrations could be explained by the animal's avoidance of muddy, sticky soils general forage quality properties by calcium requirements of lactating females and by avoidance of woodland habitats with greater predation risk (McNoughton 1990).

Water availability and distribution (De Iongh *et al.* 1999; Dunham 1986; Lindeque and Lindeque 1991; Western and Lindsay 1984) and forage quality largely dictate seasonal migrations (Western and Lindsay 1984). According to Western and Lindsay (1984) elephants are confined within the vicinity of permanent water and selected habitats with progressively more abundant but less digestible forage. Barnes *et al.* (1991) indicated that the movements of the Manyara elephants are mainly governed by their nutritional needs. During the wet season, when water is no limiting factor elephants disperse (Lindeque and Lindeque 1991) preferring floodplains due to their preference for perennial grasses (De Iongh *et al.* 1999). Patterson (1999) believes that the rivers within the Tuli influence the movements of the elephants.

Elephants concentrate near fresh water sources during the dry season and the decreasing proportion of grass from the early rainy season to the late dry season is explained by a decrease in palatability and nutrient concentration (Sukumar 1989, Sukumar 1990) and is also reported for other areas (Dublin 1996, Kabigumila 1993; Osborn 1996; Spinage 1994).

During the early rainy season elephants select high quality grass species and concentrate on these species during the first part of the growth season. Late in the rainy season, grasses decrease in quality but not in quantity. Higher numbers of plant species are also found in the diet. Late dry season is characterised by the absence of green herbaceous species and several tree species have lost their leaves. Elephants then concentrate before the start of the rains on a limited number of browse species with flowers and young leaves (De Boer *et al.* 2000).

The major factor determining the seasonal movements of elephants within the Northern Tuli Game Reserve seem to be the availability of suitable food sources and not water. Artificial waterholes are evenly distributed throughout the reserve and do not explain the concentrations of elephants in certain areas. Elephants were rarely present in the shrub Mopane area before the onset of the spring rains when the major Mopane leaf flush occurs independently of rainfall (Styles and Skinner 2000).

The major vegetation types that occur along the Motloutse, Limpopo and Shashe rivers are *Acacia tortillis* woodlands. This seems to be the major factor attracting elephants to these areas. Along the Shashe River and the Motloutse River large sections of Mlala palm (*Hyphaene natalensis*) can be found which seem to be utilised to a large degree by the elephants during the dry season.

According to Joubert (1984) the elephant impact is obvious along the mid and lower reaches of the Majale River. A high degree of hedging of Mopane trees is apparent in this area. Impact is limited in terms of the entire area. In most of the areas surveyed by Joubert (1984) the elephant impact was surprisingly low. Page (1980) describes the utilisation of the *Colospermum mopane* east of the Majale/Pitsane river complex higher than the western part of this vegetation type.

According to Weir (1971) the distribution of elephants is determined largely by man irrespective of their preferences. Elephant densities increase with distance from human activities (Barnes *et al.* 1991). Human interference is one of the obvious factors influencing migrational behaviour (Barnes *et al.* 1991;Tchamba *et al*. 1995; Whyte 1993). This corresponds with the findings of this study where higher densities of elephants were found in areas of low human densities (Figure 11).

The Zimbabwean sub population

The Zimbabwean sub population ranges east of the Shashe River and south of Machuchuta and Masera wards within Zimbabwe. The sub population consist of approximately 200 - 250 elephants based on data from the three total aerial counts conducted during 2000, 2001 and 2004 respectively. The total number of elephants counted during the three counts was 187, 105 and 22 respectively (Table 7).

The sub population is mainly confined to three properties namely Sentinel Ranch, Nottingham Estate and River Ranch (Figure 12). This is due to high human densities on three sides. To the north the densely populated communities Machuchuta and Masera wards are located, to the east Beitbridge and to the west another densely populated ward namely Maramani. Along the southern banks of the Limpopo the Norex military fence and in some parts very steep riverbanks limit elephant movements into South Africa. Movement of elephants along the Umzingwane River to Zhove Dam was noted during the 2004 count. It is unknown how far these elephants can move along this river.

No detailed records of the movements of the Zimbabwean elephant sub population could be kept due to logistical problems. Ground observations were few and most of the data obtained were from personal interviews with landowners and local communities and data obtained from the three total aerial counts conducted within the Central Limpopo Valley during 2000, 2001 and 2004 respectively.

The Zimbabwean sub population established during 1991/1992 when a group of approximately 200 elephants crossed from the Northern Tuli Game Reserve onto Sentinel Ranch. For the first few years the elephants remained mainly on Sentinel Ranch. With the building of the dam on Nottingham Estate the elephants started moving across onto Nottingham Estate spending more time in the vicinity of the dam. High elephant impact can be observed in the vicinity of the dam. Currently the elephants move freely between Sentinel Ranch, Nottingham Estate and River Ranch.

Elephant paths run mainly along the major rivers in the area namely the Limpopo, Pahzi and Umzingwani rivers. Elephants seem to utilise the Pahzi River on Sentinel Ranch on a regular basis and the dam on Nottingham Estate including the Umzingwani River on the border of Nottingham Estate. During the harvesting of the oranges on Nottingham Estate excess oranges get dumped in specific areas and herds visit these sites on a daily basis. This has an obvious effect on the natural movement patterns of the elephants.

Movements into the communal areas to the north and east of the two private game farms are irregular and correlated to the status of the crops on the perimeter of the communities. Elephants do not cross far into the communities surrounding the sub population due to the high density of humans in the area. From the three aerial counts conducted no elephant paths could be seen moving into the community areas. Interviews with local inhabitants of the surrounding communities indicated little elephant activity in the central areas of the communities, but high incidences of crop raiding by elephants are recorded along the perimeters of the communities along the borders with Sentinel Ranch, Nottingham Estate, the Limpopo and the Shashe rivers. The communities, in a survey done by CESVI during 2000 (CESVI 2001), indicated the elephants and hyenas as the biggest problem animals in the area.

Baines Drift to Motloutse River Tuli Block Farms sub population

This sub population established in the early 1990's when a large herd of elephants moved west out of the Northern Tuli Game Reserve and established themselves on Mawana Nature Reserve within the Tuli Block.

Regular movements and interactions between the Northern Tuli sub population and the Tuli Block farms west of the Motloutse River to Baines Drift sub population (BDMRF) is likely. Some herds frequenting the Motloutse River area have been observed within the Northern Tuli Game Reserve. A variation in the numbers counted during the three total aerial counts conducted in 2000, 2001 and 2004 further indicate movements between the two sub populations.

Before the erection of the electrified game fence along the back line of the Tuli Block elephants frequently moved between the Tuli Block and the communal areas in Botswana. With the erection of the fence and at times when the fence is maintained limited movement is observed between the Tuli Block and the communal areas within Botswana.

Elephants do cross the Limpopo River when it is not in flood in order to reach the Limpopo Riverine on the South African side. In areas where the Norex fence is in disrepair elephants can cross onto properties on the South African side. Two such farms often frequented by elephants are Ratho and Kruitfontein.

Daily movements within the Northern Tuli Game Reserve

The daily movements of known herds within Mashatu Game Reserve, a part of the Northern Tuli Game Reserve, were observed between August 1999 and December 2003. Elephant herds within Mashatu appear to move towards the riverine areas along the major rivers in the morning and move out into the open areas in the late afternoon (Figure 18-20). This pattern is followed during both the wet and dry season. The concentration of elephants found in both the wet and dry season in the riverine areas during midday can be due to the requirement of elephants for shade during the heat of the day.

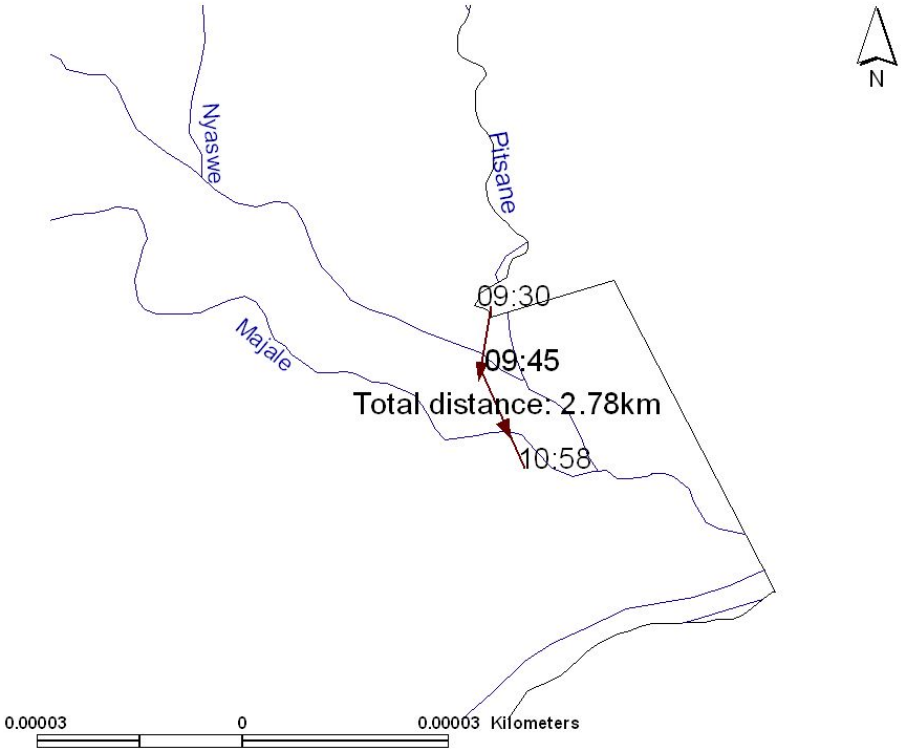

Figure 18: Herd TH movements on 20 July 2003

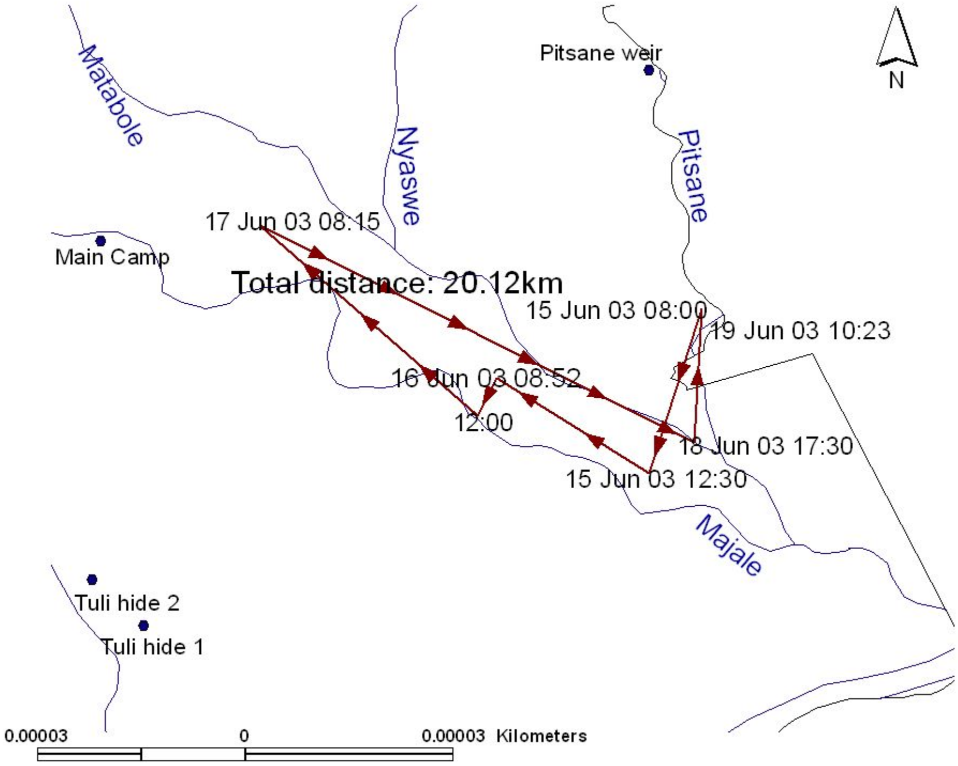

Figure 19: Herd CHR movements from 15th to 19th June 2003

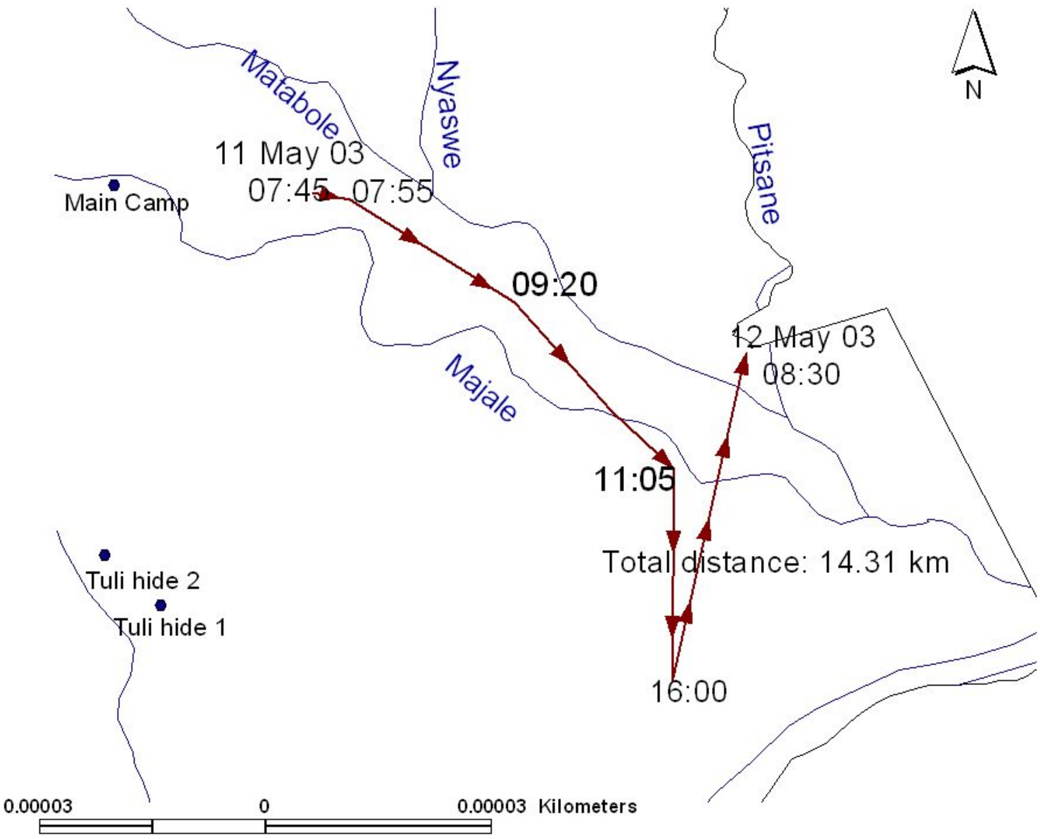

Figure 20: Movement of large elephant congregation on the 11th May 2003

It was observed that during the wet season elephants moved earlier into the riverine areas and only moved out of the riverine areas in the late afternoon. In the dry season with lower temperatures elephants were observed moving later into the riverine areas and moved out earlier in the afternoons.

Elephants were seen to be walking significantly more during the morning and evening time periods than during the midday time period. From the data elephants were seen walking 26.58% and 26.95% of the morning and afternoon sightings respectively compared to the 12.16% of the sightings during the afternoon period (Table 12). This was also found during the winter time period.

All year round elephants can be seen moving into the Majale/Pitsane river complex during the early mornings leaving the area again in the afternoons to return on the same route the following morning. Herd BLU has been observed on several occasions to move into the Majale/Pitsane river complex in the early morning from the Charter Reserve and seen moving to the east in the late afternoon towards the Charter Reserve. The following morning the same herd will once again enter the Mashatu Game Reserve from the Charter Reserve in the east. This pattern can continue for several weeks before the herd changes their pattern completely. A large congregation of elephants were followed on the 11th of May 2003 from the north of Mashatu Game Reserve along the Matabole River (Figure 20). The congregation travelled the length of the reserve towards the Limpopo River. At sunset the congregation was left at Nels vlei close to the Limpopo River. The following morning the congregation was once again spotted coming in from the north of the property along the Pitsane River. This indicates that elephants might be moving and feeding a lot more at night than expected.

Table 12: Percentage contribution of different activities during different times of the day in different seasons

Activity	Summer			Winter		
	Morning	**Afternoon**	**Evening**	**Morning**	**Afternoon**	**Evening**
	04H00-09H00	09H01-16H00	16H01 04H00	05H00-10H00	10H01-15H00	15H01-05H00
Resting	0.63	21.62	0.00	1.50	10.28	0.50
Walking	26.58	12.16	26.95	27.52	15.89	21.16
Feeding/walking	7.60	0.00	23.44	7.12	3.74	7.56
Browsing	23.42	28.38	21.88	41.39	36.45	44.33
Grazing	25.95	17.57	16.40	4.68	2.80	2.52
Drinking	15.82	20.27	11.33	17.04	28.97	23.43
Other	0.00	0.00	0.00	0.75	1.87	0.50

Activity patterns

According to Poché (1974) elephants seem to be responsive to diurnal periodicity of light as well as to lunar periodicity in that they are more active in moonlit nights.

Elephants in the Sengwa Area, Zimbabwe rested more in the hot season when daytime temperatures were high. Apparently more need to remain stationary than the cooling effect of resting in shade that is required by elephants because they walked and fed the least at midday in the hot season but also rested in the open more than in either of the other two seasons (Guy 1976) According to De Villiers and Kok (1988) daily activities are influenced to a large extend by the availability of sufficient shade.

Similarly in this study elephants rested during the middle of the day and moved more in the morning and late afternoon. Also similar to other studies, they also rested more at midday during summer than in winter. Feeding occurred throughout the day, but feeding whilst walking occurred most in the morning and late afternoon. Similarly drinking occurred throughout the day with a peak in drinking at midday (Table 12).

Seasonal habitat selection of elephants within the Northern Tuli Game Reserve

A total of 1496 elephant sightings were recorded between August 1999 and September 2004 whilst traversing as much of the road network in the Northern Tuli Game Reserve each month as possible. The data set was split into wet and dry seasons (summer and winter). The beginning of the wet season depended on the month of first rainfall within the wet season with no season stretching for more than seven months. Overlays of the locations in the wet and dry seasons on Cheney's (1998) habitat types (Aquatic Grassland, Mixed Riverine, Mixed Shrubland, Mopane Veld and *Acacia tortilis* Woodland) were used to establish habitat preference (Figure 21 and 22). The proportions of sightings in each habitat were compared with the proportions of each habitat type in the total area of the reserve, to calculate a preference ratio (PR) for wet and dry seasons separately. A preferred habitat (PR>1) is defined as one that is utilised proportionally more frequently than its proportion in the total area, whilst avoided habitat types have a PR<1.

