Elephant Movements and Human-Elephant Conflict in a Transfrontier Conservation Area

by
Katharina E. M. von Gerhardt-Weber

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Supervisor: Professor M. J. Samways
Co-supervisor: Professor J. Hanks
Faculty of AgriSciences
Department of Conservation Ecology and Entomology

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Abstract

In this thesis I explore how elephant movements are impacted by human activity within the context of the proposed Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA) in southern Africa. Being a wide-ranging species, the movements of elephants could be an excellent indicator as to the success of TFCAs in supporting species persistence in an anthropogenic matrix. Understanding which areas beyond protected area boundaries are of heightened conservation importance can provide managers and governments with insights for the management of the elephant population of KAZA TFCA, and assist managers and governments in prioritising conservation efforts.

Satellite radio collar data were used to model long-range elephant movement within KAZA TFCA. Movement was compared between land use types (protected and non-protected areas). Home ranges, core areas and seasonal ranges were calculated from collar data. Core and non-core areas were tested for significant differences in distance to settlements, rivers, protected area, AFRI and elevation as these spatial and ecological variables are believed to play a role in elephant habitat selection. Short-range elephant movements were examined in a heterogeneous, patchy landscape mosaic of settlements and agricultural fields, remnant forest patches, and secondary forests which were surrounded on three sides by protected areas. Elephant penetration of the anthropogenic matrix through the use of pathways was explored through ground-based surveys, and the impact of pathways use on human-elephant conflict calculated.

I found that elephant behavioural plasticity allows for their persistence in a spatially heterogeneous landscape. Elephants, especially bulls, penetrated the landscape matrix beyond protected area boundaries. Land use planning initiatives are needed to identify and protect reachable core zones/stepping stones of quality habitat outside of protected areas, particularly in riparian zones. Differing male and female ranging behaviour within the landscape matrix may require separate land use management strategies: bulls travelled at night in non-protected areas at speeds that were four times faster than in protected areas, and made use of core zones necessary for species persistence in a fragmented landscape. A habitat corridor in the Zambian West Zambezi Game Management Area was identified.

I found that during short range movements in heterogeneous environments, elephants made use of pathways. Pathways may facilitate penetration of the anthropogenic matrix and optimize foraging strategies by connecting predictable resources, such as crop fields, with landscape features such as preferred shelter/ resting areas, crossing points at roads and preferred drinking spots. Pathways were found to be the only significant spatial variable in crop-raiding. Elephants foraged randomly while in homogenous crop patches, but when travelling through a heterogeneous environment (entering or leaving agricultural locales), movement was directional and non-random.

Lastly I suggest that crop attractiveness may be enhanced by water availability. Results indicated that at both the landscape and the regional scale, repeat elephant movements to core zones and along elephant pathways provided landscape ecological variables that need to be considered by conservation managers in land use planning. In addition, research on spatial awareness and navigational capabilities with regards to pathway use

by elephants should be encouraged, as this research topic has been largely unexplored in the scientific literature.

Opsomming

In hierdie tesis verken ek die moontlike impak van menslike aktiwiteite op olifant beweging binne die beoogde Kavango-Zambezi Oorgrens Bewaringsarea (KAZA TFCA) in suider-Afrika. Olifante is wydlopende spesies, en dus kan hul ruimtelike strekking ‘n uitstekende indikator wees van die sukses van oorgrens bewaringsareas in terme van die ondersteuning wat dié programme bied om spesies se volharding in ‘n antropogeniese matriks te verseker. Besturrders en regerings kan insig verkry deur te besef watter areas buiten die in beskermde gebiede, van verhoogde bewarings belang in KAZA TFCA is. Hierdie insig verleen ook bystand aan bestuurders en regerings met die prioritisering van bewarings inisiatiewe. Satelliet-radio nekband data was gebruik om olifante se langtermyn ruimtelike beweging binne die KAZA TFCA te modelleer. Olifant beweging was vergelyk tussen verskillende grondgebruik tipes (beskermde en onbeskermde areas). Tuistestrekking, kern areas asook seisoenale strekking was bereken vanaf nekband data. Kern en nie-kern areas was getoets vir betekenisvolle verskille in afstand vanaf nedersettings, riviere, berskermde gebiede, AFRI, en hoogte bo seevlak, omdat hierdie ruimtelike en ekologiese veranderlikes ‘n belangrike rol mag speel in olifant habitat seleksie. Kortafstand olifant bewegings was bestudeer in ‘n heterogene, gelapte landskap mosaïek van nedersettings en landbougrond, oorblywende woudareas, en sekondêre woude waarvan drie sye grens aan bekermde areas. Olifant indringing binne die antropogeniese matriks deur die gebruik van weë/toegangsweë was verken deur middel van landgebaseerde opnames, waarvolgens die impak van olifante se gebruik van hierdie paaie op mens-olifant konflik bereken kon word.

My bevindinge wys dat plastisiteit in olifant gedrag dra by tot hul voortbestaan in ‘n ruimtelik heterogene landskap. Olifante, maar meer spesifiek olifantbulle, penetreer wel die landskap matriks buite beskermde area grense. Grondgebruik beplannings inisiatiewe word dus benodig om bereikbare kern areas van kwaliteit habitat buite beskermde areas te identifiseer en te beskerm – veral in rivieroewer sones. Verskille in bul en koei ruimtelike strekking gedrag binne die landskap matriks, mag afsonderlike bestuur stratgieë vereis: bv. bulle beweeg vier keer vinniger in die aand in onbeskermde areas teenoor in beskermde gebiede, daarby maak hulle ook gebruik van kern areas wat kardinaal is vir die voortbestaan van spesies in gefragmenteerde landskappe. ‘n Habitat deurgang was geïdentifiseer in die Zambiese Wes-Zambesie Wildbestuurarea. Die studie het gevind dat olifante gedurende kortafstand bewegings in heterogene omgewings gebruik maak toegangsweë. Toegangsweë mag penetrasie van die antropogeniese matriks fasiliteer, en verleen ook dat olifant weidingstrategieë die optimum bereik deur voorspelbare hulpbronne soos gewaslanderye te konnekteer met landskap eienskappe soos voorrang skuiling/rusareas, kruisingspunte by paaie, asook voorrang drinkplekke. Toegangsweë was gevind om die enigste betekenisvolle ruimtelike veranderlike in gewasstrooptogte te wees. Olifante wei lukraak in homogene gewaslanderye, maar in teenstelling, wanneer hulle deur ‘n heterogene omgewing beweeg het (binnegang of uittog uit landbou lokaliteite) was die beweging gerig. Laastens, die studie stelvoor dat gewas

aantreklikheid verhoog kan word deur water beskikbaarheid. Resultate dui aan dat by beide die landskap- en streekskaal verskaf herhaalde olifant beweging na kern areas en langs olifants togangsweë, landskap ekologiese veranderlikes wat in ag geneem moet word deur bewaringsbestuurders tydens grondgebruik beplanning. Bykomend, navorsing op die ruimtelike bewustheid en navigasie vermoëns van savannah olifante met betrekking tot die gebruik van toegangsweë, moet aangemoedig word aangesien hierdie onderwerp grootliks onverken is in wetenskaplike literatuur.

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Ultimate thanks go to my parents, especially our matriarch, who instilled in my brother and I respect and responsibility for our environment.

Last but not least, to all the elephants I have had the privilege of observing, and to those tasked with their protection - I am indebted. In the words of John Corse (1799): *Since the remotest ages, the elephant, on account of his size, his sagacity, and his wonderful docility, has attracted the notice, and excited admiration, of philosophers and naturalists, both ancient and modern; and few travellers into Asia or Africa, have omitted giving some account of him.*

Dedication

This thesis is dedicated to my husband Didi: with you, anything is possible.

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List of Acronyms and Abbreviations

AfESG	African Elephant Specialist Group
AFRI	Aerosol Free Vegetation Index
ANOVA	Analysis of Variance
BNP	Bwabwata National Park
CBNRM	Community Based Natural Resource Management
CI	Conservation International
CITES	Convention on International Trade in Endangered Species
CSF	Caprivi State Forest
EWB	Elephants Without Borders
EVI	Enhanced Vegetation Index
GIS	Geographical Information System
GMA	Game Management Area
GPS	Global Positioning System
HEC	Human-elephant conflict
HWC	Human-wildlife conflict
IRDNC	Integrated Rural Development and Nature Conservation
IUCN	The World Conservation Union
KAZA TFCA	Kavango-Zambezi Transfrontier Conservation Area
KC	Kwandu Conservancy
LPR	Luiana Partial Reserve
MCP	Minimum Convex Polygon
MET	Ministry of Environment and Tourism
MNP	Mudumu National Park
MRA	Multiple Resource Areas
NDVI	Normalized Difference Vegetation Index
NNF	Namibian Nature Foundation
Non-PA	Non-protected area
NP	National Park
OFT	Optimal Foraging Strategy
PA	Protected Area
PAC	Problem Animal Control
PPF	Peace Parks Foundation
SADC	Southern African Development Community
SNNP	Sioma Ngwezi National Park
TFCA	Transfrontier Conservation Area
VHF	Very high frequency
WWF	World Wide Fund for Nature
ZAWA	Zambian Wildlife Authority

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'It may be concluded that unwavering international support for National Parks here and elsewhere is vital in times of adversity, instability and political turbulence.'
Iain Douglas-Hamilton

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

The continual decline of elephant numbers and reduction in range in Africa due to human population growth and illicit hunting is recognized as one of the continents most serious conservation challenges (Hoare & du Toit, 1999; Naughton-Treves, 1997, Hanks, 2003). Significant population declines of large mammals in African protected areas have been recorded by Craigie *et al*. (2010) between 1970 and 2005. Range compression and fragmentation result in range reduction, inbreeding depression, local species extinction and competition between humans and elephants for requisite resources such as water and space. A potential solution for elephant persistence in fragmented habitats has been the establishment of Transfrontier Conservation Areas (TFCAs) (Hanks, 2003) or megaparks (van Aarde & Jackson, 2007) with protected areas connected by spatially large linkages/wildlife corridors. In a recent southern African initiative, the governments of Angola, Botswana, Namibia, Zimbabwe and Zambia agreed to the establishment of the Kavango-Zambezi TFCA (KAZA TFCA), an area of nearly 310 000 km^2 which includes 36 designated conservation areas and the major parts of the Okavango, Kwandu, Kafue and Upper Zambezi River basins. These protected areas exist in a matrix of multiple land-use types. Much of the justification for the KAZA TFCA is to provide wildlife, and particularly elephants, uninterrupted movement corridors (Scovronick *et al*., 2007), particularly from source habitats in Botswana and Zimbabwe into sink habitats in Zambia and Angola. A large proportion of the KAZA TFCA has been modified by subsistence agriculture, especially along the major rivers. Land tenure within the KAZA TFCA is multi-faceted (Metcalfe & Kepe, 2008), with the matrix surrounding protected areas consequently varying in quality. Research indicates that spatially heterogeneous environments could benefit elephant persistence, while monogamous land use over vast areas decreases probability of species occurrence (Murwira & Skidmore, 2005).

One of the more popular approaches to maintaining populations in fragmented habitats has been to retain or create linkages between isolated habitat patches (Margules & Pressey, 2000; Haddad *et al.,* 2003). Based on the equilibrium theory of island biography, metapopulation theory provides an ecological approach to the development of corridors between protected areas in TFCAs (Olivier *et al*., 2009, van Aarde & Jackson, 2007). Much research has focused on elephant corridors linking reserves (Foley, 2002; Douglas-Hamilton *et al.,* 2005; Osborn & Parker, 2003; Parren *et al.,* 2002; Joshi & Singh, 2008). In the KAZA TFCA, corridors for elephant movement are being investigated (Cushman *et al.,* 2010). Yet empirical data on corridor existence, effectiveness and use by elephants is lacking (Lee & Graham, 2006; Simberloff *et al*., 1992). Chetkiewiecz *et al*. (2006) further note that corridor studies have been impeded by the missing integration of patterns of landscape composition and configuration, and the processes of habitat selection and movement by target species. Corridors, which are often termed 'linear strips', are also not binary features, and penetration by elephants of the broader matrix must be considered. In the absence of high quality corridors (satisfying all five functions of a corridor), a cluster of stepping stones or small patches, have been put forward as land use planning solutions (Samways, 2005). In terms of metapopulation dynamics, stepping stones which lie in suitable matrix habitat and connect protected areas that lie close together appear to increase recolonisation rates (Forman, 1995). This study presents stepping stones beyond protected areas as complimentary alternatives to corridors for providing connectivity in KAZA TFCA's landscape mosaic (Fig 1.1). In terms of the KAZA TFCA, the provisioning of stepping stones beyond protected areas boundaries could enable recolonisation of sink habitats.

The identification of stepping stones necessitates research into patterns of elephant movement. Elephant movement and navigational ability result in patterns of movement, which are influenced by an animal's internal state (e.g. risk aversion). According to Wittemyer *et al.* (2008), this in turn is an expression of external factors within the landscape (e.g. human disturbance). Elephant movement is suggested to be non-random (Loarie *et al*., 2009), with animals creating a cognitive map of their home range and the distribution of available resources within that range (Forman, 1995). Movement can be separated into types, with migration and dispersal occurring between patch mosaics, while shorter movements are associated with foraging between resource and habitat patches (Chetkiewicz *et al.*, 2006). As elephants are a keystone species, movement patterns have a direct impact on ecosystem dynamics (Owen-Smith, 1988). Long-range movements also ensure genetic exchange between sub-populations. Eighty percent of elephant area of occupancy lies beyond protected area boundaries (Hoare & du Toit, 1999), bringing humans and elephants into increasing contact, often resulting in conflict around resources such as crops and water. Current barriers to elephant movement in the KAZA TFCA include roads, settlements and fences as well as human disturbance and land transformation. These are considered a critical conservation issue as barriers hinder or halt the genetic exchange between sub-populations, and deny elephants access to critical seasonal resources such as shelter, food and water.

Satellite data from collared elephants within the KAZA TFCA suggest that elephants avoid densely settled areas (Chase & Griffin, 2009), yet human-elephant conflict is on the rise. Many human-elephant conflicts occur along traditional elephant routes (Galanti *et al*., 2006, Sukumar, 1990), with natural elephant movements being disrupted by human activities. The creation of large scale migration corridors within the KAZA TFCA is currently being investigated through analysis of satellite data from collared elephants and in conjunction with local communities (Conservation International, 2006). Daily elephant movements to and from resources have not been investigated at a finer, more localised spatial scale. Elephant pathways and path types may play an important role in determining local spatial patterns of human-elephant conflict (HEC) and crop-raiding (Sitati *et al.*, 2003). The identification and protection of such pathways could reduce conflict between local villagers and elephants (Douglas-Hamilton *et al*., 2005) by allowing safe thoroughfare between resources for both species.

Ensuring that the KAZA TFCA elephants have access to ecologically relevant resources that lie beyond protected boundaries is the cornerstone of management planning at the landscape scale. This study provides insights into the spatial relationship between landscape features and elephant movement and habitat selection. Satellite data from three collared elephants were used to investigate long-range elephant movements and ranging behaviour within the KAZA TFCA's landscape mosaic, while ground-surveys were conducted to examine short-range elephant movements and their impacts within a HEC 'hotspot'. Results from this study allow managers to make inferences about movement patterns and the factors governing these. Grounded in Landscape Ecological Theory, results could also provide regional managers with tools for sustainable land use planning.