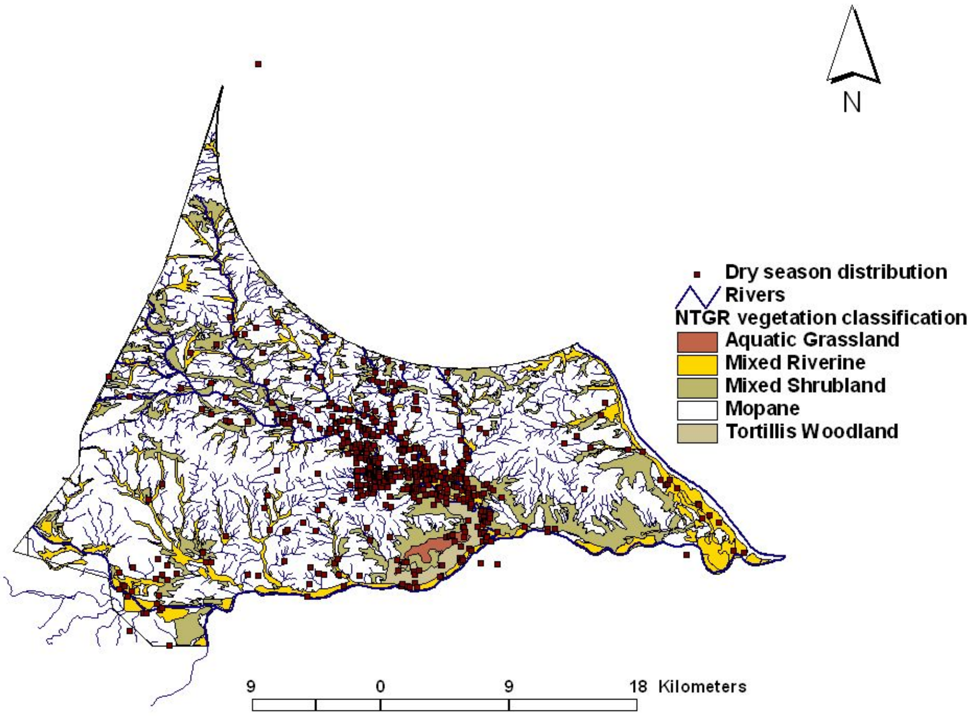

Figure 21: Dry season distribution of breeding herds within the different habitat types in the Northern Tuli Game Reserve

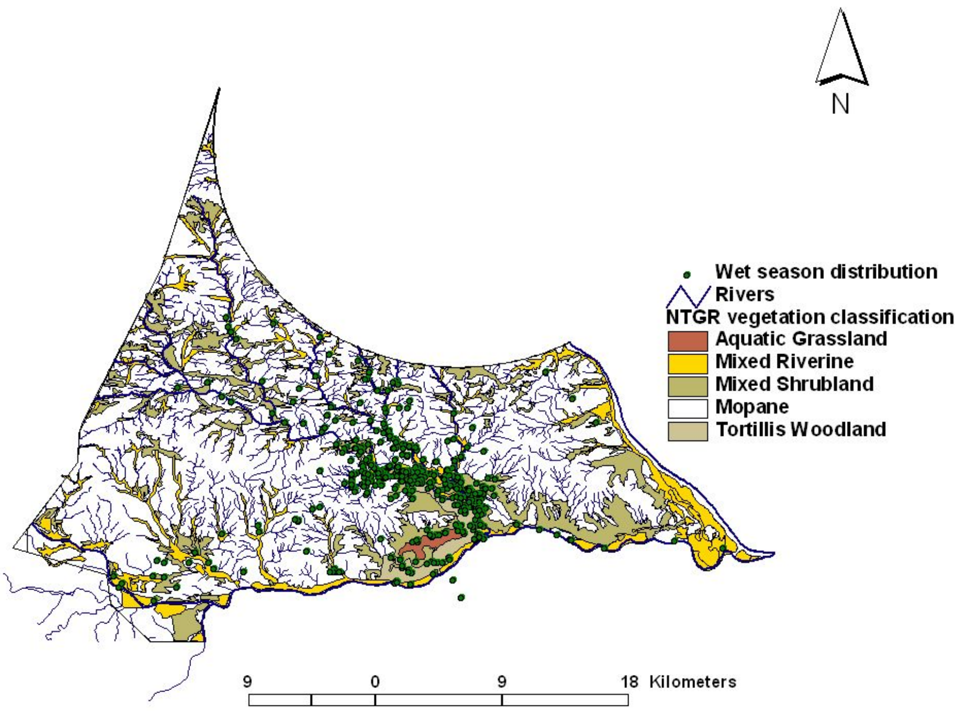

Figure 22: Wet season distribution of breeding herds within the different habitat types in the Northern Tuli Game Reserve

Breeding herds were observed in all the different vegetation types in both the wet and dry season but selected for different vegetation types in the different seasons. *Colophospermum mopane* was not selected for during neither the dry or wet season (0.62 and 0.43 respectively), while the mixed shrubland was selected for during both the dry and wet season (1.33 and 1.80 respectively). During the dry season breeding herds selected mainly for the aquatic grassland (6.73 compared to 0.17 in the wet season), while in the wet season the *Acacia tortilis* woodland were mainly selected for (10.01 compared to 3.11 in the dry season). Mixed riverine was selected for during both seasons with no difference between the two seasons (1.33 in dry season and 1.80 in the wet season).

In the Northern Tuli Game Reserve, two broadly classified vegetation types make up most of the area (Page 1996). These are (i) Riparian woodland along the floodplains of the major rivers, and (ii) Mopane woodland away from the floodplains (Styles and Skinner 2000). An elephant's preference for certain species appears to be an important factor dictating its movements in some habitats (Osborn 2002). Several studies have demonstrated the pronounced seasonal variation in the elephant's diet, with increase in grass intake after the onset of the rains, and a significant drop to low levels as the dry season progress (Hanks 1979).

In areas where at least part of the year are devoid of surface water, water dependent animals may aggregate at permanent water in the dry season and disperse in the wet season to areas with temporary water supplies and higher quality and or quantity of forage (Skarpe *et al.* 2004). During the dry season adult bulls frequent more habitat types than family units, whereas family units used a wider diversity of habitats than bulls during the wet season (Stokke and Du Toit 2002). Bulls roam widely from perennial drinking water in the dry season, when family units congregated within 3.5 km of the rivers (Stokke and Du Toit 2002). Family units are unable to range far from water in the dry season due to comparatively high rates of water turnover among juveniles and lactating cows and the reduced mobility of neonates (Stokke and Du Toit 2002).

Satisfying nutritional requirements is not the only factor governing the distribution of large herbivore populations across habitats. Predation avoidance (Du Toit 1995) and access to drinking water (Western 1995) are factors that bear particular consideration in African savannas (Stokke and Du Toit 2002). In the case of elephants, small calves are sometimes preyed on opportunistically by large carnivores (Ruggiero 1991).

Elephants within the Northern Tuli Game Reserve selected for the mixed riverine habitat type in both the wet and dry season. During the dry season the selection may be due to the presence of waterholes along the major river courses, whilst in the wet season the selection of this habitat type might be due to the presence of shade along the major rivers. Styles and Skinner (2000) indicated that even though the new leaf flush of the *Colophospermum mopane* is highly palatable elephants where rarely present within these areas at the onset of the spring due to the lack of water in these areas. According to a study conducted within Venetia-Limpopo Nature Reserve *Colophospermum mopane* was selected for and was the dominant constituent of the elephants diet (Smallie and O'Connor 2000).

In a study conducted in the Chobe National Park, Botswana, elephant browsing pressure (% of trees utilised) was highest in the mixed woodlands and *Combretum* shrublands, while ungulate browsing pressure (% of shoots utilised) peaked in the *Capparis* shrublands (Skarpe *et al*. 2004).

The use of different plant species by elephant has been relatively well documented (Anderson and Walker 1974; Barnes 1982; Buss 1961; Guy 1976; Jachman and Bell 1985; Kalemera 1989; Meissner *et al.* 1990; Viljoen 1989). Tree species fall into four broad categories in terms of how they are utilised (i) those that are searched for or selected, (ii) those that are used opportunistically or in proportion to their occurrence in the environment, (iii) those used infrequently, and (iv) those not used at all, or rejected. (Page 1996) (Table 13).

Table 13: Preference ratios of elephant for a selection of different species from Mopane woodlands in the Northern Tuli Game Reserve (Page 1996)

Species	Selected	Opportunistic	Infrequent	Rejected
Commiphora tenuipetiolata	3.8			
Commiphora pyracanthoides	2.6			
Commiphora merkerii	2.1			
Sclerocarya birrea	2.0			
Sterculia rogersii	2.0			
Cassia abbreviata	1.8			
Colophospermum mopane		1.1		
Combretum apiculatum		0.9		
Terminalia prunioides			0.6	
Boscia albitrunca			0.5	
Adansonia digitata			0.1	
Rhigosum brevispinosum				0
Rhigosum zambesiacum				0
Catophractes alexandri				0

Known Herd Movements within the Northern Tuli Game Reserve

The wet and dry season home ranges of the known herds show a distinct overlap in their wet and dry season home ranges (Figure 23 a-d). Most of the herds observed dry season (winter) home ranges were found to be bigger than their wet season (summer) home ranges and overlapped the wet season home ranges. For herd CH the dry season home range size was 81% larger than the wet season home range size. For herds CHR, HE and TH the dry season home range area were 54%, 57% and 29% larger than the wet season home range areas respectively. Whitehouse and Schoeman (2003) found that family units have overlapping home ranges. This corresponds with the current study. Female core range sizes were found to be larger than non-musth bulls, presumably because bigger areas are needed to satisfy the nutritional requirements of their young (Whitehouse and Schoeman 2003).

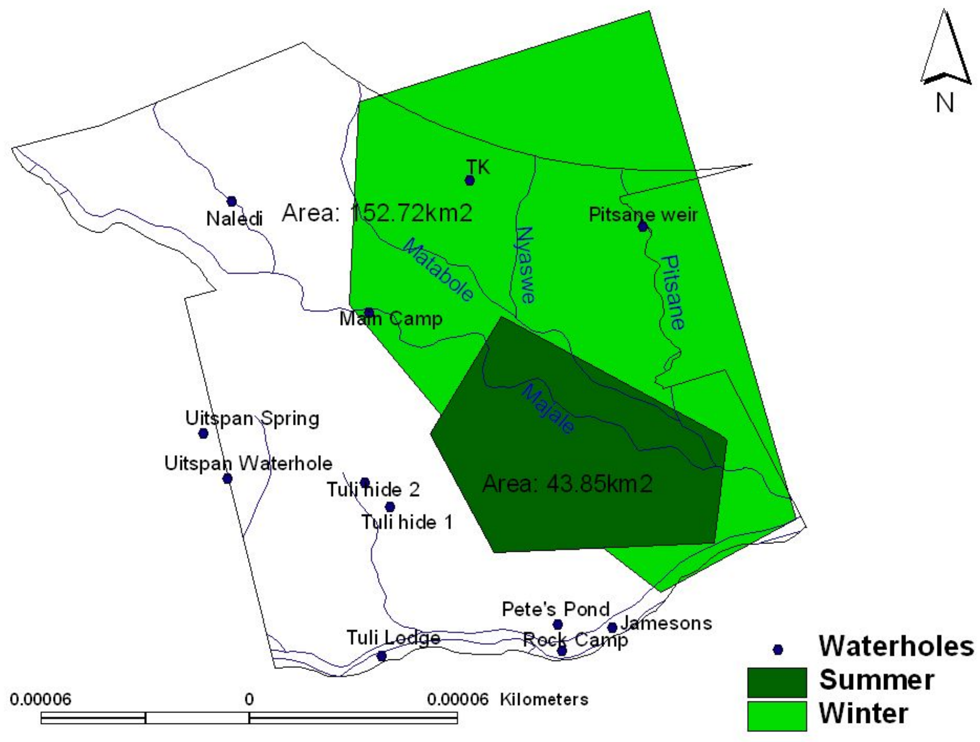

Figure 23a: Winter (dry season) and summer (wet season) distribution of Herd TH

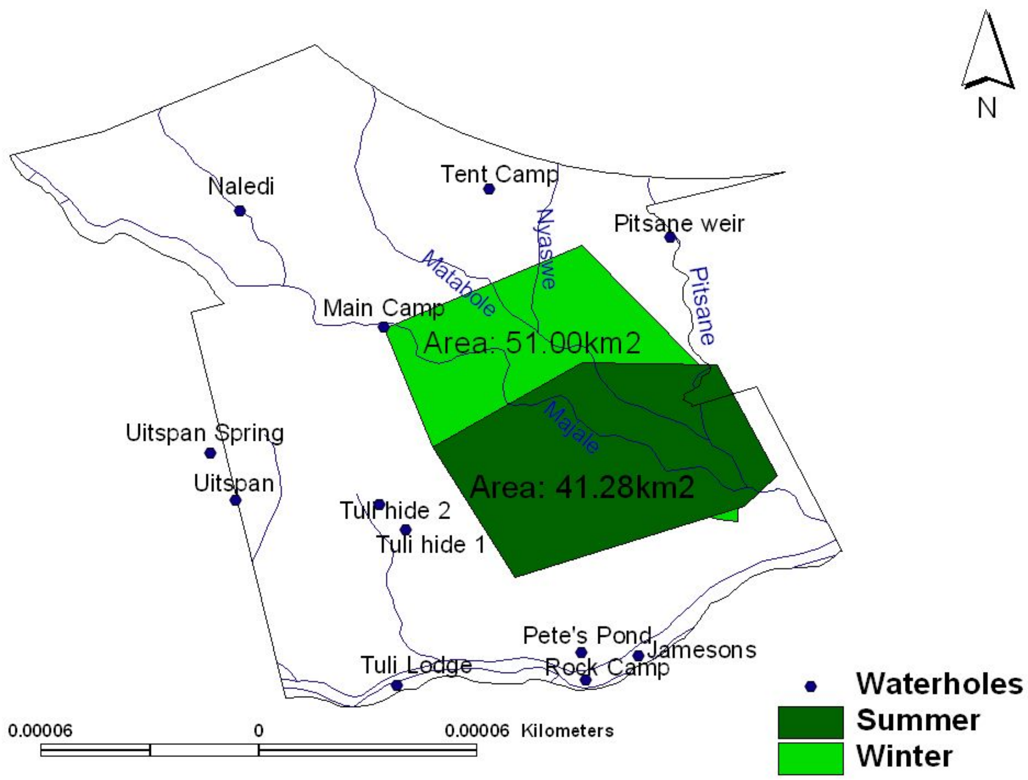

Figure 23b: Winter (dry season) and summer (wet season) distribution of Herd CH

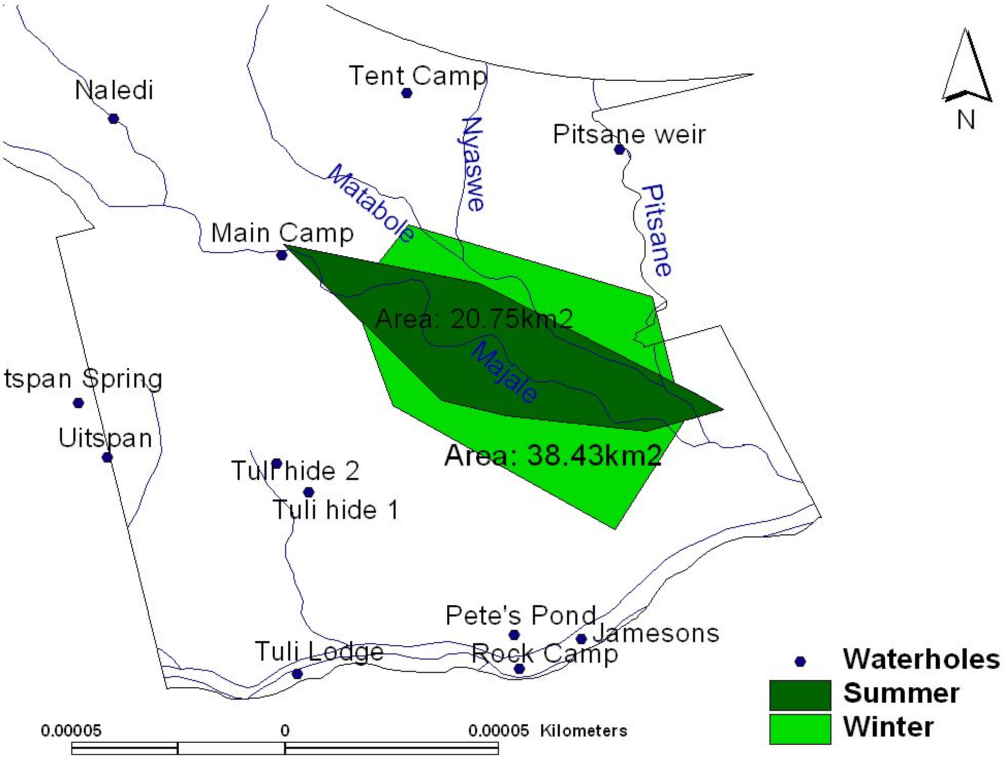

Figure 23c: Winter (dry season) and summer (wet season) distribution of Herd CHR

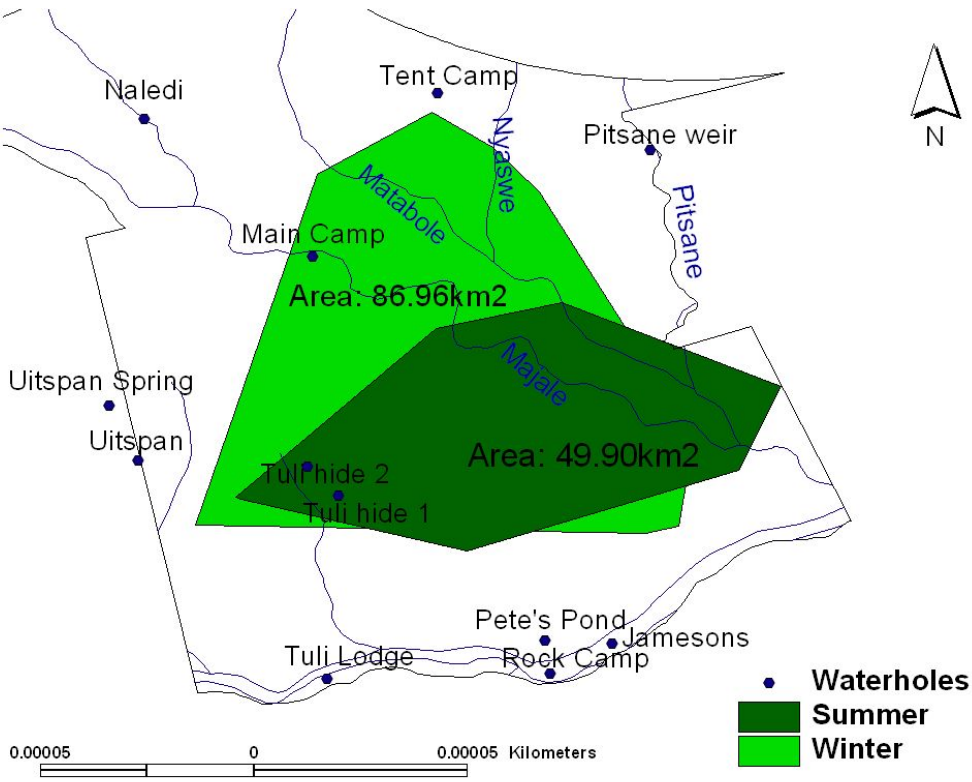

Figure 23d: Winter (dry season) and summer (wet season) distribution of Herd HE

Figure 23(a-d): The dry season (winter) and wet season (summer) distribution of known herds in the Northern Tuli Game Reserve

CONCLUSIONS

The Central Limpopo Valley elephant population is a free roaming population and movement out of the indicated study area occurs. These movements seem to follow the major rivers within the study area namely the Shashe, Ramokgwabane, Simukwe, Shashani, Tuli, Umzingwane and Limpopo rivers. The extent of these movements and the number of elephants involved are as yet unknown.

Due to the continuous cross border movements elephant numbers within the three countries fluctuate and differ between seasons and consecutive years. At present man irrespective of the elephant's preferences largely determines the distribution and long distance movements of elephants within the Central Limpopo Valley. In areas with low human densities elephant numbers increase where as in areas with high human densities elephant numbers decrease.

The major factor determining the seasonal movements of elephants within the Northern Tuli Game Reserve seem to be the availability of suitable food sources and not water. It is proposed that this is the same for the entire study area. Daily movements are mainly determined by temperature with elephants moving into the thick riverine during the day and out into the more open habitat types at night.

Even though the food choices and habitat preferences of elephants have been studied to exhaustion, more still needs to be known about their impact on tree communities and in turn, the responses of woody plants to the utilisation by elephants.

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THE SOCIAL DYNAMICS OF THE CENTRAL LIMPOPO RIVER VALLEY ELEPHANT POPULATION

INTRODUCTION

It is well documented that the African elephant exhibits a complex and dynamic social system with adult males and females living under contrasting social conditions (Douglas-Hamilton and Douglas-Hamilton 1975; Laws *et al.* 1975; Leong *et al*. 2003; Poole and Moss 1989; Poole 1994). The occurrence and size of social groups is highly flexible and patterned in response to ecological conditions. Group size appears to be determined by factors based on habitat quality.

In several studies there appeared to be a relationship between rainfall and group sizes. The dynamics of group sizes within elephant populations are however still poorly understood as well as the effect of rainfall, either directly or indirectly, on group sizes. As part of this study we examined the relationship between rainfall and group sizes in the Central Limpopo River Valley elephant population. It is hypothesized that as elephants reach the ecological carrying capacity and the resources get limited, groups will split into smaller family units and thus increase the competition amongst individual family units.

OBJECTIVES

The objectives of this study were to

1. Determine the group size dynamics of the elephant groups within the study area
2. Determine the influence of rainfall on group sizes

LITERATURE STUDY

Adult female elephants and their dependent offspring live in highly structured social units called family units (Leong *et al*. 2003; Moss 1988). These family units form the basic stable unit in an elephant society (Hanks 1979; Moss and Poole 1983; Moss 1988). Family units consist of related females and their immature offspring, ranging from new-borns to calves up to about ten years old (Moss 1988). The oldest female, the matriarch, leads a family. Male calves leave the family on reaching sexual maturity at anywhere from 10 to 15 years old and largely are solitary although they may form loose bachelor herds (Laws *et al.* 1975; Poole 1994). Female calves stay in the family and begin to breed at around 11years, while producing their first calve at about 13 years of age (Moss 1988). Adult males associate with the females and calves only infrequently (Leong *et al*. 2003; Moss 1988). The family unit of the African elephant averages about 4 – 12 animals (Owen-Smith 1988).

In addition Douglas-Hamilton (1972) has found that family units often have special relationships with certain other family units in the population and that they spend a great deal of their time together. He called the families making up such an association a kin group. Moss (1988) used the term bond group rather than kin group because even though it was thought that the families making up these groupings were one extended family it is not known whether the members were definitely related. Kinship or bond groups form the higher slightly less stable unit and mostly consist of two to four family units with all together less than 50 animals (Hanks 1979). Surveys in the Sengwa Research Area, Zimbabwe indicated the existence of distinct clans of breeding herds, including a hundred or more animals (Owen-Smith 1988). While the ranges of neighbouring clans overlap peripherally, members of different clans are seldom in the overlap area at the same time (Martin 1978; Owen-Smith 1988).

Several factors may influence the merging or splitting of elephant groups. Larger groups may be formed following disturbances and disruption of the normal pattern of social life (Barnes 1982; Douglas-Hamilton 1972; Hanks 1979; Moss 1983; Western and Lindsay 1984). Buss (1990) also found that the congregation of some large groups might be a prelude to an intended migration. A positive correlation was found between group size and density (Buss 1990). This could be as a result of elephants encountering each other more in an area where elephant's densities are high or elephants are confined.

The spatial occurrence and size of social groups is highly flexible and patterned in response to ecological conditions (Abe 1994). Dublin (1996) and Whitehouse and Schoeman (2003) showed that group size appeared to be determined by factors other than random aggregation based on habitat preference. In general, average group size was correlated with season, with larger groups forming in the wet season when availability of preferred forage is greater. Such seasonal variation in group sizes may be attributed to the seasonality of mating and birth peaks (Dublin 1996). In a number of populations mating occurs during or slightly after the peak of the rains (Dublin 1983; Hanks 1969; Moss 1983). At this time males temporarily join cow-calf herds to gain access to oestrus females. Births then occur just before or during the rains (Dublin 1983; Hanks 1969). Group formation patterns and the sex ratio play an important role in mate searching (Barnes 1982; Poole 1989; Poole and Moss 1989).

Leuthold (1976) also found a positive relationship between the mean group size and rainfall. Elephant's tend to aggregate in areas of green vegetation following substantial rainfall. The mean group size was greater in areas with more open vegetation than in those with denser woody cover and also varied seasonally, with higher mean group sizes found in the rainy season than in the dry season (Dublin 1996).

METHODS

Group size distribution

In this study the term 'group' was defined operationally as any number of elephants that are associated in space and appear to be fairly co-ordinated in their activity at the time of observation (Leuthold 1976).

Groups were separated into units containing only adult bulls and units containing females of all ages and young males as well as mixed groups consisting of female groups and adult bulls. In this way the basic unit of elephant social organisation can be studied (Viljoen 1988).

Operationally the basic family unit in this study was defined as the maximum number of individuals which forms a close association especially during times of stress (e.g. dry season) and which are always co-ordinated in their movements and geographical range.

Field data were collected from observations of elephants in the Northern Tuli Game Reserve and surrounding areas in Botswana as well as in Zimbabwe from September (1999) to December (2004). Notes were kept on group size and composition, range, habitat type, distribution of tracks, activity patterns, physical condition and feeding habits. Monthly rainfall data was obtained from the Pont Drift weather station.

Aerial Surveys

The purpose of the aerial counts was to determine, not only total numbers of elephant – population size – but also their detailed distribution, movements and group size frequency distributions. For this reason "complete" area counts were made in August 2000, July 2001 and October 2004. The number of groups observed during the aerial counts and the composition of the groups established from the aerial photographs were used to determine the group sizes and social structure of the population. Elephant data from total aerial game counts conducted within the Northern Tuli Game Reserve from 1986 to 2004 were included in the group size data analysis.

Estimation of the numbers in known herds

Individual elephants were identified by the patterns on the edges of the ears and by tusk and tail characteristics (Croze 1974, Moss 1988). The cuts and holes are acquired through encounters with branches, thorns and other elephants, as the animal grows older. Animals from one to three years old invariable have smooth ear edges (Croze 1974). The variation in the type of distinctive marks (large or small V-shaped, U-shaped or square cuts, or holes) which can be combined in a number of ways on various parts of the ear edge, makes at least 15 000 possible ear-prints (Croze 1974). When ear-print information is combined with the size, shape and any peculiarities of the tusks (breaks, one-tuskedness, asymmetry) and the shape and thickness of the tail hairs, the number of different marking combinations is vast and consequently the chance of confusing two elephants is very small (Croze 1974).

Individuals in the various groups of elephants located during traverses of the study area (range of the elephant population) were identified. The group was identified from these known animals. Sizes and locations of all such groups were noted and mapped at various times during the study period (September 1999 – December 2004).

Data analysis

Group size data obtained were grouped into group size classes. Group size classes used were 1 - 3; 4 - 5; 6 - 10; 11 - 15; 16 – 20; 21 – 30; 31 – 50; 51 – 75; 76 – 100; 101 – 150; 151 – 300; >300 elephants. For the regression analysis group sizes 151 - 300 and >300 were combined to form one group size >150.

RESULTS AND DISCUSSION

Group size category 21 – 30 elephants showed the highest percentage occurrence at the end of winter (October) and in mid-summer (January) (Figure 24a-b). This modal group size is much higher than the 8 – 10 elephants per family unit as found by Lee (1991) and the 4 – 12 animals as found by Owen-Smith (1988).

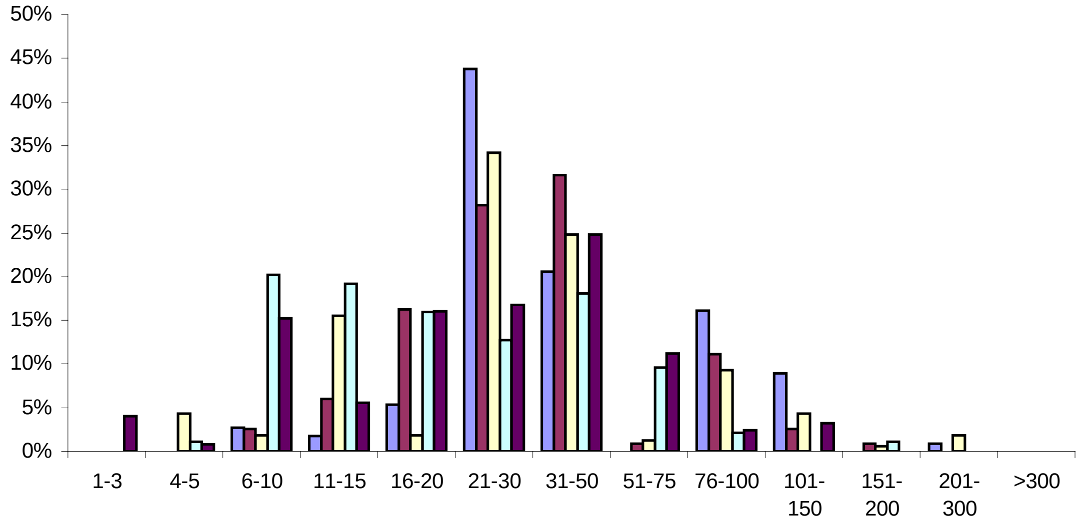


Figure 24a: Percentage of groups per group size category during January 2000 to 2004. Rainfall in the '99/'00 season was 916.70 mm, in the '00/'01 season 168.20 mm, the '01/'02 season 329.50 mm, the '02/'03 season 218.50 mm and the '03/'04 season 257.30 mm

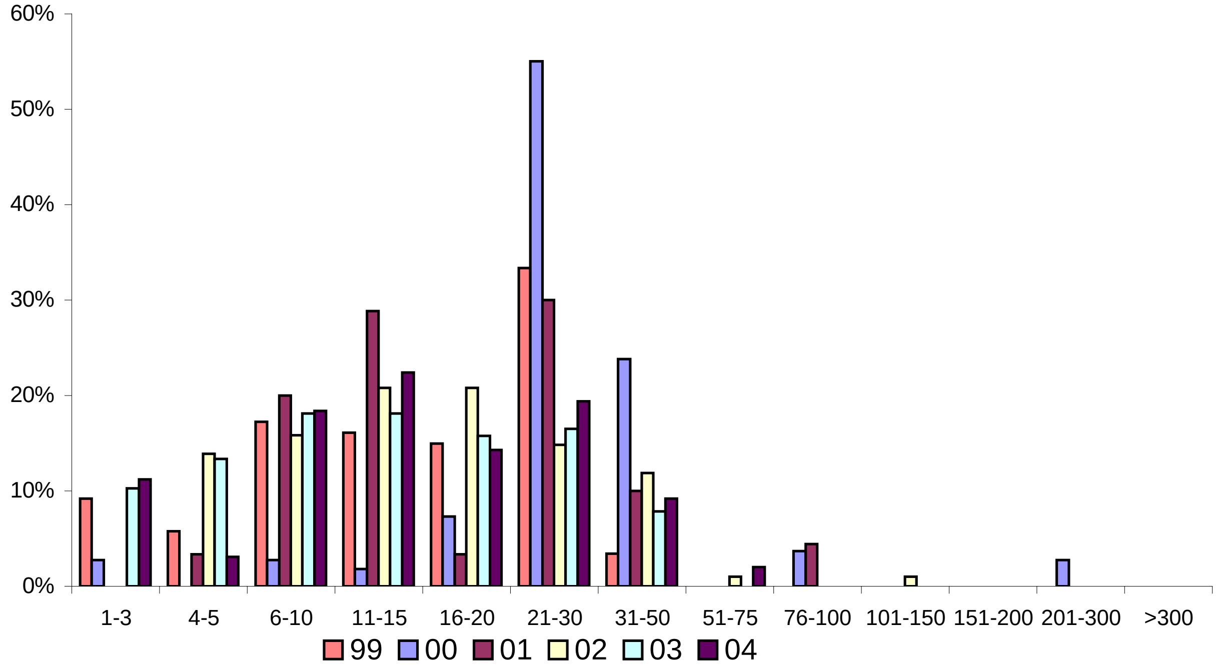


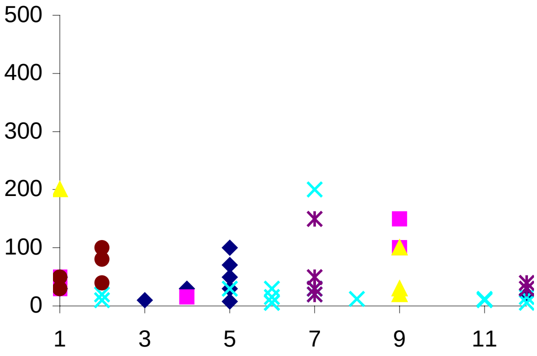
Figure 24b: Percentage of groups per group size category during October 2000 to 2004. Rainfall in the '99/'00 season was 916.70 mm, in the '00/'01 season 168.20 mm, the '01/'02 season 329.50 mm, the '02/'03 season 218.50 mm and the '03/'04 season 257.30 mm

An explanation might be the high densities of elephants occurring within the reserve. The higher the densities of elephants, the more often they will encounter each other and thus the more often are sighted together.

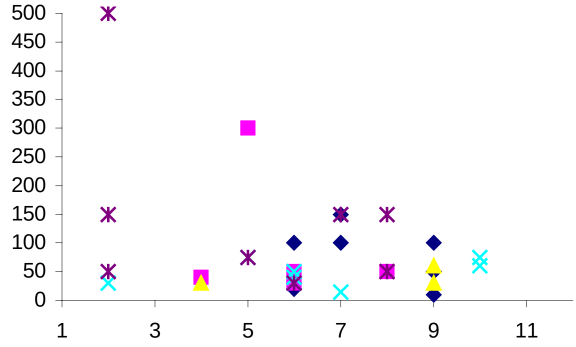
Months with high rainfall resulted in larger groups. For the years 2000 to 2004 during January, a high rainfall month, a higher percentage of large groups were observed and fewer smaller groups (Figure 24a), while during October, a low rainfall month, of the same years a higher percentage of smaller groups and fewer large groups were observed (Figure 24b). During years were the rainfall continues to be high for several months the larger groups seem to stay together for longer periods. During years with low rainfall smaller groups are observed and the large groupings are less stable with groups joining and breaking up regularly within shorter periods of time. This corresponds to other studies where the size of the group in which an individual may find itself can change from day to day and season to season, with small scattered groups typically in the dry season and large aggregations more common in the wet season (Western and Lindsay 1984).

Ground observations of known groups showed that smaller groups combined to form larger groupings during certain times of the year (pers. obs.)(Figure 25a-h). The smallest group size of family units PA, DI, CHR and AG was approximately 15 elephants. From March through to June all these groups were regularly seen in groupings ranging from 50 to 300 elephants (Figure 25a-h). For family unit CH the group size ranges from 30 to approximately 300, with the largest groupings observed during March to June. Family unit BLU is a fairly large group with an average group size of 40 elephants. Family unit BLU often joins up with other groups forming larger groups ranging in size to a maximum of 500 observed in December 2003. The majority of the large groupings were observed between March and June for all known groups presented in Figure 25. When comparing this to the seasonal rainfall in the reserve there appears to be a direct relationship. During 2000 the highest rainfall was measured within the reserve with January to March receiving the largest amount of rain (Figure 25h).

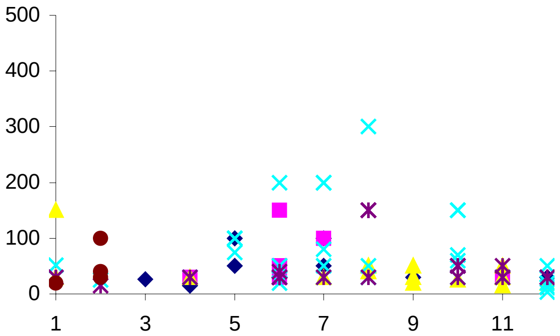
Group sizes were consistently smaller from July onward and no large groups were observed during September or October (Figure 25a-h).