1.2 Research objectives

Main research objective:
To investigate long and short-range elephant movements within an anthropogenic landscape mosaic at a landscape scale and at a regional scale, and to relate elephant movement to landscape features.
The immediate objective:
To investigate the existence and use of elephant pathways along a defined stretch of the Kwandu River.
The ultimate objective:
To investigate whether elephants raid crops at random distances from pathways and refuges (high risk), or whether they only raid crops opportunistically (low risk) near pathways and refuges. Pathway use between seasons will be compared.

1.3 Specific research questions:

Landscape scale:

- What are elephant movement patterns in the KAZA TFCA?
- Does human disturbance have an impact on elephant movement beyond protected area boundaries?
- Which core areas beyond protected area boundaries are of conservation importance to elephant persistence within the KAZA TFCA?
- Which environmental or spatial variables explain elephant selection of core areas?

Regional scale:

- Do elephant pathways exist in the Kwandu Conservancy (KC)?
- Does human disturbance have an impact on elephant movement along pathways?
- Does pathways functionality differ across seasons?
- What is the group size of elephants using these pathways?
- Does sexual segregation occur in the utilisation of these pathways?
- Are elephant pathways significant spatial factors influencing the intensity and frequency of HEC and specifically crop-raiding incidents?
- Is crop-raiding further initiated by bulls only?

1.4 Research Approach:

Before one can begin to understand to what extent elephants make use of core areas and pathways, one needs to understand the temporal and spatial movements of elephants in the study region: Chapter 2 describes long-range, seasonal movements of three elephants fixed with satellite collars at a landscape scale, and maps elephant core zones even beyond protected area boundaries. Conservation implications are discussed. At a regional scale, Chapter 3 investigates pathway existence and pathway functionality in a heterogeneous environment. Different types of pathways, and their patterns of use by the local elephant population in the wet and in the dry season, are described. In Chapter 4, spatial variables of crop-raiding, including distance to nearest pathway, are investigated. Chapter 5 is a synthesis of the main research findings and conservation recommendations are put forward.

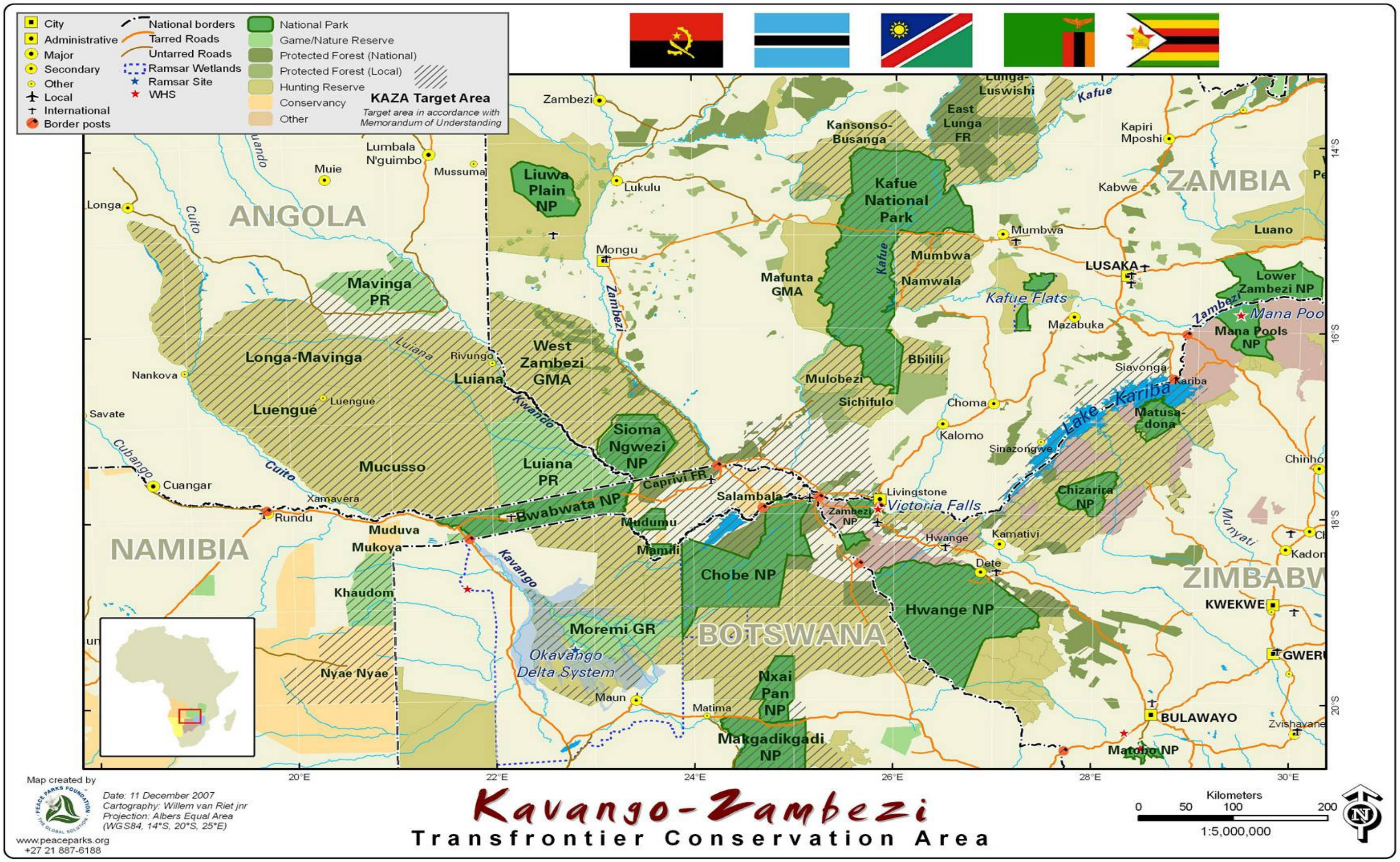

Fig 1.1: The proposed Kavango Zambezi Transfrontier Conservation Area (Peace Parks Foundation, 2008).

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'The number of elephants in the Zambezi Valley is prodigious, so much so that the inhabitants are obliged to pursue and make frequent hunting courses after them, to preserve from their ravage the lands they sow with rice and millet, in which lands these animals generally commit waste.'
Joao dos Santos in 1568

CHAPTER 2

LONG-RANGE MOVEMENTS OF THREE SAVANNAH ELEPHANTS (*LOXODONTA AFRICANA AFRICANA*) WITHIN A TRANSFRONTIER CONSERVATION AREA (TFCA) – ADAPTIVE MANAGEMENT IMPLICATIONS

Abstract

Satellite tracking of three elephants (*Loxodonta africana*, Blumenbach, 1797) was used within the Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA) in southern Africa to follow elephant movements across international borders. The KAZA TFCA provides a unique platform to monitor elephant spatial use in an African landscape mosaic that includes four countries, 36 designated protected areas, as well as State and private land. The tracked elephants form part of the largest contiguous elephant population on the continent. Using radio collars on two bulls and one female, elephant home ranges and core zones were identified, and elephant behaviour investigated in protected and non-protected areas. The results show that human disturbance significantly affected elephant ranging behaviour. On average, elephants spent more than 50% of their time in protected areas and moved faster than average when travelling in non-protected areas, often under cover of darkness. The collared female remained mostly in protected areas or areas of low settlement density. She had a small home range with seasonal overlap. A possible habitat corridor was identified. The two collared bulls had much larger home ranges, with greatest long-distance movement occurring in the wet season. Bulls made extensive use of the landscape matrix, including Conservancies and Game Management Areas, and crossed four country borders (Angola, Zambia, Namibia and Botswana). The movement patterns of bulls suggested distinct core zones within wet and dry season dispersal areas. High resolution spatio-temporal mapping of movements revealed nocturnal elephant activity in settlement areas. Although the results are based on only three individuals, they have important implications for the metapopulation approach to TFCA Planning. Overall, the results showed that 1) elephant behavioural plasticity allows for their persistence in a spatially heterogeneous landscape, 2) land use planning initiatives are needed to identify and protect reachable stepping stones of quality habitat outside of protected areas, particularly in riparian zones, and, 3) differing male and female ranging behaviour within the landscape matrix may require separate land use management strategies.

2.1 Introduction

Inter- and intra-specific competition between species for resources and space in fragmented ecosystems is a critical conservation issue. Mammals with large range requirements, such as the African elephant, are particularly at risk due to illegal hunting and agricultural expansion into natural areas (Naughton-Treves, 1997). Poaching has seriously decreased Central, East and West African populations (IUCN, 2007). Habitat fragmentation is considered the most significant threat to elephant conservation today (Hoare & du Toit, 1999), and with burgeoning human populations, elephants are increasingly confined to protected areas. The combination of range compression and elephant population increase in protected areas, due to a lack of hunting pressure, has resulted in certain elephant populations stabilising if not increasing in southern Africa (van Aarde & Jackson, 2007). More than half of Africa's elephants live in southern Africa, and 80% of their range lies outside of protected areas (Blanc *et al*., 2005). Conservation of elephants has included protection in fenced national and private parks. However, research has shown that high numbers of elephants in fenced areas are unsustainable, as their wasteful feeding ecology may compromise park biodiversity (Owen-Smith, 2006; Guldemond & van Aarde, 2007).

Culling, translocation and contraception have been criticised as solutions for management (van Aarde *et al*., 1999). A more sustainable management solution to increasing elephant populations has been the establishment of Transfrontier Conservation Areas (TFCAs) (Hanks, 2003) or megaparks (van Aarde, 2007) with the development of linkages between protected areas (Baldus, 2003). Connecting several protected areas with corridors could ensure habitat heterogeneity, which has been shown to benefit elephant persistence at landscape and regional scales (Murwira & Skidmore, 2005). Resource heterogeneity is further functionally stabilising as it spreads consumption away from preferred resources (Wittemyer *et al*., 2008; Murwira & Skidmore, 2005; Owen-Smith, 2004).This is relevant to resource-based aggregation by large numbers of elephants – for example, at water points in protected areas such as in the Chobe National Park in Botswana. Corridors and TFCAs could consequently mitigate the factors that increase

local elephant numbers like those in northern Botswana, and moderate their negative impact on the vegetation and other taxa.
However, penetration by elephants of the broader landscape matrix must be considered in corridor planning: elephants tend to have preferred core zones within the landscape matrix, which they access along a number of routes. Core areas and traditional migration and dispersal routes are increasingly being threatened by human encroachment with the result that the landscape is becoming fragmented, and human-elephant conflict (HEC) is increasing (Graham, 2009; Jackson, 2008; Galanti *et al*., 2006; Hoare & du Toit, 1999; Sitati *et al.*, 2003). Fragmentation leads not only to habitat loss and discontinuity, but to habitat isolation. This may lead to local extinction outside reserves with an increase in elephant populations in protected areas. Increasing numbers of elephants and humans in Caprivi have led to increasing conflict, with reserves in Caprivi inadequate for sustaining increasing numbers of elephants (O'Connell-Rodwell *et al*., 2000). In Uganda's Murchison Falls National Park for example, a relatively sudden and permanent increase in the elephant population was caused by increased intensity of local land use in surrounding areas (Rodgers & Elder, 1977). In the case of megaherbivores, local overpopulation is further coupled with higher grazing and browsing pressure that can threaten the survival of sensitive habitats as well as compromise park biodiversity (Owen-Smith, 1988). The potential bottleneck of increasing elephant populations in protected areas as a result of human disturbance in surrounding communal lands begs the question: Are Transfrontier Conservation areas viable when it comes to elephant conservation?

Little is known of the spatial resource use of elephants moving beyond protected areas and boundaries in the KAZA TFCA. This is a critical knowledge gap, and one that needs to be addressed for effective transboundary conservation management among biologists, local communities and political leaders (Assessment of South African Elephant Management, 2008). Radio and satellite tracking is a popular tool for long-term monitoring of wildlife movements in inaccessible terrain or over large areas. This technology has been successfully used on elephants in Namibia (Lindeque & Lindeque, 1991), Botswana (Verlinden & Gavor, 1998, Junker *et al.*, 2008), Kenya (Douglas-

Hamilton *et al*., 2005; Thouless, 1995; Thouless *et al*., 1992), Chad (Dolmia *et al.*, 2007), Cameroon (Tchamba *et al*., 1994), Mozambique (Harris *et al.*, 2008), South Africa (Harris *et al*., 2008), Central African Republic (Fay & Agnagna, 1991) and Tanzania (Galanti *et al.*, 2006).

The aim of this study is to gain insights about movements of three collared elephants within the KAZA TFCA (Fig 2.1) in relation to land use types, using Global Positioning System (GPS) satellite tracking data with high spatio-temporal resolution. The objectives of this study are to 1) map home ranges and core zones within the KAZA TFCA 2) investigate penetration by collared elephants of the broader matrix (non-protected areas) and 3) discuss the conservation applications in view of TFCA planning. Although the study is based on only three individuals, it provides a first step in filling the knowledge gap of transboundary elephant movements in the KAZA TFCA.

2.2 Materials and Methods

i) Study area

The study area lies within the KAZA TFCA, an area of nearly 310 000 km^2 which includes 36 designated conservation areas, as well as State and Private Land. For the purpose of this study, 'protected areas' included areas of limited human disturbance such as National Parks (NPs) and State Forest Reserves. 'Non-protected areas' included Multiple Resource Areas (MRAs), including any form of state and private land, as well as Conservancies. Conservancies, relevant to Namibia only, are areas with overlapping land use (wildlife, agriculture, tourism) where community based natural resource management (CBNRM) is practised (for further information on Namibian Conservancies, please refer to www.irdnc.org.na). However, disturbance is high and Conservancies have therefore been included in 'non-protected areas' for the purpose of this study (Table 2.1).

Table 2.1: Protected and non-protected areas used by collared elephants within the Kavango Zambezi Transfrontier Conservation Area.

Area Name	Country	Area status	Area (ha)
Coutada Publica do Luiana	Angola	Non-Protected	59710
Kwandu Conservancy	Namibia	Non-Protected	18909
Lusese Conservancy	Namibia	Non-Protected	32552
Mashi Conservancy	Namibia	Non-Protected	29914
Mayuni Conservancy	Namibia	Non-Protected	15072
NG/13	Botswana	Non-Protected	274328
NG/14	Botswana	Non-Protected	220485
NG/15	Botswana	Non-Protected	116804
NG/16	Botswana	Non-Protected	134045
SADC block	Namibia	Non-Protected	3177562
Salambala Conservancy	Namibia	Non-Protected	92169
Sikunga Conservancy	Namibia	Non-Protected	35936
West Zambezi GMA	Zambia	Non-Protected	1371189
Wuparo Conservancy	Namibia	Non-Protected	14093
Luiana Partial Reserve (LPR)	Angola	Protected	848536
Bwabwata National Park (BNP)	Namibia	Protected	415591
Caprivi Forest State Forest (CSF)	Namibia	Protected	148649
Chiobe State Forest	Zambia	Protected	986
Chobe National Park	Botswana	Protected	1068168
Lusu State Forest	Zambia	Protected	1432
Mamili National Park	Namibia	Protected	34049
Mudumu National Park (MNP)	Namibia	Protected	72066
Nampiu State Forest	Zambia	Protected	29094
Nanduka State Forest	Zambia	Protected	1018
Shokosha State Forest	Zambia	Protected	3837
Sikabenga Conservancy	Namibia	Protected	2903
Sioma Ngwezi National Park (SNNP)	Zambia	Protected	499520

Within this range, elephants are discontinuously distributed in national parks, communal, state and private land. The KAZA TFCA is home to the continent's largest contiguous elephant population, estimated at 180 000 individuals.