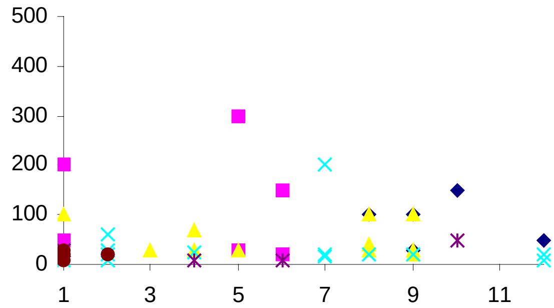
(a) Herd AG



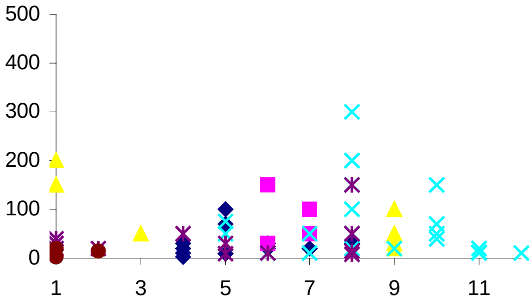
(b) Herd BLU



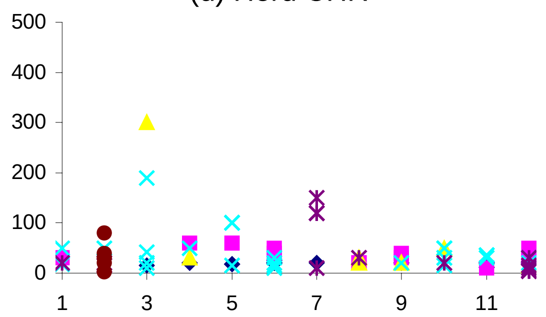
(c) Herd CH



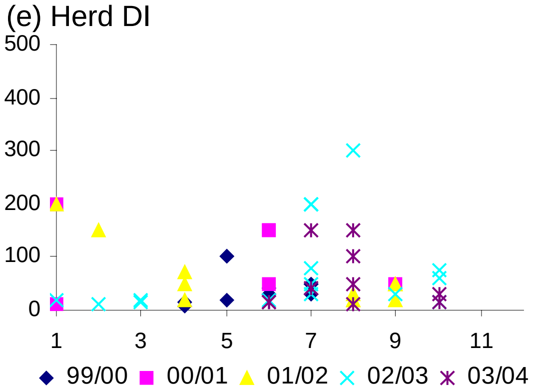
(d) Herd CHR



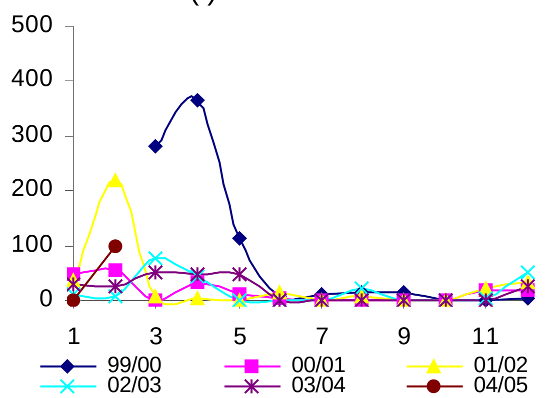
(e) Herd DI



(f) Herd HE



(g) Herd PA



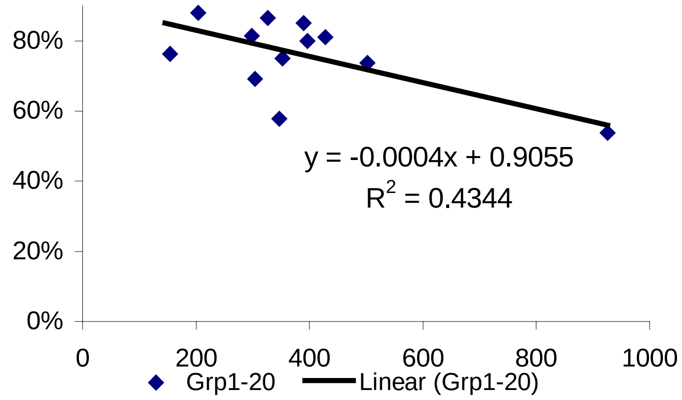
(h) Seasonal rainfall

Legend: Horizontal axis labels are 1=November; 2=December; 3=January…..12=October

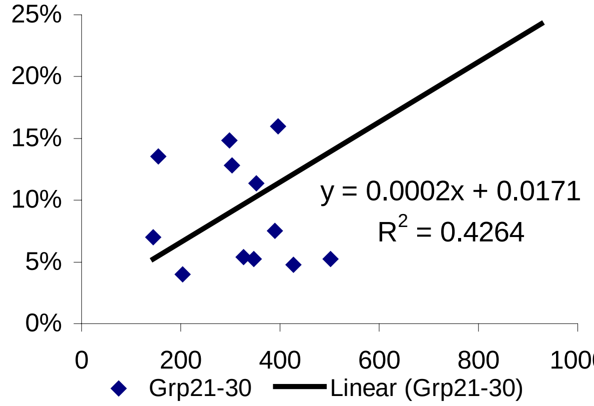
Figure 25a - h: Group size distribution of known groups within the Northern Tuli Game Reserve related to seasonal rainfall

During the wet months March to June bulls are more frequently observed with the breeding groups and more matings were noted over this period. In a number of populations mating occurs during or slightly after the peak of the rains (Dublin 1983; Hanks 1969; Moss 1983). At this time males temporarily join cow-calf groups to gain access to oestrus females. Births then occur just before or during the rains (Dublin 1983; Hanks 1969). Group formation patterns and the sex ratio play an important role in mate searching (Barnes 1982; Poole 1989; Poole and Moss 1989).

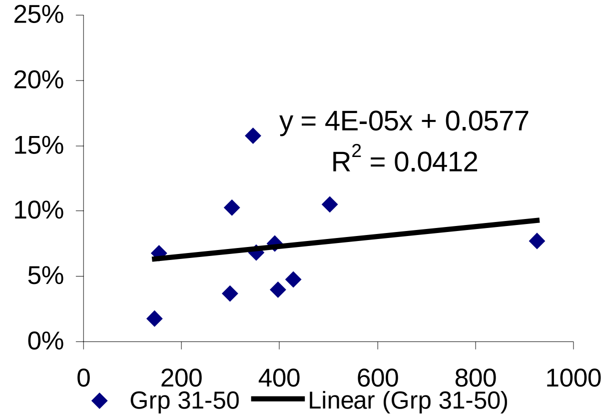
A decline in the proportion of smaller groups (1-20 individuals) was observed or both the annual aerial census data and random field observations of group size 1 – 20 in February and October with increased rainfall (Figure 26a and Figure 27a). All other group size categories showed a positive regression with increased rainfall (Figure 26b-f and Figure 27b-f). The proportion of all other group size categories increased with increasing rainfall, however figure 26(b-f) and figure 27(b-f), indicates the merging of smaller groups into larger ones.



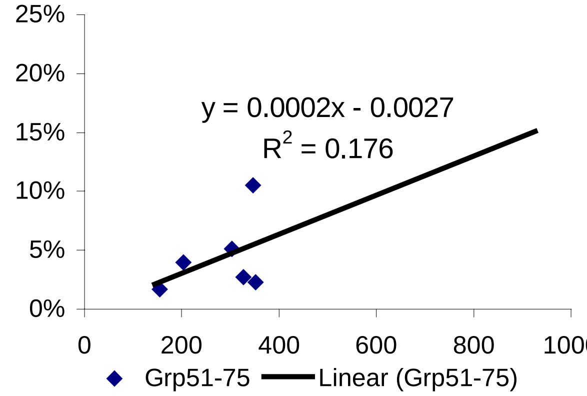
(a) Group size 1-20



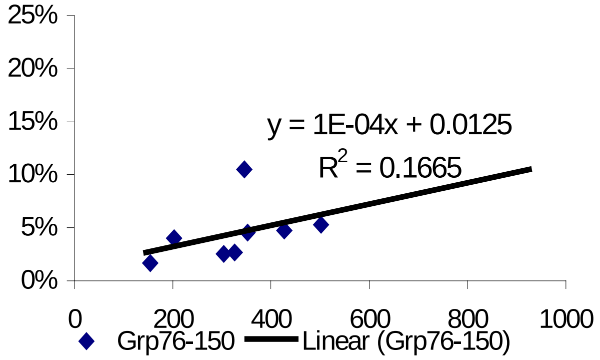
(b) Group size 21-30



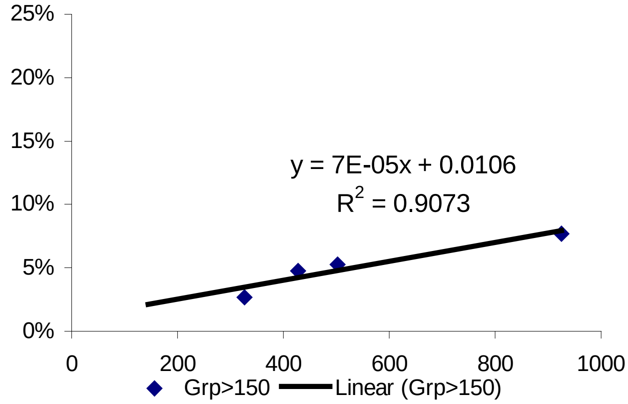
(c) Group size 31-50



(d) Group size 51-75

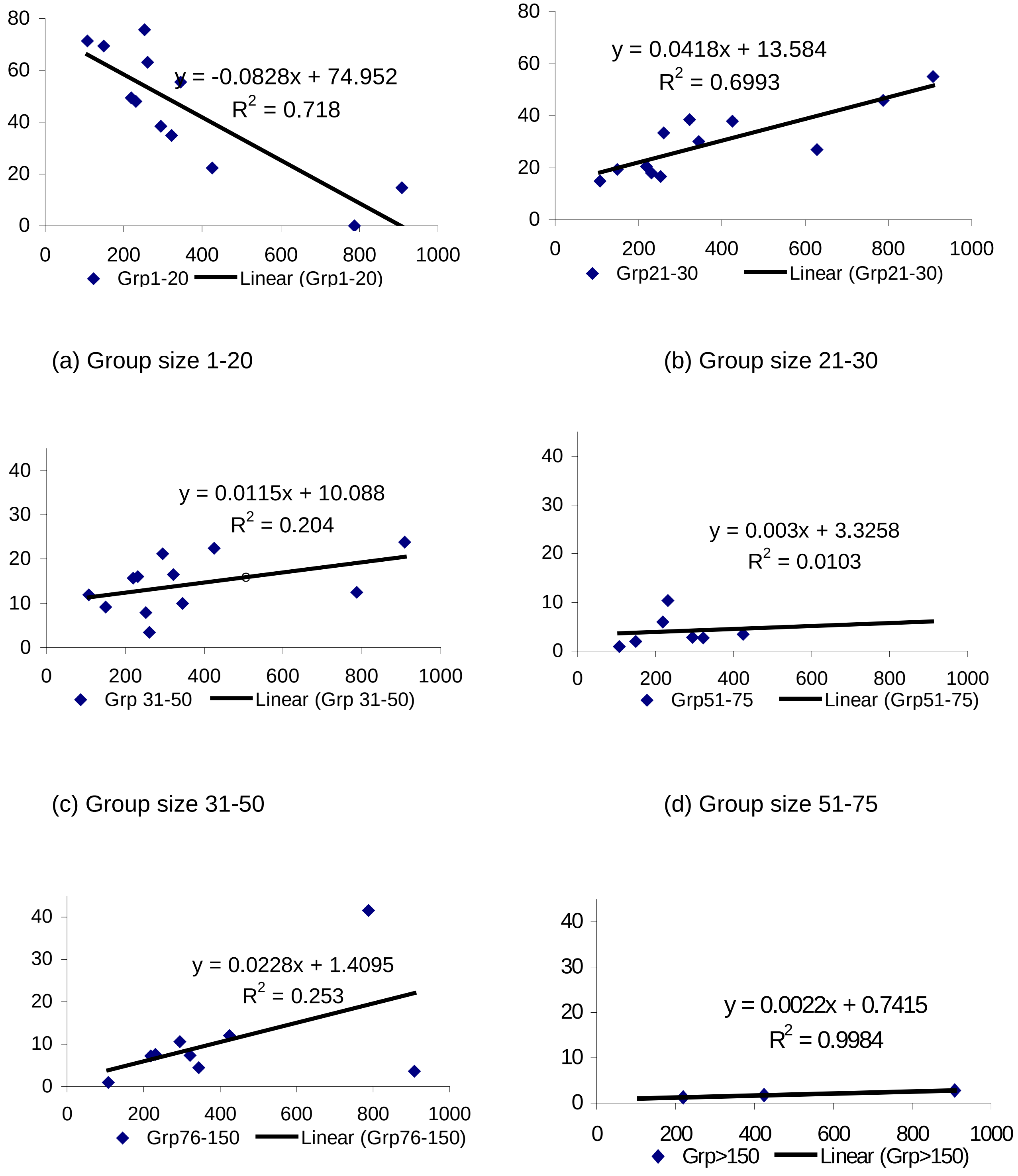


(e) Group size 76-150



(f) Group size >150

Figure 26a-f: Percentage of groups per group size category related to rainfall in the preceding 12 months. Data obtained from the total aerial counts within the NTGR during June to September - 1986 to 2004



(a) Group size 1-20

(b) Group size 21-30

(c) Group size 31-50

(d) Group size 51-75

(e) Group size 76-150

(f) Group size >150

Figure 27a-f: Percentage of groups in size categories in month of count (February and October) related to rainfall in the preceding 12-month period. Data collected from ground observations in the North Tuli Game Reserve

The average mean group size in months following high rainfall (defined as a month in which the total collective rainfall in preceding 12 months was above 900 mm) was 56.524 animals per group with a larger SDE (77.388), while the average mean for months following dry periods (months with total collective rainfall for preceding 12 months below 367 mm) was 24.157 animals per group and the SDE (22.223) (Table 14). The increase in the mean group size in the wet months is a result of family units merging, and increase in the number of bulls present in the groups. During the wet months the food availability increases as a result of the higher rainfall. During the dry month the mean group size decline due to the foraging efficiency of smaller groups when food is scarce. Fewer bulls are observed within the family units over the dry months.

Table 14: Comparison of group sizes in different months in relation to 12 month preceding rainfall

	12 month preceding rainfall (mm)		Per month					Combined		
			Mean	SDE	Median	Largest group	Smallest group	Mean	SDE	Median
Wet winter										
Jul 00 (n=48)	925.90	1	70.354	91.717	30	300	7	56.524	77.388	30
Aug 00 (n=22)	925.90	2	52.455	74.151	22	320	5			
Oct 00 (n=33)	925.90	3	39.121	50.158	30	300	6			
Wet summer										
Dec 00 (n=22)	907.70	1	32.727	21.029	30	80	5	40.689	30.570	30
May 00 (n=23)	903.80	2	48.304	36.372	30	150	11			
Dry winter										
Jul 01 (n=91)	154.50	1	21.703	23.626	13	150	3	24.157	22.223	15
Sep 01 (n=87)	172.00	2	26.724	20.476	30	100	3			
Dry summer										
Dec 02 (n=24)	107.80	1	31.292	37.913	20	200	6	30.932	29.450	20
Jan 03 (n=93)	178.80	2	30.840	27.121	20	190	5			
Intermediate Winter										
Oct 99 (n=27)	366.40	1	9.296	5.737	9	20	3	24.132	31.467	12
May 04 (n=44)	280.30	2	46.227	42.981	30	150	3			
Oct 04 (n=88)	230.20	3	17.636	22.748	10	150	3			
Intermediate summer										
Feb 02 (n=25)	322.30	1	40.000	22.730	30	100	10	37.352	23.181	30
Apr 04 (n=29)	280.30	2	35.069	23.720	30	100	10			

CONCLUSIONS

The most common (modal) group size in the Northern Tuli Game Reserve is between 21 – 30 elephants. This is larger than the 4 – 12 animals described in other studies (Lee 1991; Owen-Smith 1988). The density of elephants within the area could possibly explain the larger mean group size within the Northern Tuli Game Reserve. Due to the higher density of elephant groups, they will more often encounter each other and are thus more often seen together.

This study has shown that group sizes increase with an increase in rainfall and decrease during low rainfall periods. This may be a result of resource availability. Food quality depends on rainfall with higher rainfall resulting in a better quality of food. Studies elsewhere suggested that the reason why groups break up is as a result of increased competition for available food resources (Douglas-Hamilton 1972; Leuthold 1977 as quoted by Abe 1994).

It thus appears that the hypothesis that as elephants reach carrying capacity and the resources become limited, groups will split into smaller family units and thus increasing the competition amongst individual family units, is valid.

Having established the above, the threshold for when groups merge or split needs to be determined. A better understanding of how group sizes and daily ranging are related and what the influence of this will be on the increase in elephant groups will lead us one step closer to understanding what limits elephant populations.

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THE DEMOGRAPHICS OF THE CENTRAL LIMPOPO RIVER VALLEY ELEPHANT POPULATION

INTRODUCTION

African elephants are long-lived mammals with a relatively long period of sexual immaturity and a slow rate of reproduction. These characteristics present various problems in the study of their population dynamics and most particularly the constraint of collecting long-term data on elephant demography (Moss 2001).

Elephants are an important component of the African ecosystems, and it is thus important to understand the key demographic parameters essential for the conservation of the species and the areas in which they occur. It is equally important to understand the variables of elephant life history in order to interpret most aspects of elephant behaviour and social organisation (Moss 2001).

The benefits of long-term population research are increasingly being acknowledged (Moss 1981; Moss 1988). However, as a result of logistical, financial and other constraints, examples of successful detailed long-term studies are inevitably few. Owing to the longevity and slow breeding rate of elephants, demographic data obtained from short-term studies may produce misleading results (Whitehouse and Hall-Martin 2000).

The Central Limpopo Valley elephant population is the largest free-roaming population on private land south of the Zambezi River (Walker 1977). Through three aerial censuses (2000; 2001 and 2004) the total population has been estimated at 1400 elephants. However, very little scientific data pertaining to the demographic status of the population has been collected. In the light of the proposed Shashe/Limpopo Trans Frontier Conservation Area research on the social and demographic structure of the population is urgently required.

From January 2000 to December 2004 an individual identification study of the elephant population visiting the Northern Tuli Game Reserve was conducted. Data on demography, social behaviour and group size patterns were gathered.

OBJECTIVES

The objectives of this study were to

1. Determine the age structure and sex ratio

2. Determine the birth rate and inter calf interval of the elephant population
3. Determine the mortality rate within the elephant population
4. Determine the intrinsic rate of increase for the elephant population

LITERATURE STUDY

Patterns of social organisation reflect the cooperative and competitive interactions occurring amongst animals within local populations relating to survival and reproduction (Owen-Smith 1988). Among African elephants adult bulls and cows live under contrasting social conditions with bulls and cows only associating temporarily for breeding (Leong *et al*. 2003; Poole 1994). Elephants are non-seasonal breeders, thus reproductively active females may be present all year round (Buss and Smith 1966; Moss and Poole 1983). Generally a single calf is born after a gestation period of 22 months. The calving interval depends on habitat conditions and can extend up to 13 years (Laws 1969), but is usually between 4 and 5 years (Abe 1994). In Amboseli National Park the calving interval of individually known animals has been estimated over a period of ten years to be approximately 4.7 years (Lee and Moss 1986). This figure, however, varies between individuals and between years depending on rainfall and habitat conditions (Poole 1982).

Age structure is an important parameter in the analysis of population dynamics for several reasons. Not only does it reflect the net fecundity and mortality schedules of a population (Bhima and Bothma 1997; Lindeque 1991), but can also be used as an indicator of population increase (Bhima and Bothma 1997; Croze 1972). Furthermore, it has value as a basis for comparison between populations in differing environments (Caughley 1977; Croze 1972). If assessment of the age structure is made more intensively, say on a bi-monthly basis it is possible to calculate seasonal recruitment and age-specific mortality (Caughley 1977; Croze 1972). Age structures, however, are difficult to obtain with precision, and are only as accurate as the techniques used for estimating the age of individuals (Lindeque 1991).

Methods for estimating age in African elephants (*Loxodonta africana*) have received much attention (Buss 1990; Croze 1972, Croze 1974; Douglas-Hamilton 1972; Laws 1966, 1969; Lee and Moss 1986, Lee and Moss 1995; Sikes 1966, Sikes 1967; Western *et al*. 1983).

Several methods for ageing elephants exist ranging from recording the births of individuals and thus obtaining knowledge of absolute age to rough estimates based on general appearance. The type of study will determine what methods are to be used. Birth registration along with individual recognition is the most accurate method of collecting demographic data.

Age estimates and population age structures can be derived from ground and aerial surveys using a variety of methods including measurements of shoulder height (Laws *et al*. 1975; Lee and Moss 1995; Leuthold 1976), back length (Croze 1972; Laws 1969), foot print length (Lee and Moss 1986; Lee and Moss 1995; Western *et al*. 1983) and dung bolus circumference (Jachmann and Bell 1984; Lindeque 1991; Martin 1983) as well as assessments based on visual estimates (Moss 1990; Moss 1996; Poole 1989). All of the above methods rely on assumptions and projections to describe the population's history and predict its future trends (Moss 2001).

If reasonable close estimates of the ages of live elephants in the field is possible, it would be relatively easy to keep a check on the changing age structures of the populations being studied. In a study of this kind any changes are likely to be more pronounced in the early age groups, which are most easily identified (Laws 1966).

Laws (1966) has shown that shoulder height can be used for estimating age with reasonable accuracy up to maturity in females and considerably beyond in males. These close relationships that exist between body weight and shoulder height and body weight and total length are best expressed as logarithmic functions (Buss 1990). The correlation coefficient between shoulder height and body weight is 0.99, and between body weight and total length is 0.97 (Buss 1990). These values can serve as useful tools in the field. Body weight can thus be extrapolated with high confidence from either the shoulder height or total length (Buss 1990).

Douglas-Hamilton (1972) developed a method for assessing the ages of the Manyara elephants using photographic parallax to measure height. This technique was later used and improved by Hall-Martin and Rüther (1979). Also Croze (1972) used an aerial photographic method for analysing the age structure of elephant populations. Leuthold (1976) in Tsavo National Park, Kenya, obtained aerial photographs of elephants from which he measured body length, extrapolated ages from the body lengths and placed the elephants into five year age groups for management purposes.

The aerial photographic technique for age-structure assessment is a quick technique and provides important population dynamics information relevant to one of the most serious wildlife management problems in Africa namely the interaction of elephants and their habitats (Croze 1972). The method consists of photographing elephant breeding herd groups vertically, measuring their relative lengths and then relating the lengths to a mean breeding herd growth curve (Croze 1972).

The technique is relative simple and requires only an aircraft, a 35 mm camera and an enlarger or projector – equipment to which most management agencies have access. It takes less time and efforts than a full-scale cropping programme (Croze 1972). The data are less comprehensive, but the data on elephant population age-structure and numbers can provide enough information to describe the current status of a population and to predict future trends (Croze 1972). Moreover, an aerial photographic technique avoids any bias, which may occur with sampling of small groups, which is usually necessary in elephant cropping (Croze 1972).

Laws (1969) applied an aerial technique to ageing elephants from Tsavo National Park (Kenya) and Murchison Falls National Park (Uganda). He assessed the age structures of several populations by comparing elephant lengths measured on vertical aerial photos to an age/length ratio key derived from post-mortem data. Two different techniques were used. With either method the age structures from aerial photography conformed nicely to those derived from post-mortem results (Croze 1972).

The technique used by Croze (1972) differs in three aspects to that used by Laws (1969):

1. It requires no aircraft height data.
2. It corrects for photogrammetric errors inherent in the technique.
3. Up to the age of 24 years, divides the age-scale into finer intervals than 5-year groups.

Laws (1969) post-mortem data showed that the best measurements of length were a straight line from the junction of the ears to the base of the tail. This was the least variable parameter and was found to be almost exactly equal to the shoulder height, although elephants continue to grow in length after they have stopped growing in height (Croze 1972).

The greatest assumption in the method is that it is legitimate to apply one growth curve to different elephant populations. Laws (1969) reckoned such an assumption might be valid. The technique however is expensive and several difficulties might be experienced while obtaining photographs of the elephant herds. According to Thouless (pers. comm.) [13] data obtained through this method were inaccurate and he questions the previous results obtained through this method. Other Authors however accept the method as accurate enough to classify elephants in broad age classes in order to determine the age structure of the population.

Distinctions in size can be made between different aged animals up to at least middle age (approximately 30 years) (Croze 1972). Up to about 15 years, the growth of the sexes is rather similar; thereafter the faster growth rate of the male results in a progressively increasing size discrepancy (Laws 1966). The estimated shoulder height at birth is 86 cm and at one year about 114 cm (Laws 1966). It is generally accepted that young elephants are able to walk under their mothers belly during most of the first year of life and this criterion can be used to classify the young-of-the-year (Laws 1966). Genetic factors are known to be modified by the uterine environment and it can be reasonably assumed that in general calve size is related to maternal size (Laws 1966).

Calves are easy to distinguish up to six months of age on size and the overlap of the pinnae on the head. Young calves are still hairy, while the older ones have a more "polished" look (Hall-Martin 1992).

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. Bulls continue to grow in shoulder height and in tusk circumference but its head becomes larger across the forehead and at the base of the tusks, giving the head a more hourglass appearance from a front view as it gets older (Poole 1989; Poole 1994). 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.

The sex ratio of newborn calves does not differ significantly from 1:1, but the adult sex ratio is significantly female biased (Moss 1988; Whitehouse and Kerley 2002). In

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Amboseli the adult sex ratio (females and males over 15 years) was 1:2.5, males to females, where as data from Addo Elephant Park shows 49 males: 75 females (>12years of age) at the end of 1988 (Whitehouse and Kerley 2002). When comparing the sex ratios of breeding adults (females over 10 years and males over 25 years old) are 1:3.5 (Abe 1994). This corresponds with the findings from Laws (1969) that under natural conditions, the adult sex ratios of elephant populations are skewed in favour of females. It was found by Abe (1994) that in highly poached populations the adult sex ratio is highly skewed in favour of females.

From an extensive search in the literature very few relevant publications on the mortality and natality rates in elephants could be found (Bhima and Bothma 1997; Dudley *et al*. 2001; Jachmann 1986; Laws *et al.* 1975; Moss 2001; Viljoen 1988; Whitehouse and Hall-Martin 2000).

METHODS

An interpretation of the demographic status of the population was determined by constructing an age distribution for males and females separately and interpreting the age structure in terms of the structure of populations in other localities, and attempting to explain any differences.

Age structure

Categorical age structure from relative back lengths from aerial photography

Assessing the age structure from aerial photographs is a quick technique and provides important population dynamics information. The method consists of photographing elephant groups vertically, and grouping the individuals in the different age classes.

During August 2000 vertical aerial photographs were taken of elephant groups in different areas within the Northern Tuli Game Reserve and the Tuli Block. The photography was conducted during the dry season. During the sampling session photographs were taken from a helicopter with a 35 mm motorized Canon camera. The photographs were analysed by subjectively grouping the individuals in different age classes based on the ratio of the biggest female in the photograph to all the other elephants within the photograph. For the purpose of age structure analysis four age classes were created. The age classes used were as followed:

Infant	0 – 2 years
Juvenile	3 – 8 years

Sub adult	9 – 15 years
Adult	16 years and older

All elephants were numbered and consecutive photographs were compared.

Sex ratio

The sex of living elephants was determined by the outline of the forehead. The forehead of the female has a distinct angle as opposed to that of bulls in which the forehead curves smoothly downward (Hanks 1979; Skinner and Smithers 1990). In addition both males and females have tusks although tusklessness occurs. The rate of tusk growth is sexually dimorphic. In females the rate of growth is linear, whereas in males the growth rate increases progressively throughout life (Laws 1966; Pilgram and Western 1986).

Birth rate

Various characteristics can be used to facilitate identification of individual elephants (Douglas-Hamilton 1972; Moss 1988). These include: sex; age and body size; ear shape and notches and holes present; patterns of blood vessels in the ears and wrinkles on the face; size, shape and configuration of the tusks; lumps on the body and breaks, kinks or baldness of the tail (Whitehouse and Hall-Martin 2000). Together these features provide the necessary variation to enable recognition of each elephant within the population.

During this study elephants within the Northern Tuli Game Reserve were identified and a photographic record of the population was initiated and is ongoing. Identification photographs of all females and adult bulls were taken during ground observations of the herds within the reserve. The number and approximate ages of all calves associated with the respective cows were noted at each sighting using the age classification of Hanks (1979) and Moss (1988). All births observed were recorded. The mean inter calf interval was determined by calculating the inter calf interval for known elephant cows within the Northern Tuli Game Reserve. Data collected through ground observations of breeding herds during 1995 and 1996 by a previous researcher (Dr. Marion Garaï) were incorporated were applicable in determining known individuals and inter calving periods of individuals identified by Dr. Garaï.

Mortality rate

Data on elephant mortalities were collected throughout the study area from July 1999 to December 2004. Within the Northern Tuli Game Reserve accurate data were obtained through personal observations and notification of any dead elephants discovered on the reserve by any of the managers or landowners. Data on mortalities outside of the reserve were more difficult to obtain. Various hunting operations, landowners and government organisations were contacted to assist in obtaining correct data on elephant mortalities. Unfortunately the data received were not complete for most of the study area.

A GPS coordinate was taken of the position of any carcasses discovered within the Northern Tuli Game Reserve. The sex, shoulder height and cause of death were determined where possible. From the shoulder height the approximate age of the animal was determined.

RESULTS AND DISCUSSION

Age structure

A total of 499 elephants were measured from aerial photographs. This amounts to 35.95% of the total number of elephants counted within the Central Limpopo Valley during August 2000 (Table 15). The percentage of adults and sub adults within the population was high (49% and 30% of the total number photographed respectively) with a low infant percentage (3% of the total sample). This is much lower than percentages observed in other areas in normal rainfall years e.g. 8.5 – 9.5% in Etosha National Park, Namibia in May 1984 and August 1985 respectively (Lindeque 1991) and 10.1% in Kruger National Park, South Africa in 1995 (Anon. Referee pers. comm. as quoted by Bhima and Bothma 1997).

Table 15: Age structure of the Central Limpopo Valley elephant population

Adult >15 years	Sub Adult 9-15 years	Juvenile 3-8 years	Infant 1-2 years	Total
246	151	88	14	499
49%	**30%**	**18%**	**3%**	**100%**

The proportion of adults (>15 years) varies from 34-38% in increasing populations, such as Kruger National Park (South Africa) and Manyara (Tanzania), to over 50% for populations that were stable, or recovering from large-scale drought mortality (Owen-Smith 1988). In Liwonde National Park (Malawi) after several years of above average rainfall, low densities and low poaching the population was mainly made up of animals 10 years or younger (Bhima and Bothma 1997), with the age structure having a classical pyramid-shape indicative of a young growing population.

The high number of sub adults and adults within the Central Limpopo Valley elephant population thus indicates a relative stable population.

Sex ratio

During the three total aerial counts and from aerial photographs taken it proved difficult to identify bulls from the air. When assumed that all groups counted with two or less individuals will likely be bulls a total of 25, 43 and 33 bulls were counted during the aerial counts in 2000, 2001 and 2004 respectively (Table 16).

Page (1980) suggested that there was a marked skew in the adult male: adult female ratio (1:3.9). Hall-Martin (1987) calculated a ratio of 1:3. Elephants have been shot in the area regularly since they first appeared. Where crop raiding occurred both males and females were shot, but more frequently males. There has been regular hunting of bulls in the Tuli controlled hunting area in Zimbabwe (Walker 1971).

Birth rate

Table 15 indicates a birth rate of 1.5% in 2000. This is probably low due to the below average rainfall in the years 1996 to 1998 (348mm, 370mm and 136mm respectively).

Calving interval

The inter calf intervals of 28 known cows within the Northern Tuli Game Reserve were calculated from 1988 to 2004 (Table 17). The mean inter calf interval is 3.94 years. The median is 4 and the range is 3 to 10. Females BOT01, CH02 and HE01 had exceptionally long inter calf intervals during 1998, 2002 and 2001 respectively (Table 17). These long inter calf intervals could be due to drought conditions extending from 1996 to 2000. Long inter calving period for female HE01 could be a result of her age. HE01 is estimated to be between 50 and 55 years old at present.

Table 16: Comparison of free roaming male and female herd numbers in three different years counted

	Aug-00	01-Jul	04-Oct
Total	1262	1294	990
Number of free roaming bull groups	18	33	23
Number of free roaming bulls	25	43	33
Number of Breeding herds	36	72	59
Number in Breeding herds	1237	1251	957

Table 17: Inter calf period in years for known female elephant within the Northern Tuli Game Reserve

Individual females	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
ABI01											*				4		
ABI02												*			3		
AG01						*		3			3			3			3
Agnes (AG02)								*					5				
Botshelo (BOT01)				*							7			3			
Charge (CH01)				*					5				4				
Broken Tusk (CH02)					*										10		
Christina (CHR01)			*			3				4			3			3	
CHR03			*				4				4				4		
ELE01												*				4	
ELE04												*			3		2
ELE05								*				4				4	
ELE09											*			3			
ELE (no tusk)										*				4			
FL01								*				4				4	
Gemma (GEM01)				*				4				4					5
Hestelle (HE01)	*				4									9			
Arnika (HE02)													*				
Anita (HE03)									*				4				
1-Tusk (HE04)													*			3	
Kolobje (KOL01)								*			3				4		
Pamina (PA01)								*				4					
Siami (SI01)											*				4		
Sofie (SOF01)					*						6			3			
Sonya (SOF02)														*			
Soraya (SOR01)			*			3			3			3					
Therese (TH01)	*			3				4				4			3		
TH05			*				4				4						

** Indicates first possible date of conception for each female presented in table*

The mean inter calf interval of 3.94 years for the Northern Tuli Game Reserve is similar to that calculated in Luangwa Valley, Zambia (3.5 – 4 years) (Hanks 1979), Kasungu National Park, Malawi, (mean of 3.3 years) (Jachmann 1986) and Addo Elephant Park, South Africa (3.8 years) (Whitehouse and Hall-Martin 2000), but different to that calculated for Kruger National Park, South Africa (mean of 4.7 years) (Smuts 1975) and Manyara National Park, Tanzania where Douglas-Hamilton (1972) calculated a mean inter calf interval of 4.7 years.

A mean calving interval of 3.94 years translates to a birth rate of 25.4% per adult female. If one assumes a sex ratio of 1:1 this translate to a birth rate of 12.7% per adult. A sex ratio of 2 females: 1 male gives a birth rate of 16.9% per adult. With a proportion of 49% adults in the population this translates to a birth rate per individual of 6.2% for a 1:1 sex ratio or 8.3% for a 2:1 sex ratio. Which indicates a long-term conception rate at close to the maximum. Intrinsic rates of increase for the population, which are lower than around 7%, must therefore be achieved by mortality.

Although the mean calf interval is time specific and is greatly influenced by short-term fluctuations in the pregnancy rate the period over which data were collected here (six years) covers both wet and dry periods. Such short-term fluctuations would be enhanced by environmental fluctuations (Jachmann 1986). There are also large individual variations in the inter calf intervals. According to Laws (1966) the reproductive rate of an elephant population is density dependant. Jachmann (1986) showed that both the mean calving interval and age at first conception appears to be positively correlated with density. Jachmann (1986) further suggested that both these parameters change simultaneously, while the mean calving interval might be more short term changing. What we need to know in assessing the status of an elephant population is the inter calf interval, averaged over a longer period and its long-term trend.

Mortality rate

Between July 1999 and December 2004, 79 elephants died within the study area (Table 18). The mortality of bulls was higher than that of females (53.16% and 30.38% respectively).

Table 18: Total mortalities within the Central Limpopo Valley study area

	Bulls	Cows	Unknown	Total
1999	16	7	4	27
2000	1	-	1	2
2001	2	3	-	5
2002	13	4	2	19
2003	9	4	2	15
2004	1	6	4	11
	42	24	13	79
Percentage of total mortalities	53.16	30.38	16.46	

In South Africa and Zimbabwe hunting of elephants is a major income for safari operators and local communities (Table 19). Trophy bulls are mainly targeted during these hunts. In addition bulls are more adventurous and are more likely to be shot as a problem animal within community areas. Bulls are also known to crop raid more frequently than breeding herds (Hoare 1995; Thouless 1994). The combination of problem animal control and hunting of bulls has resulted in a significant off take of bulls within the study area. Data on the number of elephants and more specifically trophy bulls hunted within the study area are lacking and the data presented are the minimum numbers removed per annum (Table 19). The actual number of bulls hunted or shot, as problem animals could be significantly higher than the figures reflected in table 19.