The combined population roams through parts of the Caprivi Strip of Namibia, south-western Zambia, northern Botswana, north-western Zimbabwe and south-eastern Angola, and is predicted to be growing at 5% per annum (Cumming & Jones, 2005). Habitat fragmentation and illicit hunting are of concern to elephant persistence in the area. The latter is of particular concern in Zambia and Angola. Perennial water sources include the Zambezi, Kwandu (also known as the Cuando), Linyanti, Chobe and Kavango Rivers.

The Caprivi region, an important corridor for movement of elephants, forms the centre of the KAZA TFCA, and is framed in the west by the Kavango River and by the Chobe, Linyanti and Zambezi Rivers to the east. The Kwandu River divides the Caprivi into west and east, and also forms the boundary between Zambia and Angola, and in the south between Botswana and Namibia.

The landscape is flat with an average altitude of 930 m ± 1 100 m a.s.l. above sea level (Mendelsohn & Roberts, 1997). Broad-leafed savannah characterises the Caprivi Strip. *Colophospermum mopane* - *Burkea* and *Baikiaea plurijuga* mixed shrubland and grassland dominate the area with mature woodlands (*Acacia* spp.) occurring in the region (Mendelsohn & Roberts, 1997). Extensive seasonal floodplains occur along the permanent rivers, with riverine zones in Mamili NP and Chobe NP forming important wetland areas. Soils of the KAZA TFCA area are predominantly nutrient-poor, with interspersed nutrient-rich savannahs and floodplains (Robertson, 2005). The greater Kwandu Basin is marked by the presence of fossil dunes where dambos (shallow seasonally flooded areas) form in the dune troughs and ancient river valleys (*omurambas*). Agriculture is focused near settlements, mostly along major roads and perennial rivers. The region has a tropical savannah climate. Rainfall is highly variable, occurring mainly between November and May. Rural crops (maize, sorghum, millet) are harvested in the wet season – usually in April/May. Rainfall averages between 600 mm ± 1 000 mm (Coneybeare, 2004) and varies greatly with locality. The dry season runs from May to November, with September/October being particularly dry. Fire is a serious concern within the KAZA TFCA, with peak burns occurring in September/October. In 1996, 60% of the Caprivi vegetation was burned (Mendelsohn & Roberts, 1997). During the wet season, surface water is widely available in numerous waterholes, pans and *omurambas* throughout the area, but by June, most of the waterholes have dried up.

ii) Satellite tracking

Three elephants with home ranges near the Kwandu River (research base) were darted and immobilized[1] in the dry season of 2006, and fitted with GPS collars with built-in Very High Frequency (VHF) transmitters manufactured by Africa Wildlife Tracking. Collars work with Inmarsat Satellites on a mobile global two-way communication platform utilizing two-way data satellite communication complete with GPS systems. Sampling rates were programmable and set at twice a day from July 2007 to December 2007 and to every four hours from February 2008-June 2008 to monitor activity near human settlements in the wet season at a higher spatio-temporal resolution. All data were downloaded from the collar via the command unit to a laptop computer and converted to database files. Detailed information on GPS collar data has been published by Douglas-Hamilton (1998) and the African Elephant Specialist Group (AfESG). Location data were converted to geographical information system (GIS) format for analysis using ArcGIS software (ESRI, 2009). Of the three elephants, bull 16 and bull 13 were reproductively active males (30-35 and 20-30 years old respectively), while elephant 2 was a female (30-35 years old). Ages were estimated from the dentition by the attendant wildlife veterinarian.

iii) Home ranges and core zones

A GIS map was used to map each collared elephant's movements by using the positions and times of the GPS fixes. Fixes were further analysed to generate a number of important spatial variables including season (i.e. dry or wet), time of day (i.e. day or night) and distance travelled between consecutive fixes. Each collared elephant's home range and core areas was calculated using the grid-square method (Douglas-Hamilton *et al*., 2005). The landscape was divided into a quarter-kilometre grid and each grid square (or cell) scored by the number of times it was visited by each elephant. Total squares visited equalled the elephants' grid square range. Core areas were defined by those grid squares that constituted the top 25% of all grid squares in terms of number of visits by each elephant. Home sectors were defined as a set of contiguous grid squares covering an

[1] The capture and collaring was sponsored by *Conservation International* as part of the Transfrontier KAZA TFCA elephant management programme and performed by Michael Chase from the Kasane-based NGO *Elephants without Borders (EWB).*

area larger than 2 km^2, in which each grid square had been visited at least three times within one month. For the detailed methodology, refer to Douglas-Hamilton *et al.,* (2005). Potential corridors (i.e. stretches of continuous movement of >10 km within a 5 km radius of the return movement) were established using visual interpretation of the elephant ranges.

In order to understand why collared elephants preferred to spend more time in core areas, a random selection of 200 locations (i.e. points) were selected in core areas and compared to a similarly selected set of points in 200 non-core areas. Random points (locations) were generated in core and non-core areas using the "Generate Random Points" tool in Hawth's Analysis Tools, which is an extension of ArcGIS 9 (http://www.spatialecology.com/ htools/). Core and non-core samples were compared, and tested for significant differences in vegetation cover (represented by a vegetation index), elevation, slope, as well as distance to rivers, settlements and protected areas. The Aerosol Free Vegetation Index (AFRI) was used derived from a Landsat TM image with spatial resolution of 15 metres. AFRI values are very similar to NDVI values, yet have the added advantage that they penetrate the atmospheric column even through smoke or sulphates. For details regarding AFRI calculations, please refer to Karnielie *et al*. (2001). Vegetation indexes, such as AFRI, estimate vegetation productivity and density and are a common remotely sensed measure of vegetation quality used in elephant research as a possible variable to explain elephant distribution (Wittemyer *et al*., 2008; Rasmussen, 2006). Water in the dry season is considered a limiting resource while settlement density is an indicator of human disturbance. Both variables are said to be determining factors in elephant distribution and ranging behaviour (Lindeque & Lindeque, 1991; Verlinden & Gavor, 1998). Selected core areas were categorised into dry and wet season core areas, and the same variables tested between the two.

iv) Land use types and habitat selection

The land use preference of the collared elephants was measured by comparing the frequency of GPS fixes in protected areas (PA) with non-protected areas (non PA). Vegetation types dominating the home range and core zones of each elephant were described, and data were sourced from Mendelsohn & Roberts (1997) and from the Peace Parks Foundation's KAZA Integrated Development Plan (Peace Parks Foundation, 2008).

v) Elephant behaviour

The speed and distances travelled by collared elephants were measured to investigate the possible impact that human disturbance has on elephants outside of protected areas (Galanti *et al*. 2006; Douglas-Hamilton *et al.,* 2005; Graham *et al.*, 2009). Average speeds were calculated in Arc Gis based on straight line distance in km/interval in hours. In response to disturbance, Douglas-Hamilton *et al.* (2005) recorded above average travel speeds in elephants crossing unprotected land. This they termed "streaking behaviour", and speeds recorded were 4 x higher than the average (Douglas-Hamilton *et al*., 2005). This streaking behaviour was investigated for the three elephants in this study. Long distance movements were recorded in order to identify possible movement routes, and included linear distances between successive locations of 30 km or more (Viljoen, 1989).

vi) Analyses

When continuous variables were compared versus nominal input variables, ANOVA (analysis of variance) were used. If the residuals were not normally distributed, non-parametric methods were used as with ordinal variables. When ordinal variables needed to be compared versus nominal input variables, non-parametric tests were used. For completely randomized designs, the Mann-Whitney test (comparing two groups) or the Kruskal-Wallis test (comparing more than two groups) was used. When nominal variables needed to be compared to other nominal input variable(s), appropriate contingency table analyses were used and the maximum likelihood Chi-Square test used as the test statistic. Generalised linear models with Poisson distribution and log link function were used to analyse the number of core areas in protected and unprotected areas.

2.3 Results

The total number of GPS fixes for the collared elephants ranged from 1 261 to 1 546. Although the data only represent the movements of three individuals, they are likely to be representative of the movements of other elephants (Foley, 2002). Data from highly social animals like the elephant can be representative of a subpopulation (Poole & Moss, 1981), as data from a female represents the movements of her family unit. However future inferences should only be made after ground-truthing as not all elephant movements from a sub-population are cohesive.

i) Home range and core zones

<u>Home ranges</u>

Collared elephants did not have exclusive home ranges - home range overlap was evident in the wet season, when all three elephants displayed spatial overlap (not in time) in Sioma Ngwezi National Park (SNNP), Zambia, the Game Management Area (GMA) just north of the Caprivi State Forest (CSF) and on the Caprivi State Forest border. Locations and ranges suggested that collared elephants had preferred home sectors and core zones that they frequented throughout the year. Bulls ranged much wider than the female (Figs. 2.2-2.4), moving across a mosaic of land use types and making use of forest patches or 'stepping stones' between dispersal areas, whereas the female and her herd restricted her movements to the north of SNNP.

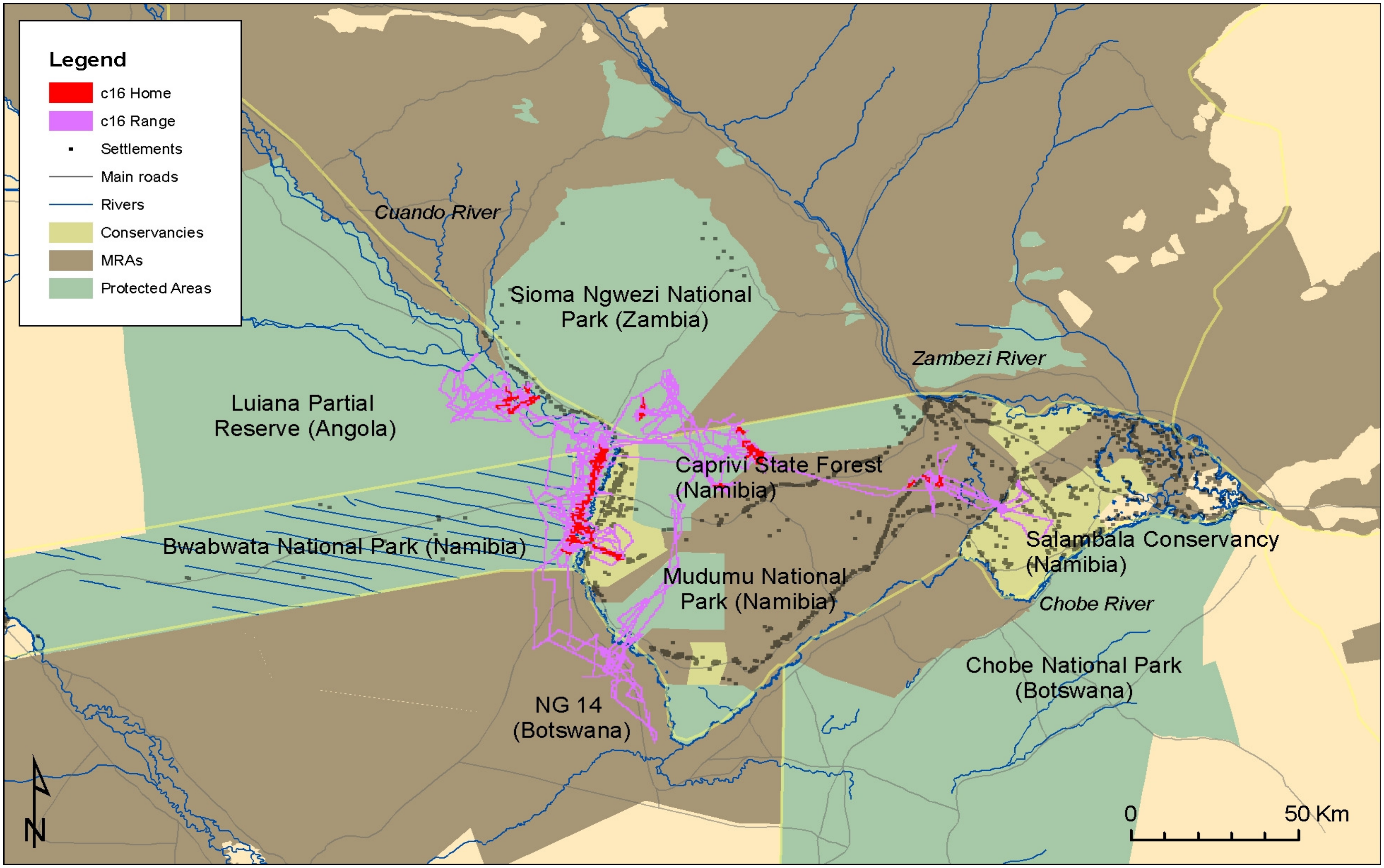


Fig. 2.2: Home ranges (mauve lines) and home sectors (darker, reddish shading) in relation to protected areas (green) for male 16.

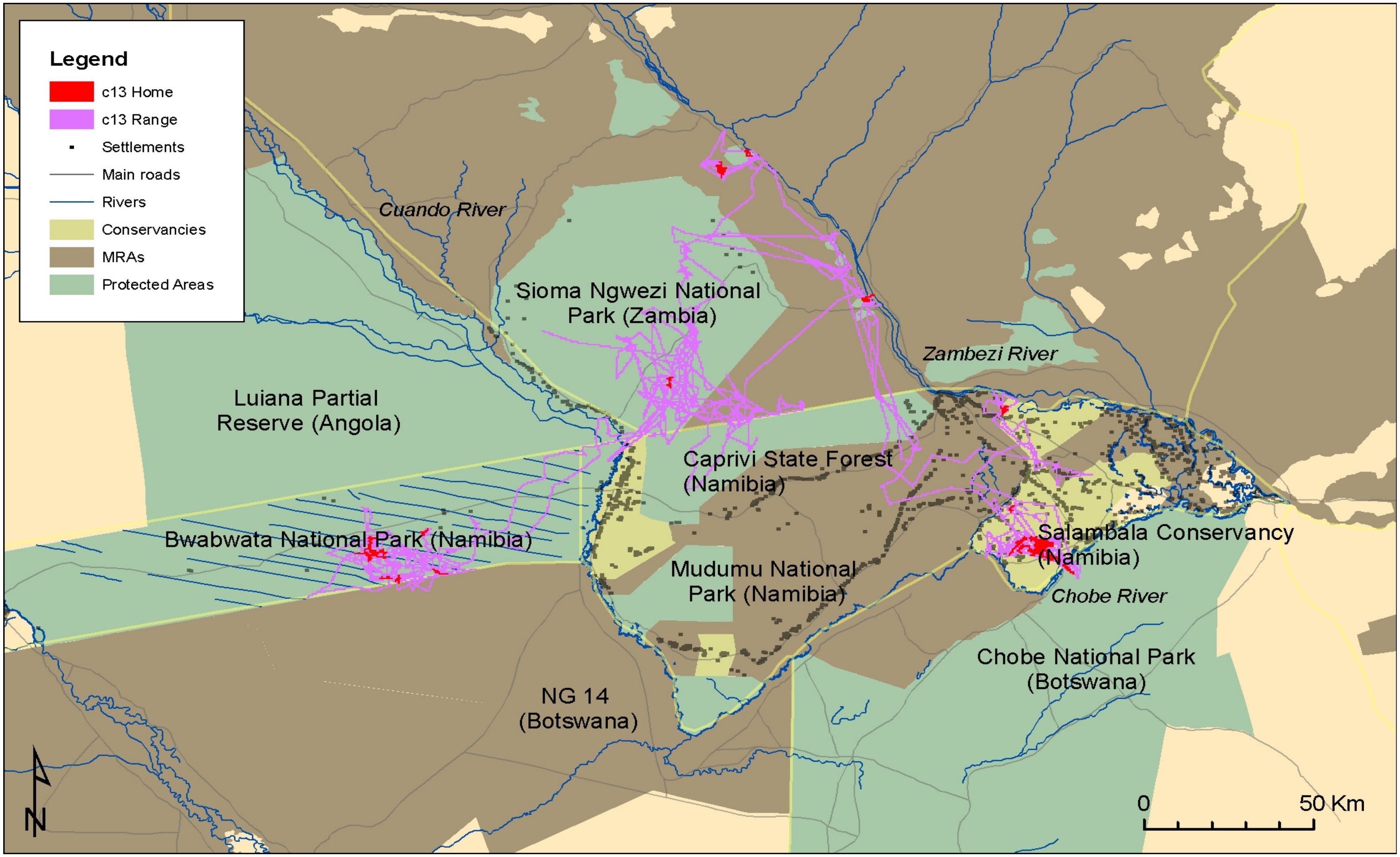


Fig. 2.3: Home ranges (mauve lines) and home sectors (darker, reddish shading) in relation to protected areas (green) for male 13.