Table 19: Causes of mortality on an annual basis within the different areas in the Central Limpopo Valley study area

		1999	2000	2001	2002	2003	2004
NTGR, Botswana	Natural	9/5/4	0/0/1	0/1/0	3/3/1	2/3/2	0/6/2
	Snared	1/0/0	-	-	1/0/0	1/0/0	0/0/2
	Hunted	-	-	-	-	-	-
	PAC*	1/0/0	1/0/0	-	-	-	1/0/0
Total		20	2	1	8	8	11
Aerial count total		559	563	965	-	-	320
% Mortality		**3.58%**	**0.36%**	**0.10%**	**-**	**-**	**3.44%**
Limpopo Farms, RSA	Natural	-	-	-	1/0/0	-	-
	Snared	-	-	-	0/1/0	-	-
	Hunted	1/0/0	-	-	2/0/0	1/0/0	-
	PAC	-	-	1/0/0	2/0/0	1/0/0	-
		1	-	1	6	2	-
Aerial count total		-	6	17	-	-	8
% Mortality		**-**	**0.00%**	**5.88%**	**-**	**-**	**0.00%**
Beitbridge District, Zimbabwe	Natural	-	-	-	-	-	-
	Snared	-	-	-	-	-	-
	Hunted	2/0/0	-	1/0/0	3/0/0	4/0/0	-
	PAC	2/1/0	-	0/2/0	1/1/0	0/1/0	-
		5	-	3	5	5	0
Aerial count total		-	250	114	-	-	272
% Mortality		**-**	**-**	**2.63%**	**-**	**-**	**0.00%**
Total mortalities		26	2	5	19	15	11

9/5/4 = 9 Bulls/ 5 Cows/4 Unknown

* PAC Problem Animal Control

Within the Northern Tuli Game Reserve only three bulls were shot as problem animals over six years. In all cases the bulls shot were already wounded in, either the community areas neighbouring the reserve or the neighbouring countries (South Africa and Zimbabwe). Snares caused in the deaths of five elephants within the reserve (Table 19). Accidents and drought related factors were the main causes of mortality within the Northern Tuli Game Reserve during the study period.

When comparing the natural mortalities for bulls and cows there seems to be no difference within the Northern Tuli Game Reserve over the six year study period (Table 20). In Addo Elephant Park mortality rates of numbers of calves in their first year were similar for both sexes, but there after male mortality rates were higher than those of females in all age classes (Whitehouse and Kerley 2002). The major causes of bull deaths within Addo Elephant Park however were as a result of conflict with humans outside of the park, and after the erection of a fence, intra specific fighting amongst adult bulls.

Elephant mortalities were higher during the months of July through to November (Table 20). Comparing the monthly mortality data to the annual rainfall a definite trend is observed (Figure 28). During years of low rainfall higher mortalities are observed compared to high rainfall years. Mortality rate for 1999 is significantly higher compared to the other years. This could be as a result of several consecutive low rainfall years (1996 – 1999). During 2000 the reserve received 907.7 mm of rain (Table 3). The highest rainfall recorded in 100 years. As a result the natural mortalities for 2000 and 2001 were very low. Rainfall for the following years until 2004 remained low with a steady increase in the mortality rate each year.

The mortality data presented for the Northern Tuli Game Reserve is fairly complete as it is not likely that many carcasses were not detected over the study period. Predation of infants has been observed on one occasion in the study area, and it has been shown to be important in Chobe National Park, Botswana (Joubert and Joubert (1994) and in Hwange National Park, Zimbabwe (Loveridge *et al*. 2006). Loveridge *et al*. (2006) showed that elephant calves were more vulnerable to lion predation during the dry months of the year and particularly in years of below average rainfall. The mortality rates may therefore be slightly higher than indicated here, as predation of infants by lions was not recorded. In addition almost complete consumption of dead infants by hyaenas occurs, and this may also contribute to a slight increase in the estimated mortality rate.

Table 20: Comparison of bull to cow mortalities from August 1992 to December 2004 within the Northern Tuli Game Reserve

Age Group	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
<1	-	-	-	-	-	-	-	-	1/0	-	-	-
1-5	1/0	-	-	-	-	-	-	-	-	2/1	0/1	1/0
6-10	-	-	1/1	-	-	-	-	1/0	-	0/1	1/0	-
11-15	-	-	-	1/0	-	-	-	-	1/0	-	3/0	-
16-20	-	-	-	-	1/0	-	-	0/1	-	-	0/2	0/1
21-50	-	-	-	-	-	0/1	2/4	2/0	0/1	1/1	0/1	2/2
>50	-	-	-	-	-	0/1	-	-	-	-	-	-

1/1 = 1 bull / 1 cow

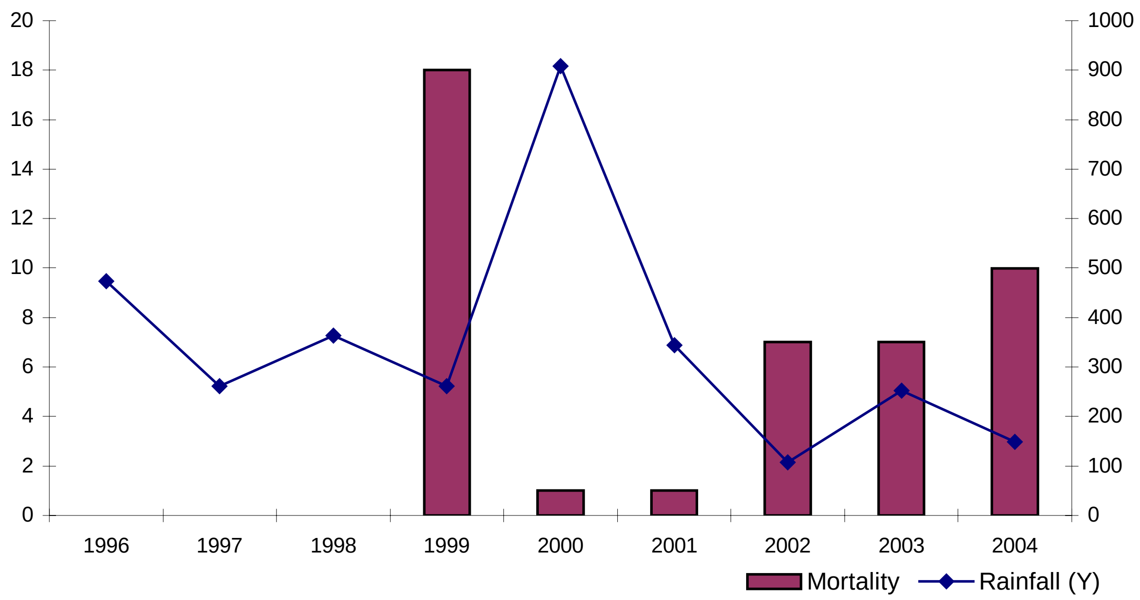

Figure 28: Comparison of annual rainfall to annual natural mortality data within the Northern Tuli Game Reserve. Mortality data were collected from July 1999 to December 2004

The annual natural mortality rate fluctuates from 0.10% (2001) to 3.40% (1999) with a mean of 1.70%. The mean annual mortality for the Addo elephant population for the period 1976-1998 was calculated at 1.43% (SD = 1.39)(Whitehouse and Hall-Martin 2000). The mortality for calves during their first year was 6.20%, after which the mortality rates decrease. The mean mortality rate for all elephants between one and 49 years in Addo National Park was 1.80% (Whitehouse and Hall-Martin 2000). The estimated rates of mortality in Hwange National Park during the peak of the 1992 – 1995 drought were 4.20% - 9.00% (Dudley *et al*. 2001). Jachmann (1986) calculated the mortality rate of the Kasungu elephants as 9.20% per annum. These results are slightly higher than the mortality rate obtained for the Northern Tuli Game Reserve during the 1999 drought year (3.40%).

In a study conducted on the Tsavo elephants by Leuthold (1976) it was estimated that about 6000 elephants died as a result of the drought and an analysis of the age and sex specific mortality patterns showed that very young animals under five years old and females of reproductive age were the most severely affected (Corfield 1973; Moss 1988) followed by senior adult elephants (≥ 50 years). This had the dual effect of reducing the elephant population, thus relieving the pressure on the vegetation, and of altering the population structure so that a further decline, through reduced reproduction, was likely to occur (Ottichilo 1986). Dudley *et al*. (2001) indicated that it appears to be the effective duration of the rainy season and not the total annual precipitation that is the best predictor for the potential severity of drought mortality among elephants in the Kalahari Sands habitat of Hwange National Park.

The highest mortalities observed within the study area were the effect of humans on the elephant population directly through hunting and problem animal control and indirectly through snaring.

Intrinsic rate of increase

The intrinsic rate of increase calculated for count data between 1976 and 2004 indicates that the population is increasing slightly at between 1.66 and 1.96% (Table 21). During a count within the Northern Tuli Game Reserve in 1976 a total of 663 (corrected total) elephants were counted (Table 22). The highest number of elephants counted within the reserve is 965 during August 2000. The rate of increase for the population over the 25 years is then calculated at 1.82% per annum.

Calef (1988) predicted a maximum rate of increase for elephant populations of 7%. According to Laws and Parker (1968), Laws *et al*. (1975) and Whitehouse and Hall-Martin (2000) the maximum intrinsic rate of increase for elephant populations with normative age structures is approximately 5% per annum. A computer simulation by Hanks and McIntosh (1973) as quoted by Owen-Smith (1988) suggested a maximum sustained rate of increase by African elephants of about 4% per annum. This was based on a 3.5 year birth interval, 5% per annum juvenile mortality, 1% per annum mortality of prime adults, and puberty at 12 years. If however females were to conceive at 8 years and the mortality of prime adults were only 0.5% per annum, a maximum population growth rate of 6% per annum could be sustained (Hanks and McIntosh 1973 as quoted by Owen-Smith 1988).

The long-term trends in population numbers indicate a population that is relatively stable or increasing slightly at around 1.8% per annum.

The approximate birth rate (1.5%) calculated for 2000, is balanced by an average natural mortality determined between 1999 and 2004 of 1.8%. The inter calf interval suggests that the long-term birth rate for the population should be higher than that for the year 2000. The difference between the combined natural and human induced mortality rates (~4%) and the birth rate suggested by the age structure and the inter calf interval (~6%) gives the ~2% long-term increase observed in the numbers.

Table 21: The intrinsic rate of increase (r) as calculated from the total aerial counts conducted in the Northern Tuli Game Reserve from 1976 to 2004

Year	2004	2001	2000	1999	1997	1996	1995	1994	1993	1991	1989	1988	1988	1987	1986	1985	1984	1983	1980	1978	1977	1976	1976	Ave
Date	Oct	Jul	Aug	May	Sep	Sep	Aug		Jul	Jul	Jul	Sep		Dec	Oct		Sep	Jul		Jun	Mar	Oct	Jun	
Corrected total counted	320	965	563	559	766	290	431		748	696	451	685	658	284	634		625	400		311	213	663	498	
5 year mean	601.75			511.5				722			542.4					512.5			421.25					
r (5 years)	3.53			-5.83				6.62			1.17					4.33								1.96
5 year maximum	965			766				748			685					625			663					
r (5 yr max)	5.20			0.48				1.84			1.92					-1.15								1.66
5 year minimum	320			290				696			284					400			213					
r (5 yr min)	2.07			-11.67				29.01			-5.80					17.56								6.24
Average last 5 years compared to first 5 years	616																		421.25					
r	**1.93**																							
Maximum last 5 years compared to first 5 years		965																				663		
r		**1.82**																						
Minimum last 5 years compared to first 5 years	320																				213			
r	**1.86**																							

CONCLUSIONS

The Central Limpopo River Valley elephant population appears to be a relatively stable population with high percentage adults and sub adults. Infants (under 2 years) were estimated at 3% indicating a low birth rate for the year 2000. The data on the age structure of the Central Limpopo River Valley was gathered during August 2000, during an extensive drought.

Births, deaths, emigration and immigration determine the size of an elephant population. Drought is one of the major factors affecting elephant births and deaths. Births can further decline as a result of higher densities of elephants. The responses to food shortages that may be more prevalent during droughts impose natural limitations on an elephant population. This could also explain the larger percentage of adults and sub adults, and lower percentage of infants. Immigration and emigration within the population was not determined but there is likely to be immigration and emigration of individuals within the population.

The calving interval within the population was estimated at 3.94% and compares well with other studies. The mortality rate within the study area fluctuates annually. Human impact on the elephant population was the biggest cause of elephant mortality. Natural mortalities within the population were correlated with rainfall. Years with low rainfall resulted in higher elephant mortalities.

The recruitment rate for the Central Limpopo Valley elephant population was calculated at 2.6%, which corresponds well with the birth and death rate, calculated for the population.

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HUMAN AND ELEPHANT INTERACTIONS WITHIN THE CENTRAL LIMPOPO VALLEY

INTRODUCTION

Many species face increasing competition with people for space and resources, and as a result are coming into increasing conflict with people. This is particularly true of large mammals (Sitati *et al.* 2003). African elephants have a considerable impact on people and are in the unusual position of being simultaneously an endangered species (IUCN 2000) and, in places, a pest species (Sitati *et al.* 2003).

Human-elephant conflict refers to a range of direct and indirect negative interactions between humans and elephants, which potentially harm both (Ngure 1995). This conflict between elephants and agriculturalists is already widespread (Hillman Smith *et al.* 1995; Kiiru 1995; Osborn and Parker 2002) and can lead to the displacement or elimination of elephants causing a further decline in their range and numbers (Hoare 2000).

Elephants in Botswana roam unrestricted with most of the parks or reserves unfenced (Ebedes *et al*. 1995). An aerial census completed in 1990 showed that there are approximately 54 700 elephant in the water-rich area of northern Botswana (Craig 1991). Today, the elephant population in northern Botswana and adjacent parts of Zimbabwe and Namibia is estimated to be more than 100 000 animals constituting the largest population on the continent (Skarpe *et al*. 2004). An increasing number of elephants and expansion of human population in Botswana has resulted in increasing conflict between elephants and neighbouring communities within the country.

The problem is becoming more severe as increasing human populations encroach onto elephant range, and elephant populations are compressed into restricted areas (Kangwana 1995; Thouless and Sakwa 1995). In the Central Limpopo Valley region of Botswana and Zimbabwe, conflicts between a steadily increasing population of elephants and people are becoming more frequent (Botswana Daily News, 2005). These conflicts between elephant and man are over the ever-decreasing resources of water and land (Buss 1990; Laws 1966; Lind 1971).

The areas surrounding the Northern Tuli Game Reserve have a high density of people and conflict has been reported (Botswana Daily News, 2005). The Bobirwa sub-district, which borders the Northern Tuli Game Reserve within Botswana, was used as an intensive study area (Figure 2).

OBJECTIVES

The objectives of this section of the study were to

1. Determine the attitudes of the local communities to elephant and the extent of human elephant conflict within the region

LITERATURE STUDY

Human wildlife conflict is a major concern for wildlife management and rural development across Africa (O'Connell-Rodwell *et al.* 2000; Osborn and Parker 2003; Taylor 1999). It typically involves crop damage by elephants, and solutions are generally set within a policy and legislative framework that attempts to address both wildlife management issues and rural development objectives (Osborn and Parker 2003). Many initiatives have been designed to address crop loss because this can undermine the success of other programmes related to agriculture or wildlife conservation (Hoare 1995). This issue can also threaten the viability of wild animal populations by creating a confrontational atmosphere between farmers and wildlife managers (Taylor 1999). In some areas the problem is chronic, predictable and threatens the livelihood security of farmers living near wildlife (Hill 1998 as quoted by Osborn and Parker 2003). Rural communities can have an influential political voice, and crop raiding often becomes a flash point for a range of local issues such as settlement and access to resources (Barnes *et al.* 1995).

"Problem elephants" are animals that extend their range into human settlement, commonly to feed on a wide variety of cultivated food and cash crops but also sometimes damaging food stores, water installations or fences and barriers, and occasionally injuring or killing people (Hoare 1999).

Human elephant conflict may take many forms, from crop raiding and infrastructure damage, through disturbance of normal activities such as travel to work and school, to injury or death of people and elephants (Hoare 2000; Kangwana 1995; Kiiru 1995; Ngure 1995; Osborn and Parker 2003;). Although they are not the only crop pest in Africa nor the most damaging overall, elephants may cause severe localised damage within affected areas and can destroy entire fields of crops (Barnes *et al.* 1995;

Hoare 2000). Moreover, elephants are also dangerous to people. As a result, elephants have a higher profile than other wildlife species and are generally less easily tolerated (Hoare 2001 as quoted by Sitati *et al*. 2003). In pastoral areas the main conflict between elephants and people is over the access to water. In thick bush elephants present a danger to people who are walking and herding.

Thouless (1994) showed that the main economic damage inflicted by the elephants in the settlement areas in northern Kenya was the destruction of crops. Elephants were the most widely feared because of their ability to eat and trample huge quantities of crops in a single night, the difficulty of stopping them with any barrier-, and the danger they posed to human life.

In the savannah elephant range, problem elephant activity shows a seasonal peak, usually corresponding to the late wet season, because the majority of incidents involve elephants destroying maturing food crops (Hillman Smith *et al*. 1995; Hoare 1995; Hoare 1999; Thouless 1994). In some semi arid areas in Zimbabwe and Kenya, elephant damage to food crops accounts for 75-90% of all incidents by large mammal pest species in each district every year (Hoare and Mackie 1993 as quoted by Hoare 1995). In the study conducted by Thouless (1994) crop raiding occurred throughout the year, but was most intense when the crops were nearly ready to harvest.

Bull elephants, either singly or in groups, are primarily responsible for crop damage (Hoare 1995; Thouless 1994), but during the peak of the season, cows and calves could be seen joining the bulls (Thouless 1994). It was found by Hoare (1999) that bull elephants were found significantly closer to human settlements than females and that the only elephants observed to penetrate into settlements in the daytime. Crop raiding is almost exclusively a nocturnal activity (Hillman Smith *et al*. 1995; Hoare 1995; Setati *et al.* 2003) suggesting that offenders seek to minimize the associated risk (Hoare 1999).

Spatial patterns have been more difficult to identify (Setati *et al.* 2003). Conflict is highest in close proximity to protected areas that act as elephant refuges (Barnes *et al.* 1995; Parker & Osborn 2001). At present there is little evidence to support the existence of clear relationships between levels of problems caused by elephants and natural food limitation or local density of elephants (Barnes *et al*. 1995; Hoare 1999). The optimal foraging theory, which predicts that animals will maximise the quality of their nutrient intake wherever possible offers the most plausible explanation for the unpredictable nature of elephant raids both in savannahs (Begon *et al.* 1986 as quoted by Hoare 2000) and forests (Lahm 1996 as quoted by Hoare 2000). Setati *et al.* (2003) indicated that elephants due to their long memories often utilise traditional movement routes and thus may return to areas where they remember having successfully raided in the past.

Hoare and Du Toit (1999) showed that elephant density is unrelated to human density until a threshold of human density is reached about 15.6 person/km^2. After this threshold, resident elephants effectively disappear.