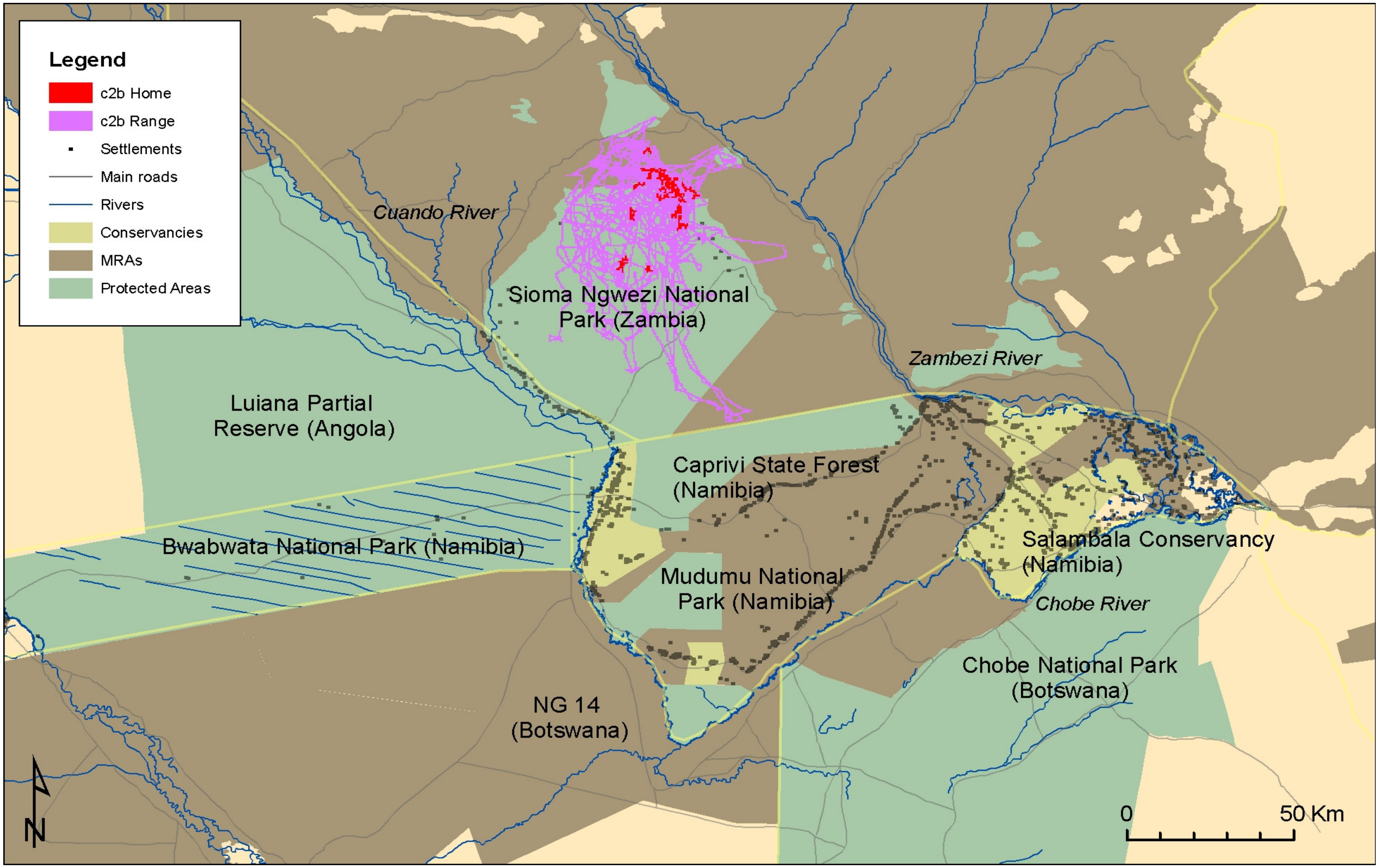


Fig. 2.4: Home ranges (mauve lines) and home sectors (darker, reddish shading) in relation to protected areas (green) for female 2.

Table 2.2 presents the estimated home ranges (grid square method and Minimum Convex Polygon (MCP) for two bulls and one cow herd within KAZA TFCA. Elephant ranges measured with the grid square method averaged 1 700 km^2, and were 3.3 times smaller than those estimated by the MCP method (12 702 km^2).

Table 2.2: Elephant core and total ranges

Elephant	Sex	Home Range (Grid)	Home range (MCP)	Proportion of core area within total range (%)	Core area dry	Core area wet
16	m	1 561 km^2	13 451 km^2	12%	131 km^2	151 km^2
13	m	1 952 km^2	19 690 km^2	14%	91 km^2	179 km^2
2	f	1 587 km^2	4 966 km^2	9%	198 km^2	215 km^2

The MCP method indicated how big an area was explored, but seriously over-estimated the actual range sizes, confirming Douglas-Hamilton's results (2005). Total home range size was similar between the two males and crossed four country borders. Home range sizes (Grid square method) for the males were 1 561 km^2 and 1 952 km^2 and for the female 1 587 km^2.

Seasonal range use

Collared elephants spent the hot dry season (August-October) near riverine areas. Bull 16 (Fig. 2.6) remained mostly in the teak woodlands and riverine areas west of the Kwandu River, in protected areas which included Bwabwata National Park (BNP) in Namibia and Luiana Partial Reserve (LPR) in Angola. Bull 13 moved between the mopane-*Terminalia* woodlands of central Salambala, Nabulongwe pan south of Katima Mulilo and the Maningimanzi woodland and channel south of the Zambezi River in Namibia among pockets of mopane woodland. The female (Fig. 2.8) remained within the Kalahari woodlands of SNNP with frequent forays to the protected teak forests (Shokosha) and the Zambezi River.

Wet season range (November-April) was larger than the dry season range for all three elephants: the female's dry season range (787 km^2) expanded to 1 149 km^2 in the wet season. Male 16's dry season range of 514 km^2 expanded to 1 313 km^2 in the wet season, while bull 13 home range was 771 km^2 in the dry season and 1 270 km^2 in the wet. Bull 16 wet season saw him move from mopane-*Burkea,* mopane-*Aristida* woodlands of Mudumu National Park (MNP) and NG14 northwards to the teak woodlands of BNP and LPR, SNNP, the teak forests of the CSF and two Conservancies in Namibia - Mashi Conservancy and the Camelthorn and mopane *Terminalia* woodlands of Salambala Conservancy. Movements in to Conservancies coincided with the cropping season. Bull 13 moved between the protected forest on the Zambezi River and SNNP, moving down towards BNP in April passing via an elephant corridor on the northern Kwandu Conservancy (KC) cutline. He moved across the *omurambas* and *Burkea-Combretum* woodlands and settled in teak woodlands of south-eastern BNP. The female and her herd (herd number unknown) moved between northern SNNP and the protected forest of Nampiu and Nanduka on the Zambezi River. A habitat corridor between SNNP and the fringe of Nampiu Forest was identified (Fig. 2.5.). However female 2 avoided entering Nampiu Forest and using this link to the Zambezi River, with only four records being observed on the southern perimeter of Nampiu Forest.

The cool dry season (May-July) at the end of the wet season saw bull 16 moving between BNP and Mashi and Mayuni Conservancies in May and ending in LPR by July. Bull 13 (Fig. 2.7) moved extensively in this time, from BNP to SNNP and on to the Kalahari Woodland forests of Chiobe and Lusu protected forests on the Zambezi River. Female 2 remained between northern SNNP and southern Nampiu in this time.

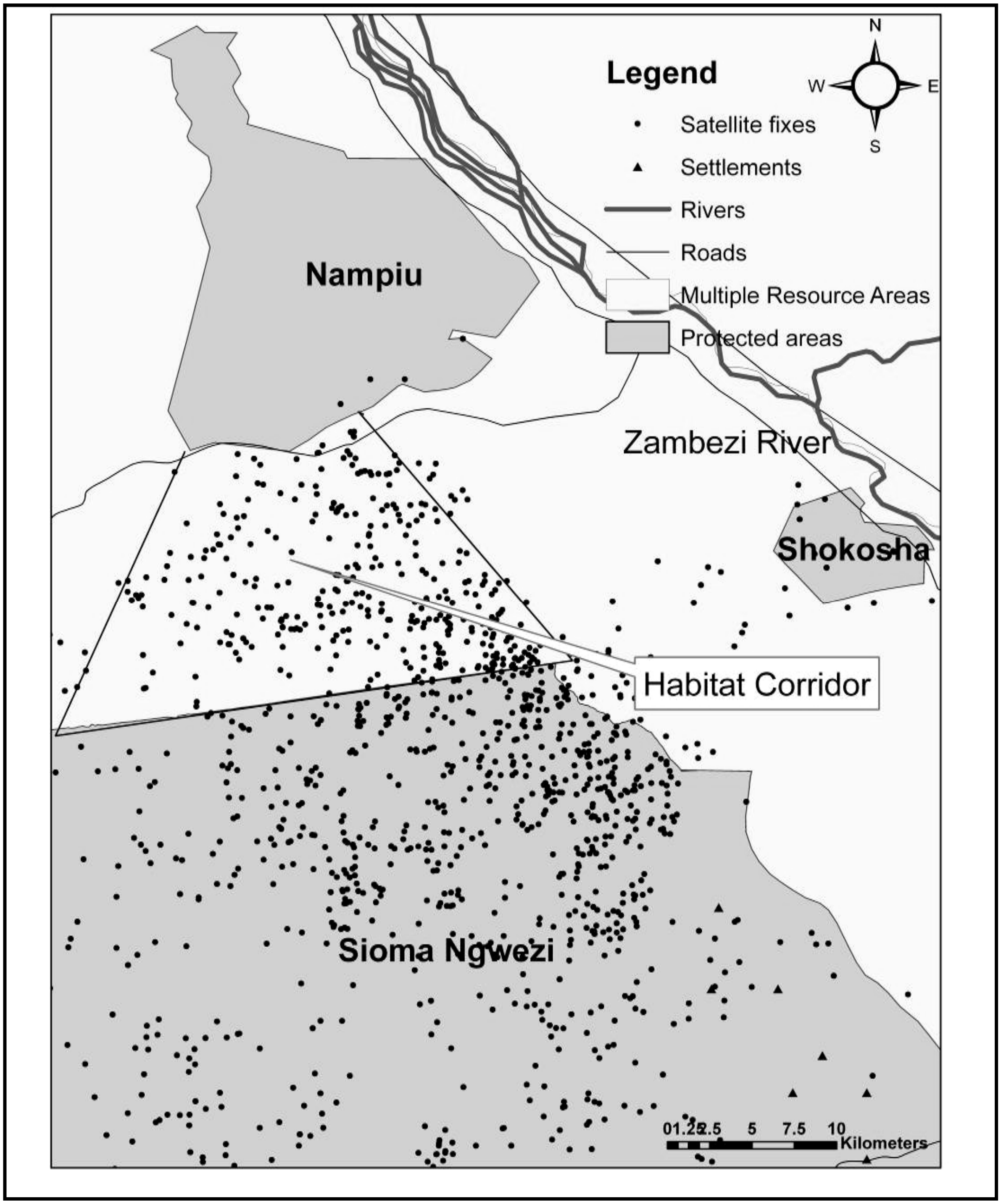


Fig. 2.5: In Zambia, female 2 spent considerable time moving between Sioma Ngwezi National Park and the southern fringe of Nampiu Protected Forest.

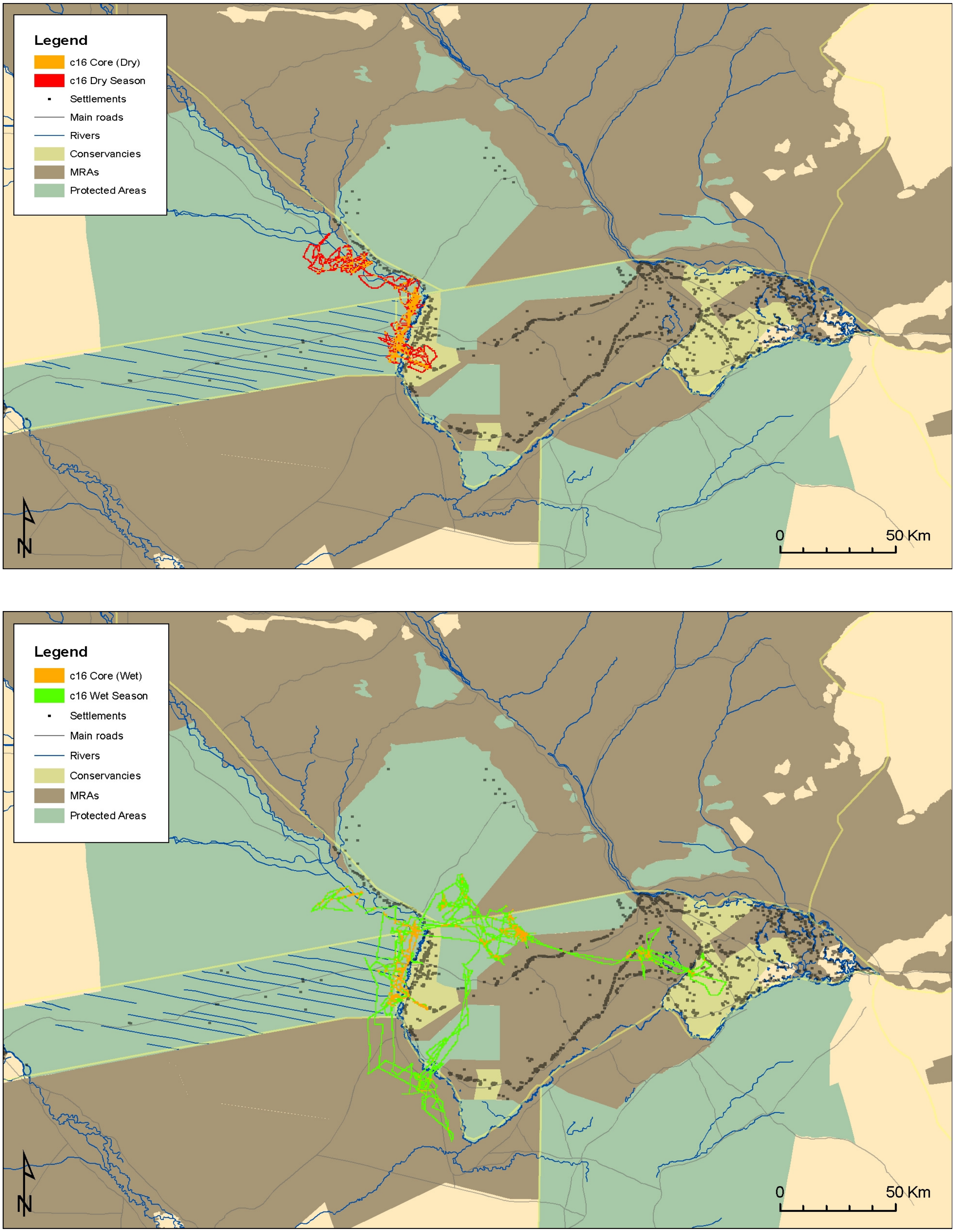


Fig. 2.6: Dry (top) and wet (bottom) season ranges for bull 16. Note core areas (orange) in relation to protected areas (green).