A range of traditional non-fatal methods has been used by communities all over Africa to combat crop raiding and can be divided into two general categories namely passive and active (Osborn and Parker 2003). Passive methods attempt to limit the movement of elephants into areas of agriculture, while active methods are typically used in fields at night (Osborn and Parker 2003).

Methods to deter elephants include guarding, scaring elephants with light, noise, fire or weapons and erecting various forms of fencing or barriers, experimental repellent sprays and alarm calls, capture and translocation of elephants, killing of selected problem animals, organising and marketing hunts for killing problem animals, compensation schemes, research effort to increase understanding of the local ecology of elephants and most importantly land zonation which reduces spatial competition between people and elephants (Hoare 1995; Hoare 2000). Although not 100% effective and subject to habituation, focusing a shifting combination of such methods on the front-line farms may be the most successful short-term approach to mitigating this most prevalent form of human-elephant conflict (Hoare 2000; Setati *et al.* 2003; Taylor 1993). The goal of management further should not be to tightly control the problem but rather to raise general tolerance of wildlife among the farmers, enhance their methods of defence, and lessen the impact of severe losses by elephants (Naughton-Treves 1998).

It has been shown in other studies in Zimbabwe that the same animals are usually the ones that continually raid croplands (repeated offenders) and threaten lives. If these animals can be correctly identified then management decisions can be made to determine the animal's future, rather than the present system where any elephant in the area at the time when the Problem control officers arrive is assumed to be the one responsible and destroyed. The need to destroy any animal in the area is driven by the local community who want the animal “taken care of” and demand a quick response.

It must however be noted that wherever people and elephants coincide human-elephant conflict will occur. Short-term mitigation can only reduce and not eradicate the problem (O’Connell-Rodwell *et al.* 2000). Thus the future of elephants over much of the continent will depend largely upon the attitudes and activities of humans (Hoare 2000).

METHODS

The distribution of local communities was determined through a map survey of the study area. The majority of the villages within the study area were visited, and the extent of the conflict determined through informal interviews with village leaders and villagers. The locations of the villages were recorded on a Geographic Information System layer and the regions of potential conflict were determined in the Geographic Information System analysis.

Two surveys were conducted during October 1999 and June 2000 within the villages of the Bobirwa sub-district in Botswana. As part of the survey informal interviews were held with various community members where questions on how often elephants were observed near the village, the herd sizes and sexes as well as the frequency of crop raiding, were asked (Appendix B). Discussions were also held with various wildlife officers of the Department of Wildlife and National Parks in the region. During August 2004 a taskforce was formed by the Department of Wildlife and National Parks (DWNP) to assess the problem animal situation within Botswana. The Bobirwa sub-district (Mathathane and Mmadinari) was included in the task force assessment and meetings were held with all the community members within the area. Possible areas of conflict were visited during this survey. The northern Botswana task force team arranged community meetings at Mathathane and Mmadinari respectively on the 14th and the 15th of July 2004. Members of the surrounding villages including councillors and chiefs attended the two respective meetings. Separate discussions with the wildlife officers situated at both Mathathane and Mmadinari were held.

Within Zimbabwe CESVI did an assessment of problem animal issues in the area during 2000 and 2001 and data from their study was used.

Along the Limpopo River within South Africa and the Tuli block within Botswana a postal survey and interviews with local farmers were conducted to determine the attitude of people towards elephants and the extent of crop raiding in these areas.

RESULTS AND DISCUSSION

Land use practises and human densities differ dramatically in Botswana, South Africa and Zimbabwe. Policies on elephant utilisation also differ between the three countries. Human densities are the highest within the Zimbabwean section of the study area with the lowest within the Botswana section of the study area (Figure 11). Land use within both Botswana and Zimbabwe consist mainly of subsistence crop farming (Figure 9). Two commercial citrus farms, Nottingham Estate and Sentinel Ranch, operate along the Limpopo River within Zimbabwe. Within Botswana one commercial farm is situated within the Northern Tuli Game Reserve namely Talana Farms. The area along the Limpopo River within South Africa is mainly dedicated to commercial crop and citrus farming with several game farms scattered in between the commercial farms. Within recent years, however several of the commercial agricultural properties have been converted into eco tourism and hunting operations.

Human elephant interactions occur throughout the range of the Central Limpopo River Valley but differ in impact in the different areas of the elephant range within the area.

Human Elephant interactions within the Central Limpopo River Valley

Human elephant interactions within the Central Limpopo River Valley vary and are both positive and negative (Table 22). Eco tourism and hunting of elephants generate income in all three countries. Eco tourism lodges market the large number of elephants within the area as an attraction to tourists. Mashatu Game Reserve, Tuli Lodge and Nitani within the Northern Tuli Game Reserve, Botswana and Mapungubwe National Park, South Africa are some of the main eco tourism lodges within the area. Trophy hunting of elephants mainly occurs on the Zimbabwean and South African side of the study area. The only revenue generated in the Tuli Circle, Zimbabwe is through hunting.

Table 22: Human elephant interactions within the Central Limpopo River Valley (based on questionnaire survey 2000-2001)

Area	Types of impact/interactions with people										
	Eco tourism	Hunting	Natural vegetation	Commercial crops	Subsistence crops	Livestock	Fencing	Housing	Boreholes/wells	Irrigation	Human lives
BOTSWANA											
Northern Tuli Game Reserve	5	0	5	0	0	0	3	0	0	3	0
Talana Farms	3	0	4	3	0	0	4	0	0	3	1
Tuli Block Farms	3	2	3	0	5	1	5	2	3	0	2
Gobojango	0	0	0	0	0	0	0	0	0	0	0
Lentswe le Moriti	0	0	4	0	5	1	5	1	4	0	3
Lepokole	0	0	1	0	2	1	2	0	1	0	1
Mabuhwe	0	0	0	0	0	0	0	0	0	0	0
Madikgaka	0	0	3	0	5	1	5	3	4	0	4
Madiope	0	0	4	0	5	1	5	2	4	0	2
Majale	0	0	4	0	5	1	5	2	4	0	2
Manyohnoye	0	0	2	0	3	0	2	1	2	0	0
Mathathane	0	0	3	0	5	1	4	2	4	0	3
Matsaganeng	0	0	0	0	0	0	0	0	0	0	0
Mmadinari	0	0	2	0	5	1	5	3	5	0	4
Mohlabaneng	0	0	3	0	5	1	5	3	5	0	3
Molalatau	0	0	2	0	3	0	3	1	3	0	1
Robelela	0	0	2	0	4	1	4	1	3	0	1
Sefophwe	0	0	0	0	0	0	0	0	0	0	0
Semolale	0	0	0	0	0	0	0	0	0	0	0
Tobane	0	0	1	0	3	0	3	1	2	0	1
Tshokwe	0	0	2	0	4	1	4	1	3	0	1
SOUTH AFRICA											
Mapungubwe National Park	4	0	4	0	0	0	3	0	2	0	0
Weipe	0	2	4	3	0	0	4	0	0	4	0
Kruitfontein	2	2	3	0	0	0	4	0	0	0	0
ZIMBABWE											
Mmadinari	0	3	3	0	5	1	5	1	3	4	2
Sentinel Ranch	3	2	4	2	0	0	3	0	2	3	0
Nottingham Estate		3	4	2	0	0	3	0	2	3	0
Machuchuta	0	3	2	0	3	1	3	1	2	0	1
Masera	0	3	2	0	3	1	3	1	2	0	1
Tuli Circle	0	4	4	0	0	0	0	0	0	0	0

Legend: 0 = no interaction; 1 = very light interaction; 2 = light interaction; 3 = moderate interaction; 4 = heavy interaction; 5 = very heavy interaction

Negative interactions between elephants and humans are widespread and diverse within the study area. Within the Eco tourism areas, Northern Tuli Game Reserve (Botswana), Mapungubwe National Park (South Africa) and Baines Drift to Motloutse River Tuli Block Farms (Botswana) the main concern is the impact on the natural vegetation, while in most of the communal areas within Botswana and Zimbabwe the main concern is towards the impact of elephants on subsistence crop farming. Commercial crop farms along the Limpopo River in South Africa, Talana Farms (Botswana) and Shashe Irrigation Scheme along the Shashe River (Zimbabwe), Nottingham Estate and Sentinel Ranch (Zimbabwe) have reported crop raiding by elephants. The extent of elephant damage and the frequency of crop raiding on the commercial farms appear to be lower than on the subsistence farms. Proper electrified fencing protecting properties and commercial crops is most likely the reason for the lower impact.

Where elephant migration routes have been cut off by veterinary fencing breaks in the fences are often reported. This is the situation along the western boundary of the Northern Tuli Game Reserve and along the Shashe River.

Human Elephant Conflict in the Bobirwa District, Botswana

A total of 22 villages were visited during the two excursions in the Bobirwa sub district (Table 23).

Based on the data obtained from the excursions and a literature survey the most likely boundaries of the Central Limpopo Valley elephant population was drawn and three total aerial counts were conducted within the study area. All the major rivers (Limpopo, Motloutse, Thune and Shashe Rivers) in the communal areas within the study area were flown during the aerial counts. Special attention was paid to the area around Letsibogo dam within the Bobirwa sub district in Botswana. The results of the aerial counts are represented in table 7.

Date obtained from the three total aerial counts indicated that the largest component of the Central Limpopo Valley elephant population is resident within the Northern Tuli Game Reserve and the Baines Drift – Motloutse River Tuli Block farms.

Table 23: The distribution of elephants within villages that were visited in the Bobirwa sub district, Botswana

No	Town		People	Resident	Number of Bulls				Number of breeding herds				Frequency Bulls				Frequency of breeding herds				Elephant	Farm	Area	When
		Respondent name	Density	Herd	Spring	Sum	Win	Aut	Spring	Sum	Win	Aut	Spring	Sum	Win	Aut	Spring	Sum	Win	Aut	Behaviour	Activity	Seen	
1	Gobojango	Madisona Mphee	4	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		Subsistence	Not seen	-
2	Lentswe le Moriti	Manjaro	2	Y	1	1	2	2	1	0	2	2	1	2	5	5	1	0	2	2	Placid	Subsistence	Limpopo	Night
3	Lepokole	Balebi Mhaladi	2	N	0	1	0	1	0	3	0	3	0	2	0	2	0	2	0	2	Shy	Subsistence	Dam	Night
4	Mabuhwe	Chief Ngala	3	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		Subsistence	Not seen	-
5	Madikgaka	Motlatsu Mokgosi	1	N	-	-	-	-	4	4	4	4	2	2	2	2	2	2	2	2	Aggressive	Subsistence	Everywhere	Night
6	Madiope	Moeng	2	N	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Shy	Cattle	Madiope	Day & night
7	Madiope	Maria Chabalala	2	N	1	1	1	1	4	4	4	4	4	2	2	2	2	2	2	2	Shy	Subsistence	Everywhere	Night
8	Majale	Anna	2	N	0	0	0	2	1	1	1	4	1	1	1	2	0	0	1	2	Shy	Subsistence	Everywhere	Night
9	Majale	Eric Marupane	2	N	0	2	0	1	1	3	3	1	2	2	2	2	1	2	2	2	Aggressive	Subsistence	Riverbanks	Night
10	Manyohnoye	Mademo	0	N	0	0	0	0	0	0	1	3	2	2	2	2	0	0	1	1	Shy	Subsistence	Riverine	-
11	Mathathane	Chief Serumola	5	N	-	-	-	-	4	4	4	4	4	2	2	2	2	2	2	2	Shy	Subsistence	Motloutse	Night
12	Matsaganeng	Elliot	0	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		Subsistence	Not seen	-
13	Mmadinari	DWNP Officer	5	Y	-	-	-	-	4	4	4	4	-	-	-	-	2	2	2	2	Aggressive	Subsistence	Everywhere	Day & night
14	Mohlabaneng	Chief Mphale	4	N	-	-	-	-	-	2	-	-	-	-	-	-	-	2	-	-	Shy	Subsistence	Motloutse	Night
15	Mohlabaneng	Josef Sasebola	4	N	0	2	0	0	2	2	2	1	1	2	1	2	1	2	1	2	Aggressive	Subsistence	Motloutse	Night
16	Molalatau	Chandapwa Pharithi	5	N	0	0	1	0	0	0	2	0	0	0	2	1	0	0	2	1	Shy	Subsistence	Motloutse	Night
17	Robelela	Chief Sikae	4	Y	0	0	0	1	1	1	1	2	1	2	1	2		2	2	2	Aggressive	Subsistence	Shashe	Day & night
18	Robelela	Gabantebe Noke	4	N	0	0	1	1	0	0	2	2	1	1	2	2	0	0	2	2	Aggressive	Crops	Shashe	Night
19	Sefophwe	Diloro Segwabe	4	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		Subsistence	Not seen	-
20	Semolale	Chief Mademo	5	N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		Subsistence	Not seen	-
21	Tobane	Ceaser	4	N	-	1	1	1	-	2	3	4	-	1	1	2	-	2	1	1	Aggressive	Subsistence	Rivers	Night
22	Tshokwe	Okaihe Maokame	3	N	0	0	0	0	3	3	3	3	2	2	2	2	2	2	2	2	Shy	Subsistence	Motloutse	Night

Table Key

Number of Elephants				**Frequency**	**Approximate number of people in area**			
0	0-2	3	11-50	0 Never	0	0-50	3	501-1000
1	3-5	4	51-100	1 Seldom	1	51-100	4	1000-3000
2	6-10	5	>100	2 Frequent	2	101-500	5	>3000

No elephants were observed within the communal areas or around the Letsibogo dam during the 2000 and 2001 aerial counts. Definite elephant paths and recent signs of elephant occupation could, however, be seen around the dam especially on the western side between the dam and the Francistown road. The aerial count done by the Selebi-Phikwe branch of the Kalahari Conservation Society (KCS) from the 9th – 12th August 2000 counted 25 elephants on the western side of the Letsibogo dam. The herd consisted of one breeding herd (19 elephants) and six bulls. Two of the bulls were within the vicinity of the breeding herd and four bulls were separate.

The Kalahari Conservation Society team observed several elephant paths crossing the Shashe River moving in the direction of Signal Hill and heading towards Hwange National Park in Zimbabwe. During the October 2004 count a total of 165 elephants were counted in the vicinity of Letsibogo Dam.

Eleven elephants were counted along the Shashe River during July 2001, while 132 elephants were counted within the same area during the previous aerial count in August 2000. Signs of elephant activity along the Shashe River close to Madikgaka indicate that elephants cross the river frequently between the two countries and that there is a far larger elephant presence in this area than is suggested by the results. The area along the Zimbabwean side of the Shashe River in this area is sparsely populated and consists for the most part out of dense Mopane woodland. Information received from the Veterinary Department, Botswana support the findings with regular breakages in the veterinary fence reported in the vicinity of Madikgaka village at the confluence of the Shashe and Ramokgwabane rivers (Nuru, pers comm.)[14].

Elephant movements within the communal areas occur on an infrequent basis and crop raiding especially during the harvesting months is a great concern. The number of elephants responsible for crop raiding is still unknown and could be from various locations within the study area. According to observations it seems that the elephants at the Letsibogo dam have formed a semi resident herd on the western side of the dam. The elephants mainly use the area between the Motloutse and Sedibe Rivers and the Francistown road to the west of Lestibogo dam. These elephants cross regularly through the veterinary fence on the Shashe River and cattle posts on the Shashe River complain about elephants crop raiding and damaging pipelines.

[14] Dr Nuru. Veterinarian, Department of Animal Health and Agriculture, Botswana. November 2004.

There is a slight possibility that some elephants might be moving along the Motloutse River to Letsibogo dam. Due to these movements it is difficult to determine the exact number of elephants occupying the Letsibogo dam area and those responsible for crop raiding at the various villages within the study area. The numbers would further fluctuate based on seasonal food and water availability in the area.

Elephant movements have also been reported higher on the Shashe River close to Nata and the Ramogkwabana/Plumtree border post. It is however speculative if these elephants are Tuli or Hwange National Park (Zimbabwe) elephants.

Interviews with the communities indicated that elephants seem to be wide spread within the communal areas but are mainly observed along the major rivers and dams within the area. Based on the community surveys conducted the only villages not affected by elephants were Semolale, Gobojango, Matsaganeng and Sefhophe (Table 23 and Figure 29).

During the Taskforce meetings, the communities of Mathathane and Mmadinari indicated elephants as the major problem animal. The current Problem animal control (PAC) strategy seems to be too reliant on government Problem animal control teams. These teams are too few, under motivated and using inefficient techniques. Residents in Mathathane and neighbouring villages indicated their unhappiness with the current situation.

Tremendous damage are caused to crops and some damage to water holes and wells in villages where these wells and boreholes are not effectively protected. Villagers in the Bobirwa District use noise, fires and in some cases shooting over the heads of elephants to deter them from the crop fields. Most of these methods are, however, unsuccessful as elephants habituate quickly to non-lethal methods (Ngure 1995; Osborn and Parker 2003). All cases are reported to the Wildlife Department, who in some cases lethal action is taken against habitual crop raiders.