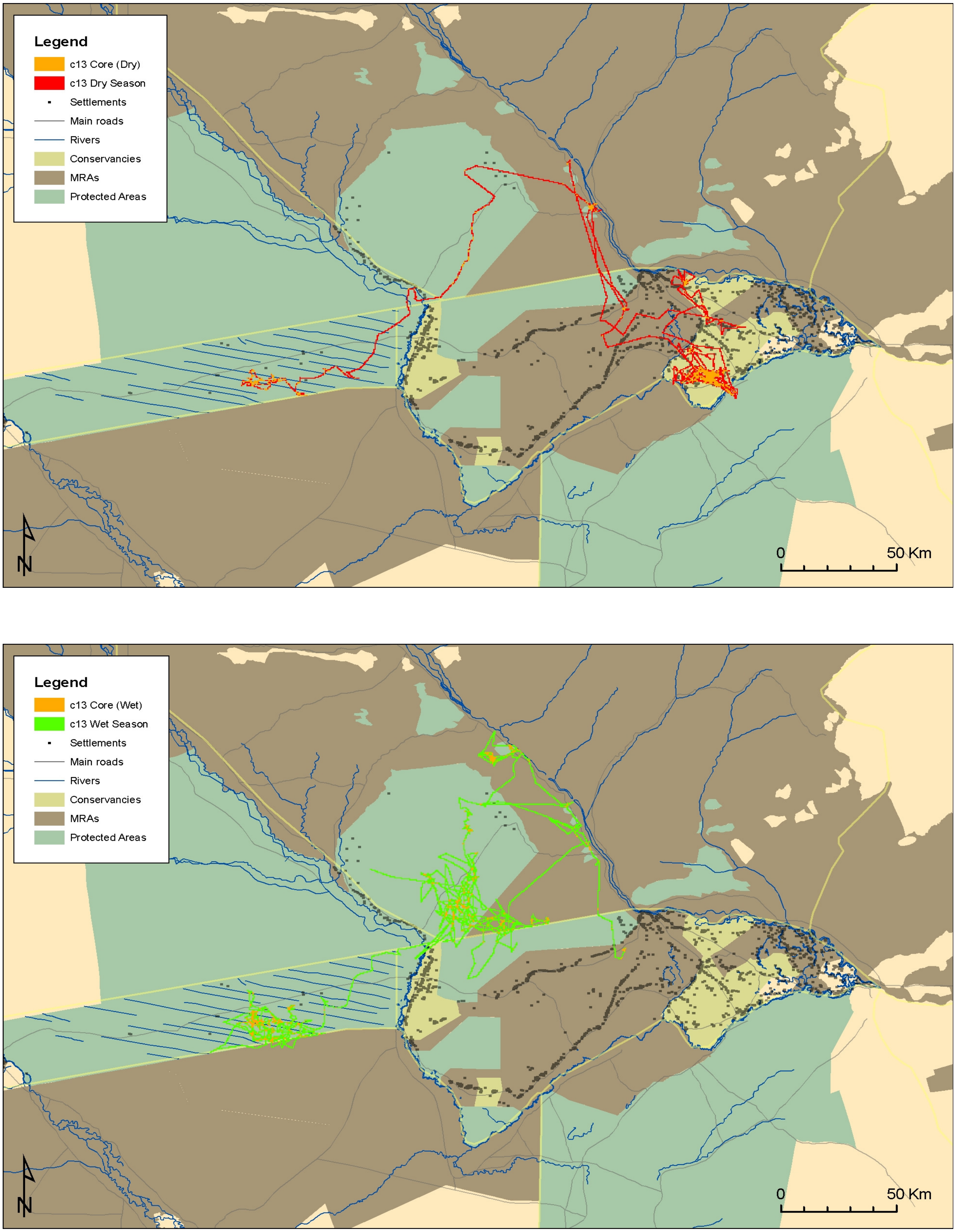
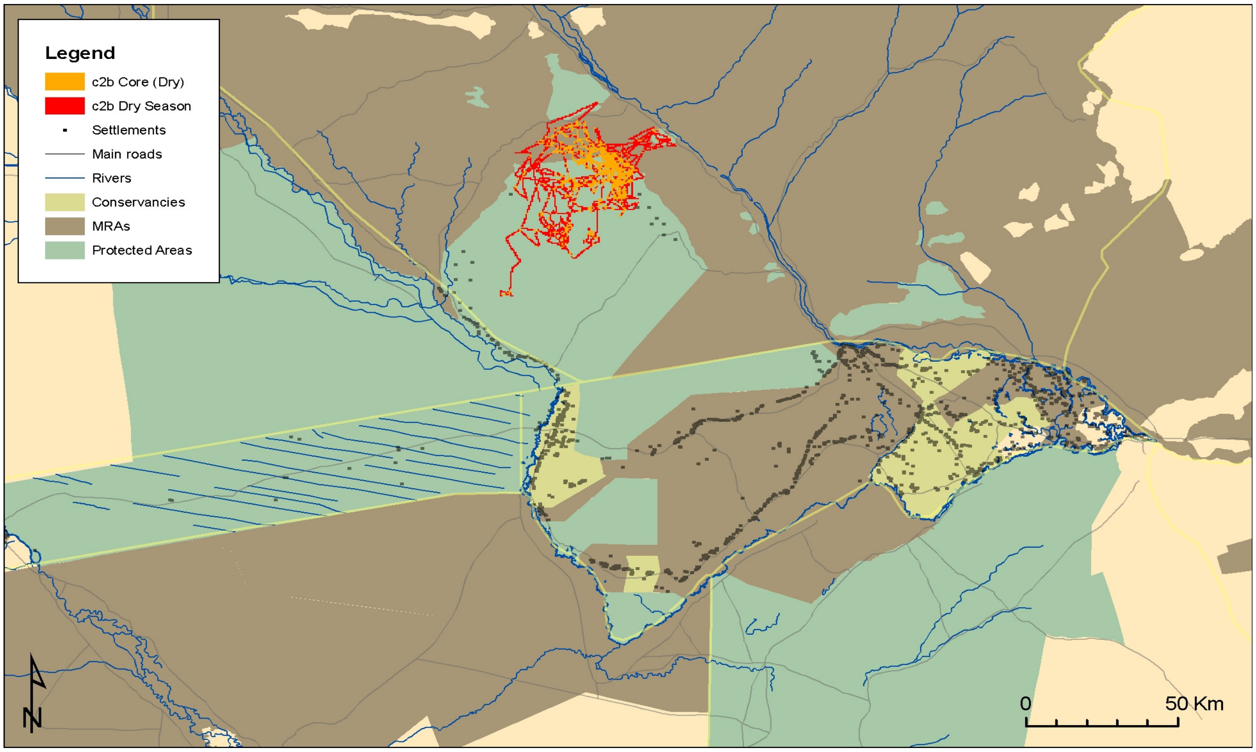


Fig. 2.7: Dry (top) and wet (bottom) season ranges for bull 13. Note core areas (orange) in relation to protected areas (green).



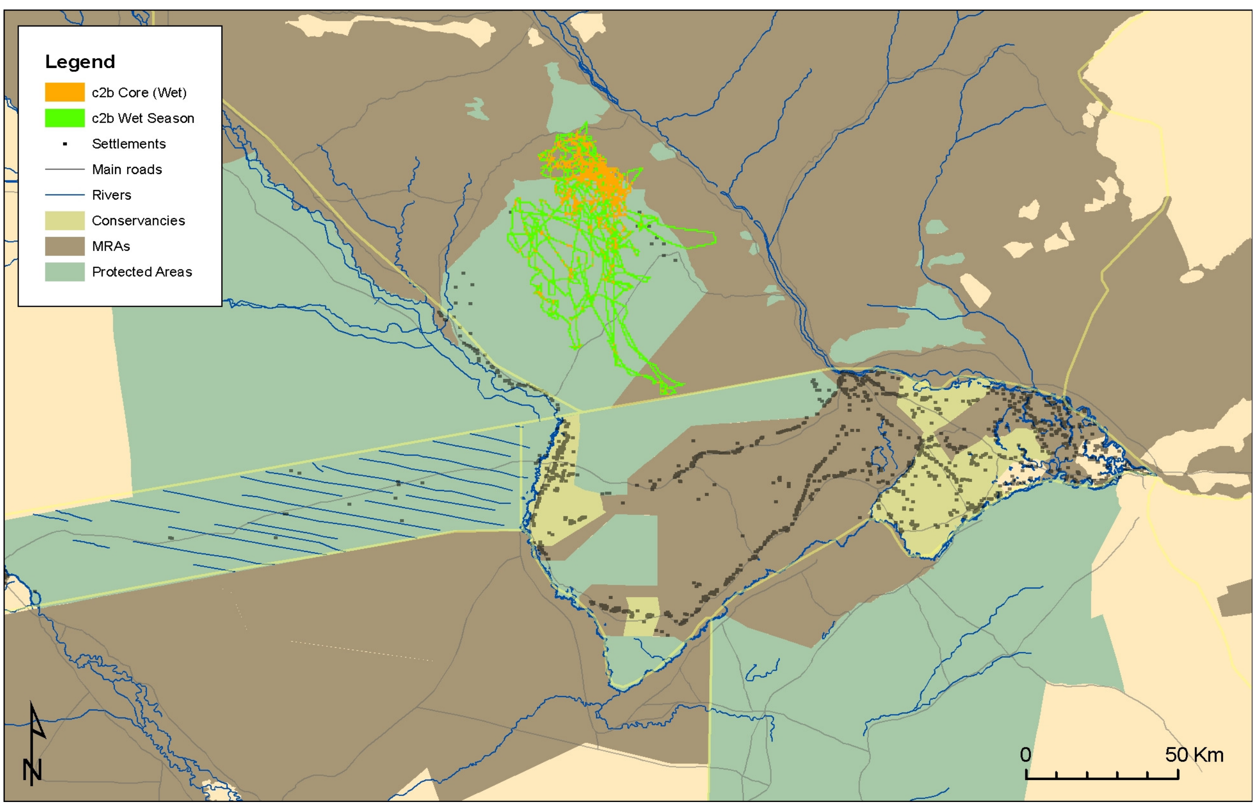


Fig. 2.8: Dry (top) and wet (bottom) season ranges for female 2. Note core areas (orange) in relation to protected areas (green).

Core areas

Home ranges of collared elephants indicated areas of heightened activity, which were mostly in protected areas. Core areas, being the most intensively used areas within each elephant's range, constituted only a small percentage of the total grid square home range: 12% (bull 16), 14% (bull 13) and 9% (female 2). During the wet season, core areas overlapped for collared bull 13 and collared female 2 in SNNP, and for the collared bulls 13 and 16 in the CSF's northern boundary. No dry season core area overlap between the three elephants was found.

Table 2.3: High numbers of core zones tended to be found in protected areas.

Elephant ID	Area identification	Area type (protected/ non-protected)	Area size (hectares)	# of elephant core areas detected
13	Bwabwata NP (BNP)	Protected	602820	105
13	Caprivi State Forest (CSF)	Protected	148649	16
13	Chiobe State Forest	Protected	986	4
13	Chobe NP	Protected	1206900	9
13	Luiana Partial Reserve (LPR)	Protected	1006019	2
13	Lusu State Forest	Protected	1432	0
13	Nanduka State Forest	Protected	1018	1
13	Shokosha State Forest	Protected	3837	6
13	Sioma Ngwezi NP	Protected	499522	105
13	NG/13	Non-Protected	274328	6
13	Lusese	Non-Protected	32552	1
13	Southern African Development Community (SADC) Block	Non-Protected	9,882,959	18
13	Salambala Conservancy	Non-Protected	92169	35
13	Sikunga	Non-Protected	35936	6
13	West Zambezi GMA	Non-Protected	1845777	75
16	Bwabwata NP (BNP)	Protected	602820	28
16	Caprivi State Forest (CSF)	Protected	148649	28
16	Luiana Partial Reserve (LPR)	Protected	1006019	58
16	Mudumu NP	Protected	72066	0
16	Sioma Ngwezi NP (SNNP)	Protected	499522	20
16	Mashi Conservancy	Non-Protected	29914	10
16	Mayuni Conservancy	Non-Protected	15072	3
16	Kwandu Conservancy (KC)	Non-Protected	18909	1
16	NG/13	Non-Protected	274328	0
16	NG/14	Non-Protected	220485	6
16	NG/16	Non-Protected	134045	0
16	SADC block	Non-Protected	1685345956	18
16	Salambala Conservancy	Non-Protected	92169	3
16	West Zambezi GMA	Non-Protected	1845777	1
2	Sioma Ngwezi NP (SNNP)	Protected	499522	79
2	West Zambezi GMA	Non-Protected	1845777	58

There were significantly more core areas in protected areas than in non-protected areas for collared bull 16 (Fig. 2.9, Wald $X^2 = 11.6$, $p < 0.001$). For collared bull 13, there was no significant difference in number of core areas in protected and non-protected areas (Fig. 2.10, Wald $X^2 = 1.1$, $p < 0.30$). However this could be attributed to the fact that he spent considerable time in the Salambala Conservancy – a settlement area with low settlement density and expansive floodplains along the Chobe River. Collared female 2 only moved between three different area types so preference for core zones could not be assessed statistically.

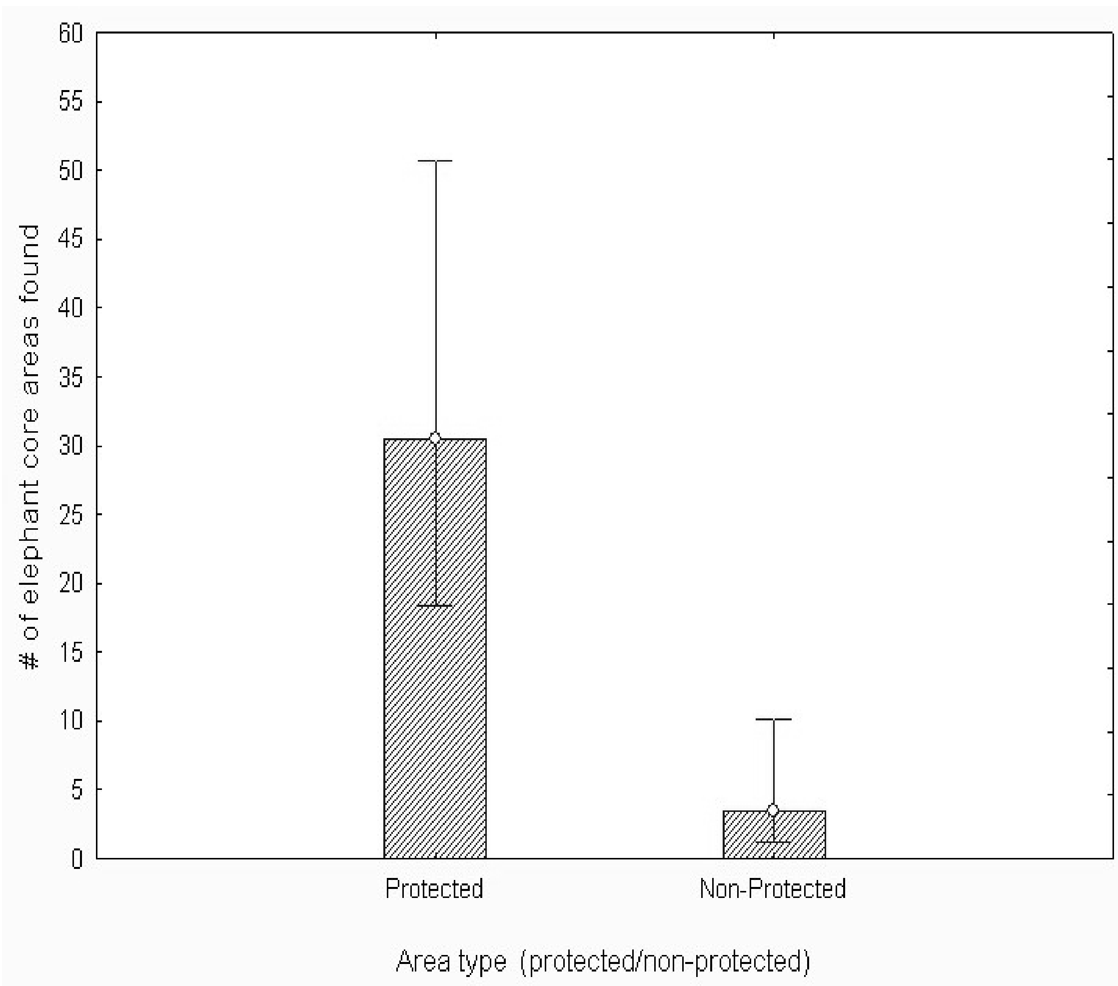


Fig. 2.9: Average number of core areas in protected areas and in non-protected areas for bull 16. Error bars indicate 95% Confidence Intervals. $p < 0.001$.

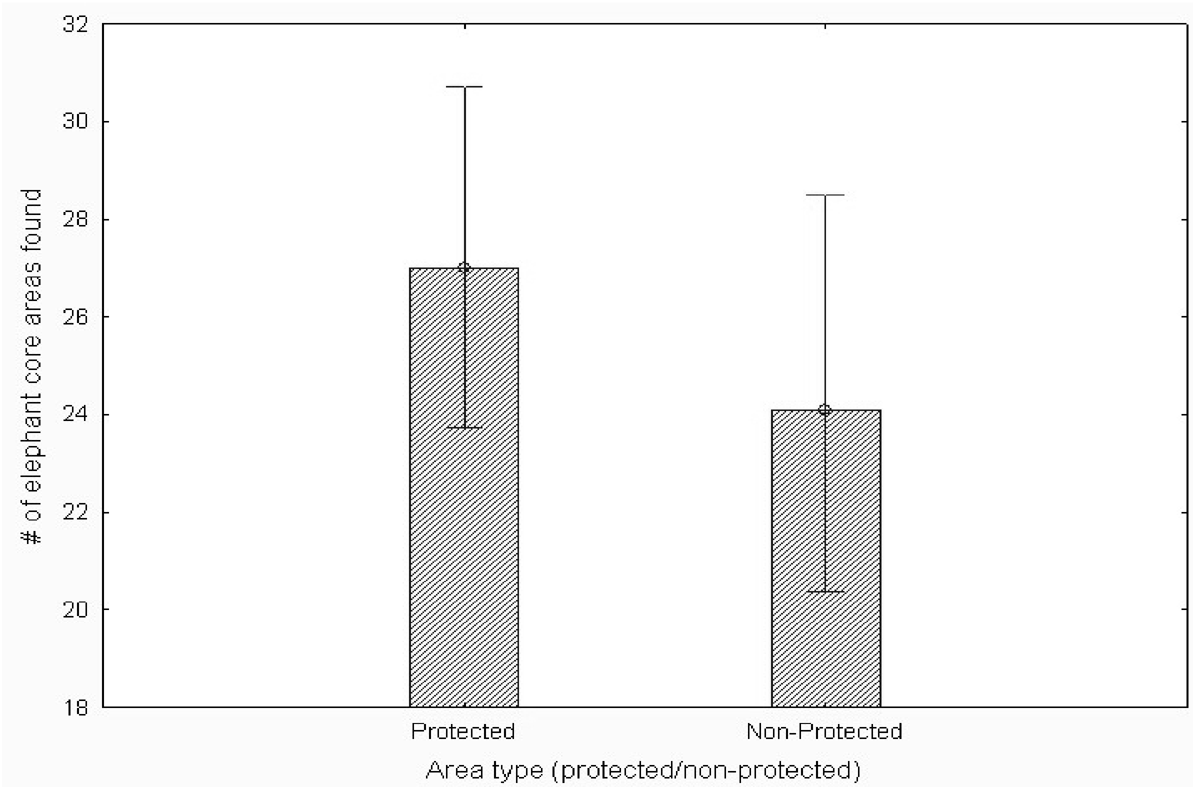


Fig. 2.10: Average number of core areas in protected areas and in non-protected areas for bull 13. Error bars indicate 95% Confidence Intervals. $p < 0.30$.

Core and non-core areas

200 core and 200 non-core areas were randomly selected and tested for significant differences in AFRI, elevation, distance to settlements, distance to rivers and distance to nearest protected area. No significant differences were found in AFRI, and distance to settlements. Core zones tended to be close to rivers (Mann-Whitney U, $F = 1.69$, $p = 0.04$). Significant differences between core areas and non-core areas were found in elevation (Figs. 2.11: Mann-Whitney U, $F = 0.39$, $p < 0.01$) and in distance to protected area (Fig. 2.12: Mann-Whitney U, $F = 37.48$, $p < 0.01$), with core areas found at higher elevations and closer to protected areas than non-core areas.

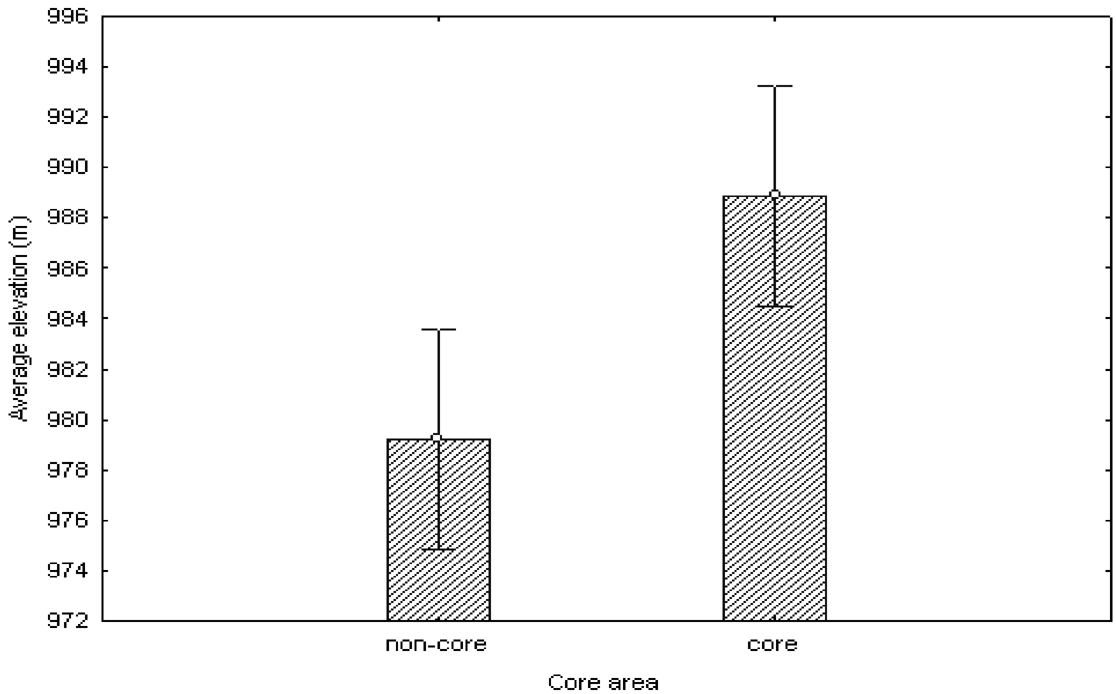


Fig. 2.11: Average elevation for core and non-core areas. Error bars indicate 95% Confidence Intervals. $p < 0.01$.

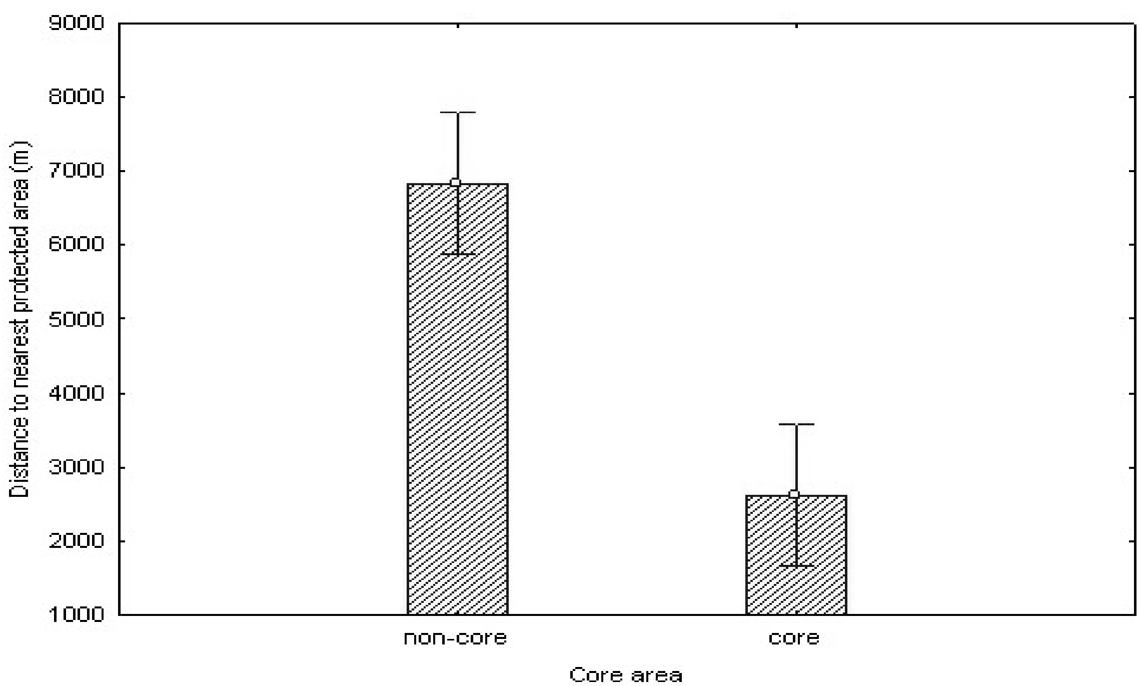


Fig. 2.12: Average distance to nearest protected area for core and non-core areas. Error bars indicate 95% Confidence Intervals. $p < 0.01$.

Wet and dry season core areas

Wet and dry season core areas were tested for significant differences in AFRI, elevation, distance to settlements, rivers and protected areas. Dry season core areas were found at significantly lower elevations than wet season core areas (Fig. 2.13, Kruskal Wallis, $F = 95.07$, $p < 0.01$). Dry season core areas tended to lie closer to settlements (Fig. 2.14, Kruskal Wallis, $F = 49.12$, $p < 0.01$) and rivers (Fig. 2.15, Kruskal Wallis, $F = 21.99$, $p < 0.01$) than to wet season core areas. Wet season core areas were significantly closer to protected areas than dry season core areas (Fig. 2.16, Kruskal Wallis, $F = 25.83$, $p < 0.01$).

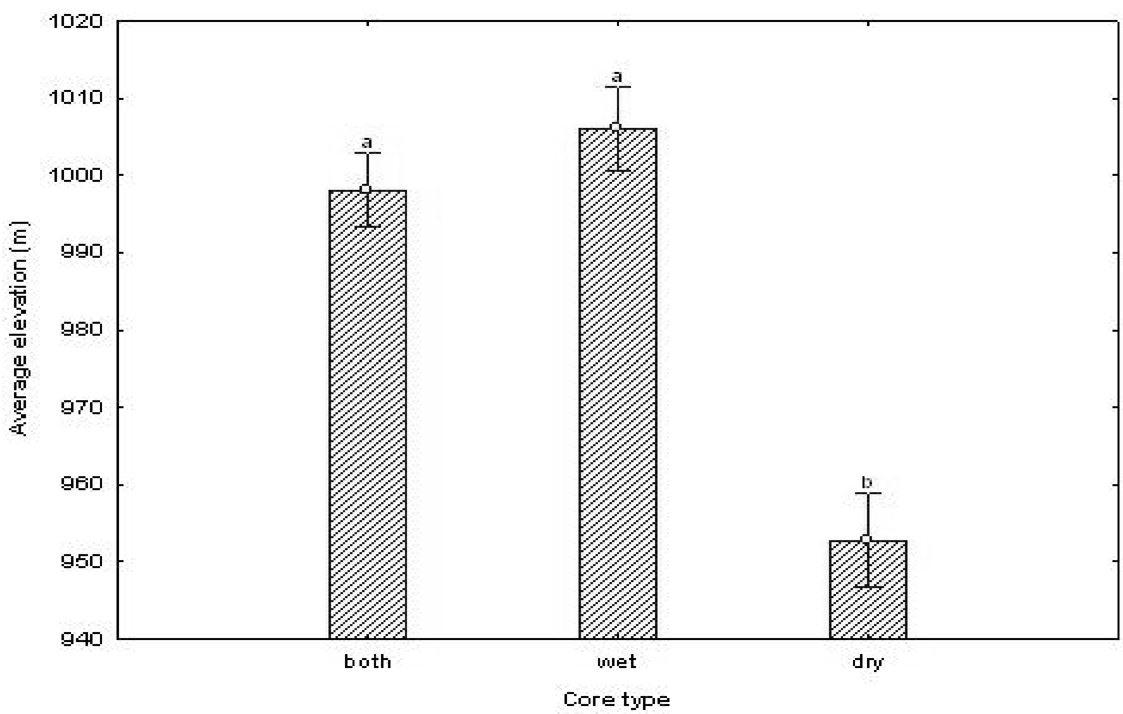


Fig. 2.13: Average elevation of dry core areas and wet core areas. Significant differences at $p < 0.01$ indicated by different letters.