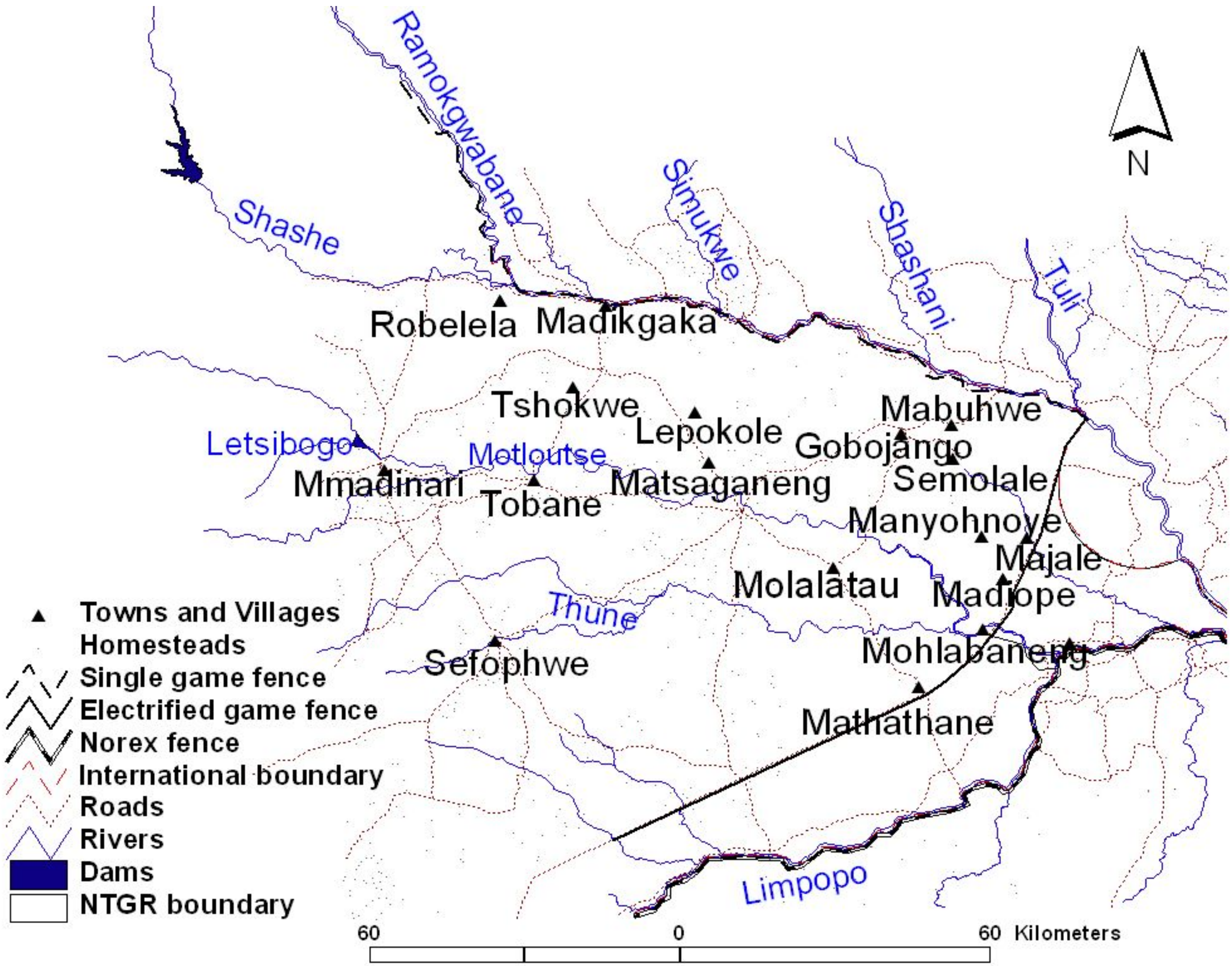

Figure 29: Villages within the Bobirwa sub-district, Botswana visited during the survey

In the Molalatau-Mathathane area raiding occurs during the dry season when the only vegetation in the area occurs around the villages and along the rivers. The consequences are especially harsh on the local communities, as the vegetable plots are their main source of food during the dry season. Elephant numbers in the community areas seem to increase during the harvesting season, and results in an increase in incidences of crop raiding. This corresponds with other studies conducted throughout Africa (Hoare 1995; Hoare 1999; Thouless 1994). Communal areas mainly affected were those along the Motloutse River near the Northern Tuli Game Reserve and Tuli Block, as well as areas along the major tributaries to the Shashe River and communities in close proximity to the Shashe River along the veterinary cordon fence. More recently communities close to Letsibogo dam have complained about an increasing number of elephants utilising the area around the dam and an increase in conflict.

Crop raiding occurs mainly at night (Table 23). The majority of the communities see elephants as being aggressive or shy, but except for two recent incidents no loss of human life or livestock has been reported in the last couple of years. Communities are scared of the elephants and would, in most cases, like them to be removed from the area.

In Africa rural populations incur the primary costs of living with wildlife but receive few of the benefits (Naughton-Treves 1998) and their attitudes towards wildlife are frequently negative as a result (Osborn and Parker 2002). Rural communities can have an influential political voice (Kangwana 1995) and crop raiding often becomes a flashpoint for a range of local issues such as settlement and access to resources (Barnes et al. 1995 as quoted by Osborn and Parker 2003). When elephants impinge on people solutions to the problem are needed. Pressures on government to find these solutions come from grassroots' levels (Kangwana 1995).

An attitudinal survey in Botswana found that rural people held negative conservation attitudes despite receiving substantial benefits from the licensed hunting of wildlife (Parry and Campbell 1992 as quoted by Gillingham and Lee 1999). Increased conflict between humans and elephants within the Bobirwa District has placed tremendous pressure on the government to come up with a long-term solution (Botswana Daily News, 2005).

This elephant population represents a small but significant threat to the commercial and subsistence farmers, their workers and the surrounding communities. Currently there is very little benefit (in financial terms) derived from living with the elephants by most of people in the region. Elephants continually raid community areas, destroying fences and ruining the infrastructure of the farmers.

The communities would like the area to be elephant free and dedicated to agriculture. Even though in most of the area the crop fields are fenced these fences are not sufficient to deter elephants. Crop fields in many cases are also located very close to the veterinary fences. This creates a big temptation for the elephants.

Human Elephant Conflict within the Zimbabwean section of the study area

Based on data from the three elephant aerial counts elephant numbers seem to be lower within the Zimbabwean section of the study area. Communities within the area are however affected by elephants entering the villages from all three countries.

Elephants regularly cross into the irrigation schemes and crop fields along the Shashe River from the Northern Tuli Game Reserve. These excursions occur mainly at night. Even though bulls are more frequently observed large breeding herds have also been observed crossing the Shashe River.

Two hunting farms, Sentinel Ranch and Nottingham Estate, within in the Zimbabwean section of the study area contain the majority of the elephants resident within this section. Elephants cross into the communal areas to the north, east and west of these to properties at night returning before dawn the following morning. Communities mainly affected are Maramani, Machuchuta, Masera and River Ranch.

The villages along the major rivers, and those bordering the protected area, seem to be mostly affected as elephants have been noted to travel mainly along the major rivers in the area (Limpopo, Phazi and Umzingwane rivers).

The CAMPFIRE program is very active in the Beitbridge District where several bulls and other problem elephants are hunted per year. CESVI survey conducted in the Beitbridge district indicated elephants as one of the major problem animals in the area causing huge damage to crop fields and infrastructure.

Human Elephant Conflict within South African section of the study area

Land use on the South African side of the study area consist mainly of wildlife related practises and commercial crop and citrus farming.

Conflict within this region are not only related to elephant damage to commercial crop farms but also related to concerns of negative vegetation changes within the Limpopo riverine. Several landowners along the Limpopo River are concerned about the impact of elephants on the Limpopo riverine believing that in time with an increasing number of elephants in the area the Limpopo riverine will be completely destroyed.

CONCLUSIONS

Interactions between humans and elephants within the Central Limpopo River Valley are both positive and negative. Humans derive benefit from elephants through eco tourism and hunting operations in all three countries.

Within eco tourism and hunting operations the main concern seem to be the impact of elephants on the natural vegetation while the major concern for local communities within Botswana and Zimbabwe is the impact of elephants on subsistence crop farming.

Throughout the study area elephants were indicated as the main problem animal. The communities within the area rely on arable farming but the growing numbers of elephants in the area have destroyed crops leaving them without a means of survival. They are forced to flee their fields before harvesting and thus discouraging them from earning a living through farming. Elephants have damaged fences, well installations and encroached onto human settlements threatening lives and increasing pressure on arable and grazing lands. Few attacks on humans have been noted but with the increase in elephant numbers and human numbers in these areas increases in conflict are likely. Another dimension of the problem in the area is an increase in human settlements over the past few years and the blockage of the migratory routes leaving no space for elephants.

The movements of elephants within the community areas are mainly along the major rivers and crop raiding only occur at night. Bulls were indicated as the main culprits. During the harvesting season however, the number of elephants in the community areas increase and breeding herds were observed crop raiding during these periods.

There is no universal recipe for controlling “problem elephants”, but a range of control measures, used flexibly and in combination, can be employed to mitigate the effects on people and their properties (Hoare 1995).

There are however, some areas where elephants cannot be maintained (Kangwana 1995). Due to the distribution and number of people within the Bobirwa sub district of Botswana elephants and humans are unlikely to coexist within this area.

Recommendations for the Bobirwa sub-district human-elephant conflict

Recently the veterinary fence along the Shashe River, the Back-line fence along the Tuli Block as far as Baines Drift and the western boundary of the Northern Tuli Game Reserve have been upgraded to game proof fences. The veterinary fence along the Shashe River has not yet been electrified. These fences will, if electrified and properly maintained, contain elephants within protected areas in Botswana and Zimbabwe. Elephants, however, caught on the communal side of the fence within Botswana, will no longer be able to migrate back into Zimbabwe along the Shashe River or back into the Northern Tuli Game Reserve or Tuli Block. These elephants are thus trapped within the communal areas. Before any decisions regarding the future of these elephants can be made the number of elephants and the composition of the herds need to be determined (Breeding herds vs. bulls).

The first step to be taken is to determine what time of the year the elephant numbers are at the lowest. Electrifying the Shashe veterinary fence would be the next step. The Tuli Block Back line fence that has recently been erected is already damaged to a large degree both by elephants and humans. This fence needs to be upgraded and properly maintained. Changing the power supply from solar power to the Botswana Power Corporation grid will solve the problem of stolen solar panels. Lastly the Northern Tuli Game Reserve western boundary fence needs to be elephant proof across all the major rivers preventing elephants from crossing from the reserve into the communal areas via the Motloutse River. All three fences need to be joined forming a continuous unit cutting elephants off completely from the communal areas. Areas were the fences cross gullies and major rivers; flap gates need to be erected to prevent elephants from crossing into the communal areas along the rivers and gullies.

Once the fences are put in place and operational a total aerial count of the elephants within the communal area needs to be conducted. This will give a proper indication of the number of elephants trapped within the communal areas. Once the numbers, locations and social structure of the population have been determined a course of action can be decided upon. Several options are available but all are dependent on elephant numbers and the social structure of the groups. These options include hunting, culling or translocation. The reasoning behind erecting the fences first and then counting the elephants is due to the continuous fluctuation of elephant numbers within the Bobirwa communal areas.

However, for this system to work effectively the cooperation of the Veterinary Department, the Wildlife Department and the communities are needed. A comparison of different fences by Thouless and Sakwa (1995) showed that there was no clear relationship between effectiveness of fences, and factors such as design, construction and voltage. The previous experience of elephants with electric fences in a particular area and shooting of fence-breakers are considered to be more important than any design criteria (Thouless and Sakwa 1995). Studies have shown that elephants lend themselves to negative conditioning and do avoid situations that can prove fatal (Kangwana 1993). Effective fencing schemes further need the support of local people for their maintenance (Kangwana 1995).

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GENERAL DISCUSSION AND CONCLUSION

Historically the African elephant was distributed continent wide from the environments of Cape Town to the fringe of the Sahara desert (Ebedes *et al*. 1991). Due to the inference of man the elephants range became more and more restricted and up to 1982 the distribution of elephants in the Transvaal (South Africa) were confined to the Kruger National Park and a small population on the border of the Transvaal, Botswana and Zimbabwe at the confluence of the Shashe and Limpopo rivers (Rautenbach 1982).

The Central Limpopo Valley elephant population is a cross border population on which very little scientific data pertaining to numbers, distribution and demographic status is available. The population is a relatively undisturbed and stable population that appears to be regulated by environmental conditions.

Archaeological evidence from the site of Mapungubwe suggests that elephants occurred in the region at the time that Mapungubwe was active from 950-1150 AD (Voigt 1983). There are however no records of the occurrence of elephants in the Central Limpopo Valley from about a 100 years ago until 1945 (Page, pers. Comm.[15]; Walker 1977). From the hunting records it is likely that the elephants were shot out by the 1900's (Walker 1977). From the 1940's onwards elephants returned to the region, and the area now known as the Northern Tuli Game Reserve became the core area of the elephants range in the Central Limpopo Valley (Walker 1971; Walker 1977).

The total number of elephants counted within the Central Limpopo River Valley was very similar on all three counts with 1388 in 2000 and 1424 in 2001 and 1339 in 2004. Comparing the distribution of fences, local households and villages and the location of major rivers with the distribution of elephants show that elephants are mainly distributed within areas of low human densities. These areas are the Northern Tuli Game Reserve and sections of the Tuli Block, Botswana, Nottingham Estate and Sentinel Ranch, Zimbabwe and Mapungubwe National Park in South Africa. Water and food availability probably influence the distribution and movements of elephants within these areas.

[15] Page, B. R. School of Biological and Conservation Sciences, University of KwaZulu-Natal, Durban. Personal communication.

Kernel analyses applied to the Northern Tuli Game Reserve aerial count data for each year from 1986 to 2001 indicated that the distribution of elephants within the NTGR is similar in different years even though the numbers counted were not.

The three very similar totals obtained over the four years suggest that the numbers in this population are stable. The estimate of the population in the region in the late 1970's was 1200 (Feely 1975; Macfarlane, pers. comm. 1976; Nchunga 1978), which suggests that the population has been more or less stable for at least 30 years.

During the dry season elephants seem to concentrate along the major rivers within the study area namely the Limpopo, Umzingwane, Phazi, Shashe and Motloutse rivers. Within the Botswana section elephants are mainly distributed along the three major rivers within the area namely the Limpopo, Shashe and Motloutse rivers. This corresponds with observations by Page (1980).

The Central Limpopo Valley elephant population is a free roaming population and movement out of the study area occurs. These movements seem to follow the major rivers within the study area namely the Shashe, Ramokgwabane, Simukwe, Shashani, Tuli, Umzingwane, Motloutse and Limpopo rivers. The extent of these movements and the number of elephants involved are as yet unknown.

Several studies have shown that the seasonal movements of elephants are characterised by elephants concentrating in the vicinity of perennial waterholes during the dry season when no natural water is available and disperse during the wet season (Owen-Smith, 1988; Wittemyer, 2001; Osborn and Parker, 2003). This pattern holds for Etosha National Park (De Villiers and Kok, 1994; Lindeque and Lindeque, 1991) where elephants preferred to use areas within 4 km of water throughout the year (De Beer *et al*. 2006). Relative to the dry season, ranging during the wet season seems less dependent of distance from perennial water sources, as seasonal water sources are widely available (De Beer *et al*. 2006).

Little data were obtained on the movements of elephants within the Zimbabwean and Tuli Block sub population. Movements between the different sub populations occurred.

Several of the known herds show a distinct overlap in their summer and winter home ranges. Most of the herds observed winter home ranges were found to be bigger than their summer home ranges and included the same area as the summer home ranges.

The lack of a substantial difference between the summer and winter ranges of the known breeding herds described may be an indication that the quality and abundance of winter forage is not substantially different from summer. On the other hand it could be that competing herds on the periphery are preventing range expansion in winter.

Breeding herds were observed in all the different vegetation types in both the wet and dry season but selected for different vegetation types in the different seasons. During the dry season breeding herds selected for the Aquatic Grassland, while in the wet season *Acacia tortilis* Woodlands were selected for. Mixed Riverine Woodlands were selected for during both seasons with no significant difference between the two seasons.

Group sizes of elephant herds within the Central Limpopo Valley differed between seasons. During the wet season large congregations of elephants can be observed while during the dry season group sizes seem to be much smaller. Similarly in different years group sizes increase with an increase in rainfall and decrease during low rainfall periods. The average mean group size in months following high rainfall (defined as a month in which the total collective rainfall in preceding 12 months was above 900 mm) was 56.524 animals per group with a larger SDE (77.388), while the average mean for months following dry periods (months with total collective rainfall for preceding 12 months below 367 mm) was 24.157 animals per group and the SDE (22.223) This is probably a result of resource availability. Food quality dependents on rainfall with higher rainfall resulting in a better quality food.

The percentage adults (>15 years old) and sub adults (9 to 15 years old) within the population was high relative to other populations (49% and 30% to the total number of 499 respectively) with a low infant (1-2 year old) percentage (3% of the total of 499). The proportion of adults (>15 years) varies from 34-38% in increasing populations, such as Kruger National Park (South Africa) and Manyara (Tanzania), to over 50% for populations that were stable, or recovering from large-scale drought mortality (Owen-Smith 1988). The 1-2 year old frequency is much lower to those observed in other areas in normal rainfall years e.g. 8.5 – 9.5% in Etosha National Park, Namibia in May 1984 and August 1985 respectively (Lindeque 1991) and

10.1% in Kruger National Park, South Africa in 1995 (Anon. in Bhima and Bothma 1997). August 2000 followed a long (3 years) dry period within the Central Limpopo Valley and this could explain the low percentage of infants within the population.

The inter calf intervals of 28 known cows within the Northern Tuli Game Reserve were calculated from 1988 to 2004. The mean inter calf interval is 3.94 years. This is similar to the results from Luangwa Valley, Zambia (3.5 – 4 years) (Hanks 1979), Kasungu National Park, Malawi, (mean of 3.3 years) (Jachmann 1986) and Addo Elephant Park, South Africa (3.8 years) (Whitehouse and Hall-Martin 2000).

The recruitment rate of the Central Limpopo valley elephant population was calculated at 2.6% of the total population.

The mortality rate within the study area fluctuates annually. Natural mortalities within the population were correlated with rainfall. Years with low rainfall resulted in higher elephant mortalities. Accurate values were difficult to determine, but varied between 0.10% (2001) to 3.40% (1999) with a mean of 1.70%. Natural mortalities within the population were correlated with rainfall. Years with low rainfall resulted in higher elephant mortalities.

The intrinsic rate of increase calculated for count data between 1976 and 2004 indicates that the population is increasing slightly at between 1.66 and 1.96%. The approximate birth rate (1.5%) calculated for 2000, is balanced by an average natural mortality determined between 1999 and 2004 of 1.8%. The inter calf interval suggests that the long-term birth rate for the population should be higher than that for the year 2000. The difference between the combined natural and human induced mortality rates (~4%) and the birth rate suggested by the age structure and the inter calf interval (~6%) gives the ~2% long-term increase observed in the numbers.

Interactions between humans and elephants within the Central Limpopo River Valley are both positive and negative. Humans derive benefit from elephants through eco tourism and hunting operations in all three countries.

Within eco tourism and hunting operations the main concern seem to be the impact of elephants on the natural vegetation while the major concern for local communities within Botswana and Zimbabwe are the impact of elephants on subsistence crop farming.

Throughout the study area elephants were indicated as the main problem animal. The communities within the area rely on arable farming but the growing numbers of elephants in the area have destroyed crops leaving them without a means of survival. They are forced to flee their fields before harvesting and thus discouraging them from earning a living through farming. Elephants have damaged fences, well installations and encroached onto human settlements threatening lives and increasing pressure on arable and grazing lands. Few attacks on humans have been noted but with the increase in elephant numbers and human numbers in these areas increases in conflict are likely. Another dimension of the problem in the area is an increase in human settlements over the past few years and the blockage of the migratory routes leaving no space for elephants.

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There are however, some areas where elephants cannot be maintained (Kangwana 1995). Due to the distribution and number of people within the Bobirwa sub district of Botswana elephants and humans are unlikely to coexist within this area.

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