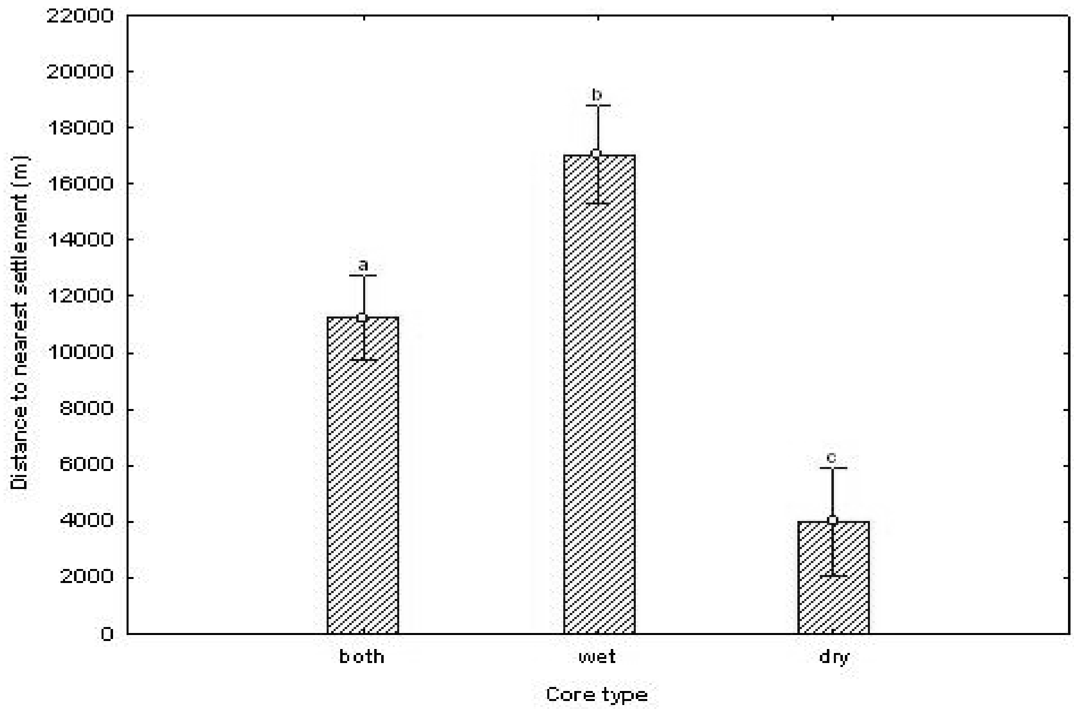


Fig. 2.14: Average distance to nearest settlement of dry core areas and wet core areas. Significant differences at $p < 0.01$ indicated by different letters.

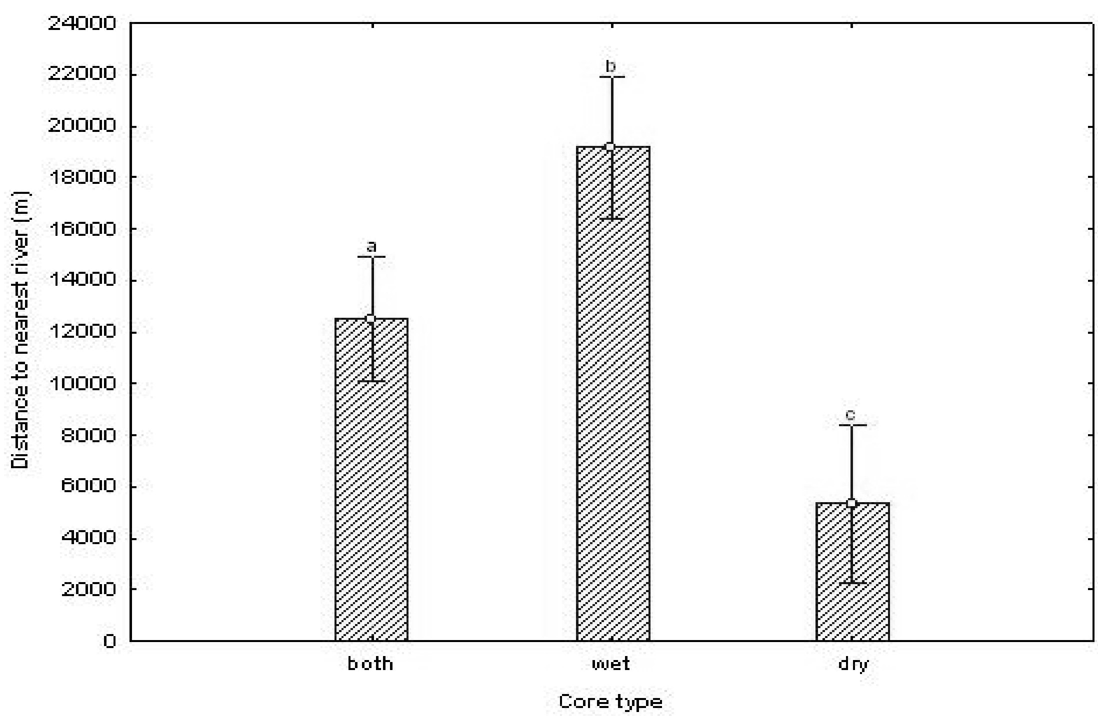


Fig. 2.15: Average distance to nearest river of dry core areas and wet core areas. Significant differences at $p < 0.01$ indicated by different letters.

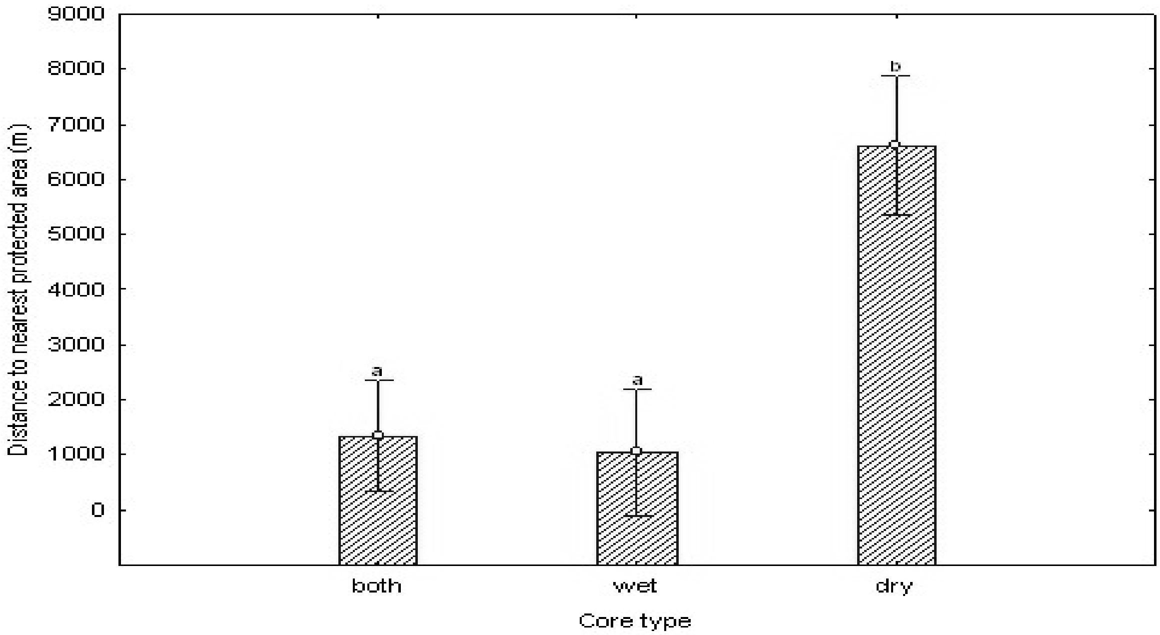


Fig. 2.16: Average distance to nearest protected area of dry core areas and wet core areas. Significant differences at $p < 0.01$ indicated by different letters.

ii) Land use types and habitat selection

Collared elephants had over 50% of their range inside protected areas (Fig. 2.17), with bull 16 and female 2 spending as much as 83% and 73% of their time respectively in PAs (Table 2.4). Communal land was used the least by the collared elephants, although both males were active within communal areas in Namibia on numerous occasions. MRAs and Conservancies adjoining protected area boundaries nevertheless played an important role, constituting between 35 and 45% of the total range. Non-protected areas consist of Conservancies (communal land), GMAs, hunting concessions as well as private and public land. No significant difference in AFRI was found between protected and non-protected areas (Mann-Whitney U test, $F = 0.21$, $p = 0.43$).

Table 2. 4: Two out of three collared elephants spent more than 73% of their time in protected areas.

Elephant Id	Hours in PAs	Hours in Non-PAs	Total Hours
Bull 13	5721	6905	12 626
Bull 16	10506	2128	12 634
Female 2	9172	3463	12 635

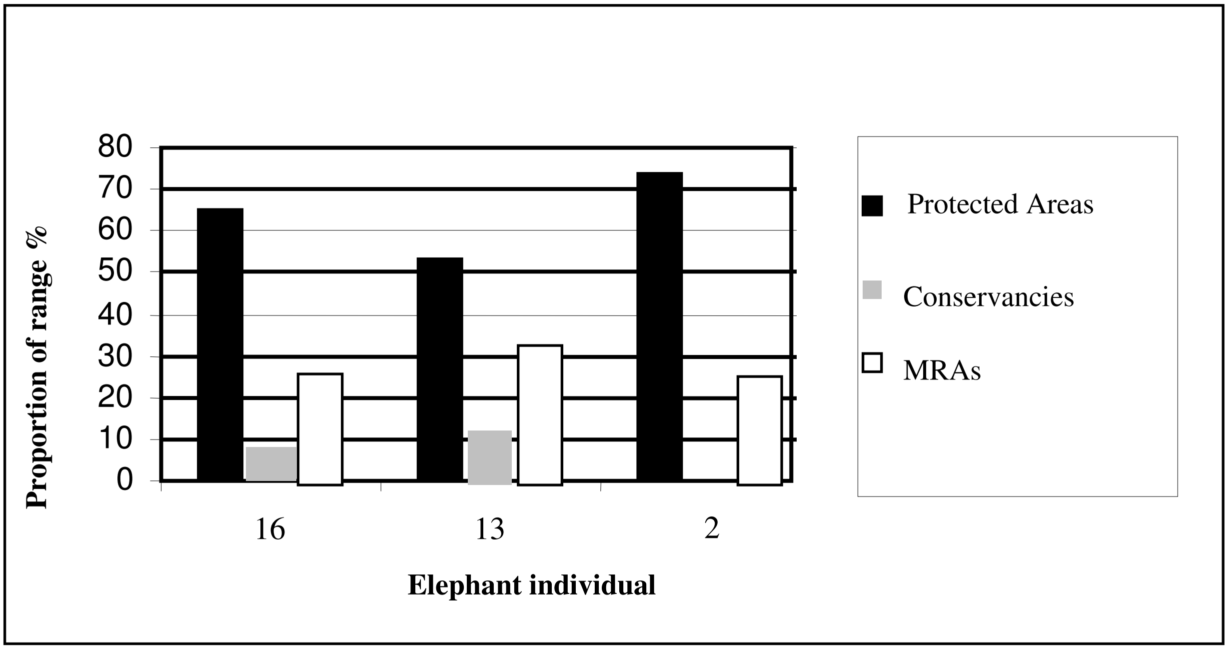


Fig. 2.17: Ranges and land category preference for three collared elephants in Kavango Zambezi Transfrontier Conservation Area (2 = ♀, 13 and 16 = ♂).

iii) Elephant behaviour

<u>Speed</u>

While little difference in speed was found between day and night speeds in PAs, a significant difference between day and night speeds in non-protected areas was found (Fig. 2.18, ANOVA, $F = 6.65$, $p < 0.05$) with bulls travelling faster at night in non-protected areas.

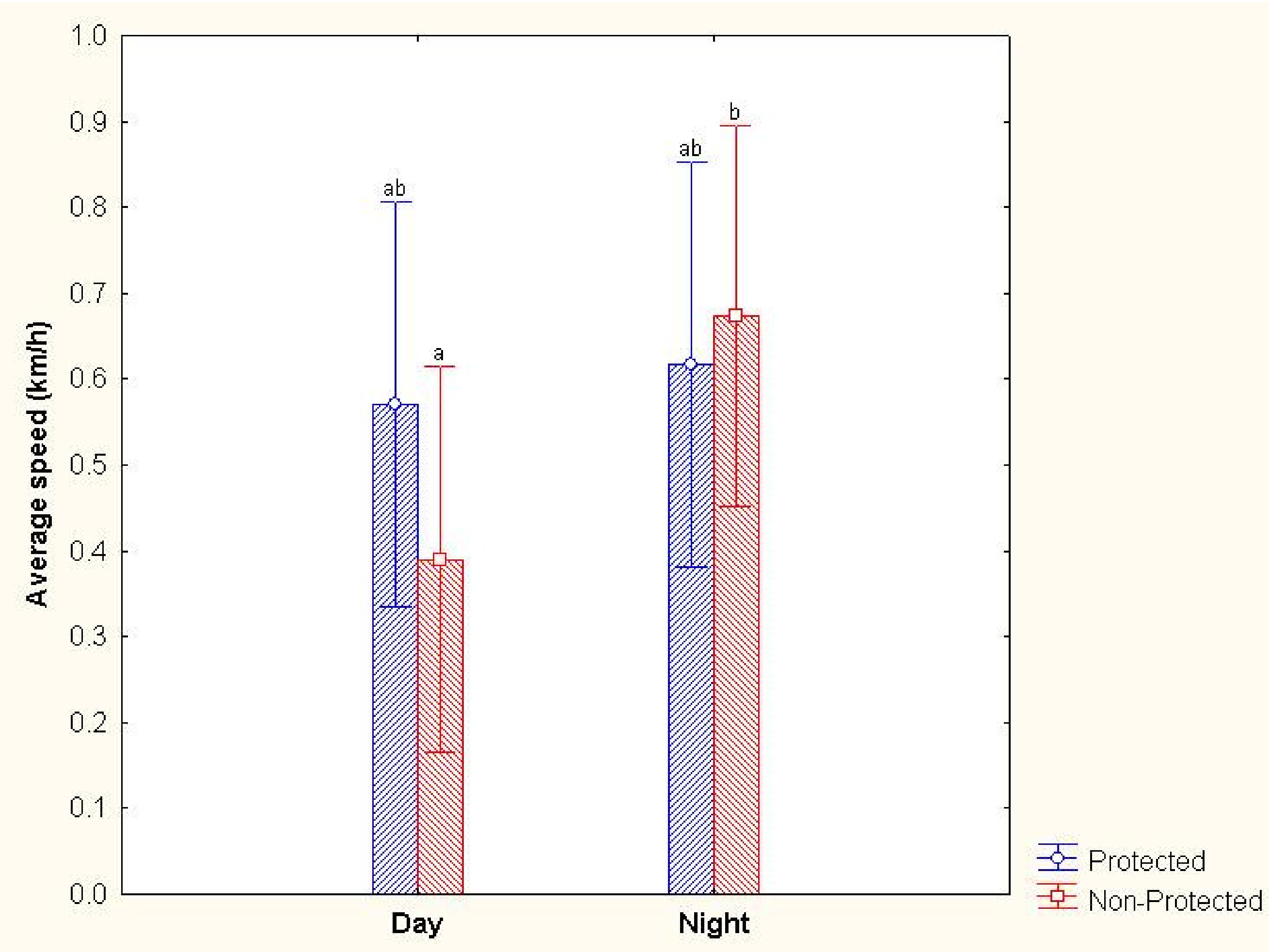


Fig. 2.18: Average diurnal and nocturnal speeds for collared bulls 13 and 16. Significant differences at $p < 0.05$ are indicated by different letters.

Table 2.5:

Time	Area type	Av. speed (mean)	Av. Speed (Standard error)	No. of observations N
Day	Protected	0.57	0.11	13
Day	Non-Protected	0.39	0.10	14
Night	Protected	0.62	0.11	13
Night	Non-Protected	0.67	1.10	15

Speeds of the collared elephants were categorised and mapped (Figs. 2.19-2.21). Streaking behaviour by bulls was recorded when bulls travelled through settlement areas at night. Collared bull 16 displayed nocturnal streaking behaviour (>4 km/hr) when moving through settled areas and over roads between Salambala Conservancy and the

CSF. In March, he moved from the Caprivi State Forest to Salambala, returning along the same route one month later. The speed recorded was more than 4 x higher than his average speed of 0.93 km.

Collared bull 13 displayed streaking behaviour (>4 km/hr) when moving in an easterly direction from SNNP through the unprotected West Zambezi GMA to the protected forests of the Zambezi. On three occasions (April, May, October), he moved from the protected forests south through the CSF to the Salambala Conservancy. Speeds in this potential linkage ranged from 2.11 km/hr to 2.46 km/hr.

Collared female 2 showed streaking behaviour within SNNP when moving from the southern section of the park to a core area in the north, suggesting in this case that faster than usual travel may indicate searching behaviour during feeding forays rather than disturbance.

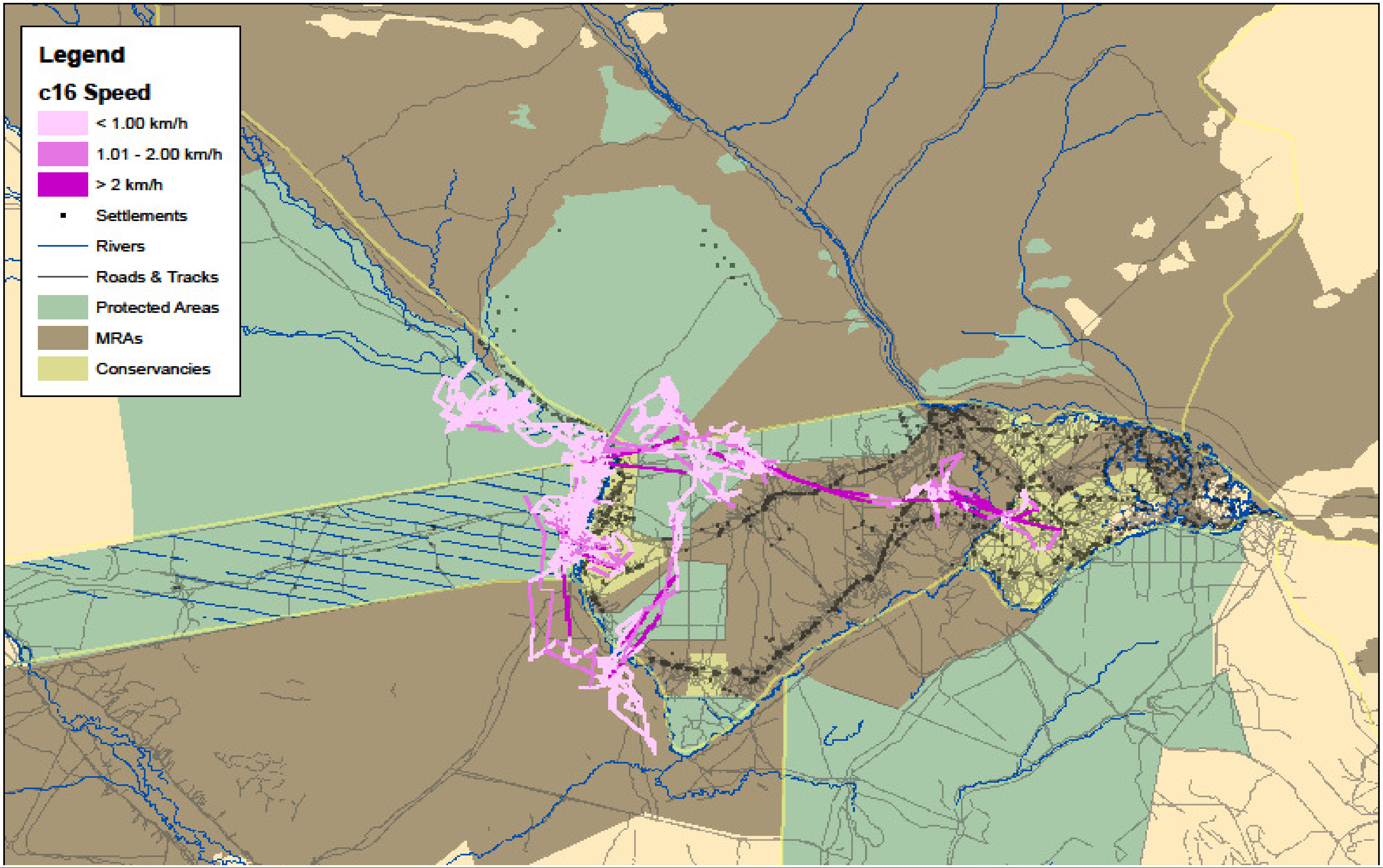


Fig. 2.19: Speed travelled by bull 16 within its home range.

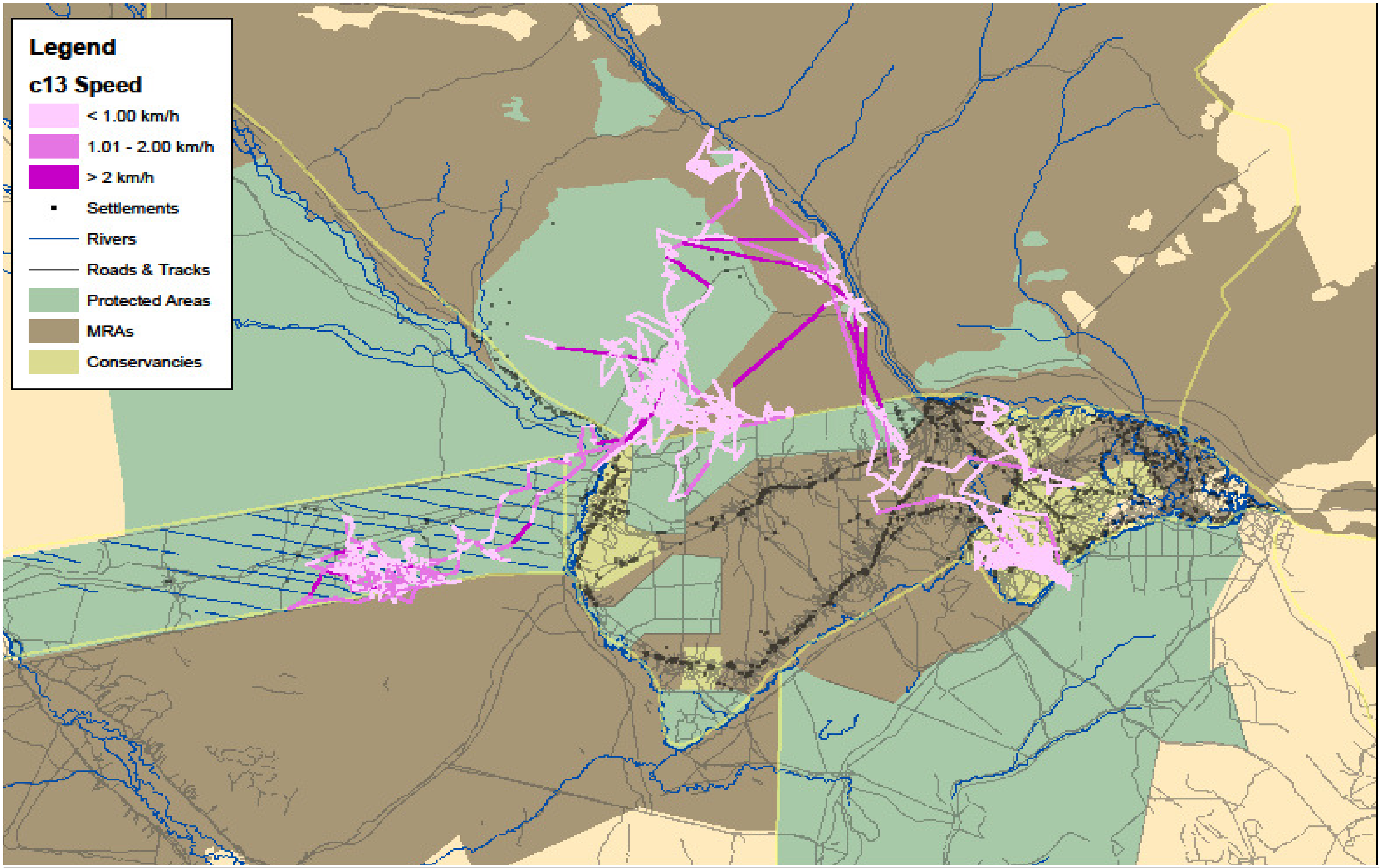


Fig. 2.20: Speed travelled by bull 13 within its home range.

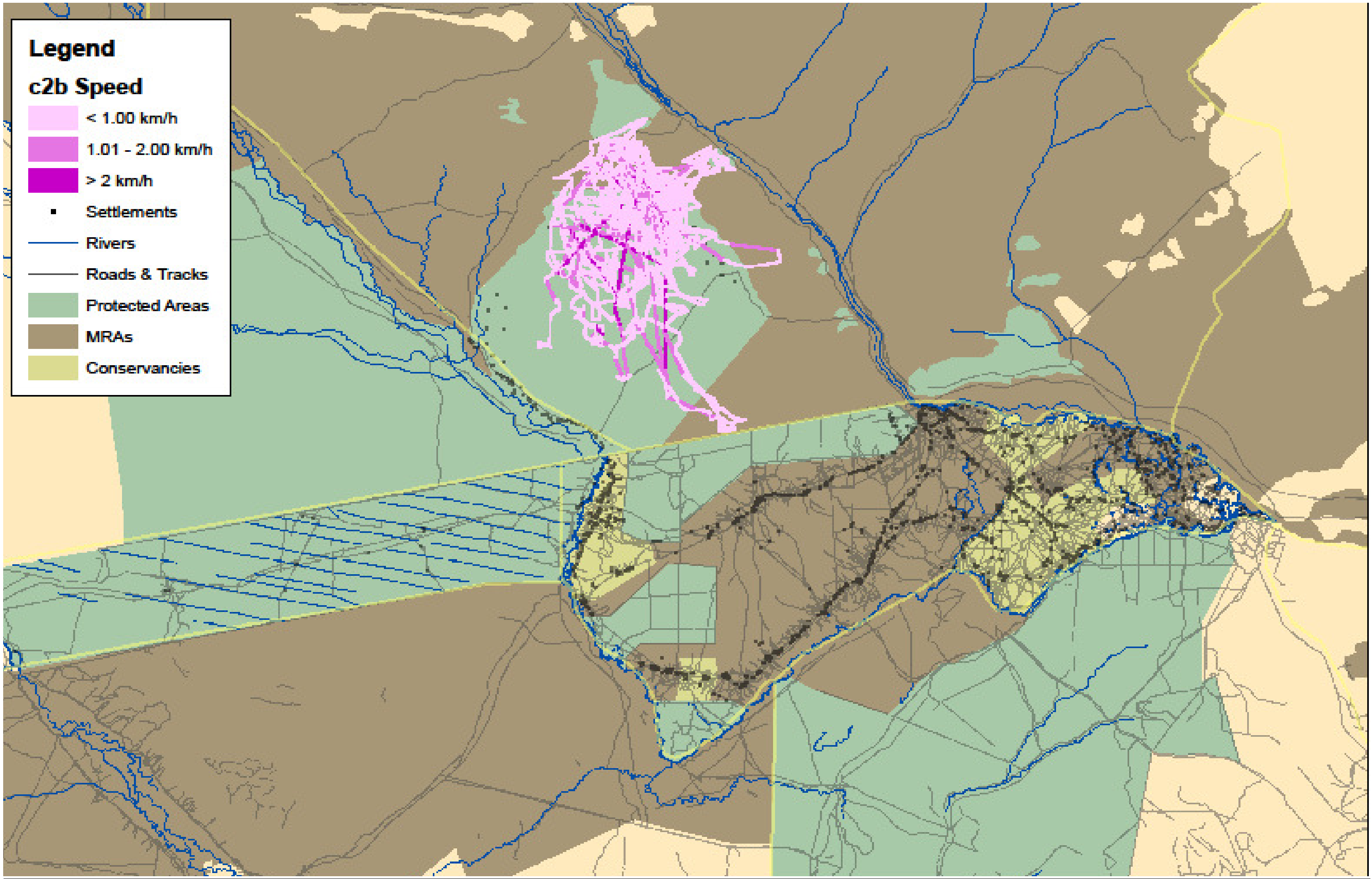


Fig. 2.21: Speed travelled by female 2 within its home range.

Distance

Behaviour varied markedly with collared bull 16 avoiding travel in non-protected areas at night as well as during the day, whereas there was no significant differences in distances travelled at night or during the day between land use types for collared bull 13 (Table 2.4.).

Table 2.6 (a): Diurnal and nocturnal distances travelled in land use types differed markedly between bulls.

Bull	ANOVA p values	F values	Day / Night	Distances in protected areas versus non-protected areas
16	**p = 0.02**	**F = 7.66**	Day	During the day, traveled further in protected areas than in non-protected areas.
16	**p < 0.01**	**F = 12.63**	Night	At night, traveled further in protected areas than in non-protected areas.
13	p = 0.98	F = 0.01	Day	During the day, no significant difference found in distances traveled between protected and non-protected areas.
13	p = 0.54	F = 0.40	Night	At night, tendency to travel further in non-protected areas than in protected areas, but this was not significant.

Table.2.6 (b): Means, standard deviations, standard error and number of observations for diurnal and nocturnal distances travelled across land use types.

Bull	Area type	Total Distance/DAY			No. of obs
		(mean)	*(Standard Dev)*	*(Standard Error)*	(N)
16	Protected	352.52	280.42	125.41	5
16	Non-Protected	60.37	70.24	24.83	8
13	Protected	172.71	269.14	95.16	8
13	Non-Protected	175.75	198.88	81.19	6

Bull	Area type	Total Distance/NIGHT			No. of obs
		(mean)	*(Standard Dev)*	*(Standard Error)*	(N)
16	Protected	290.90	172.72	77.24	5
16	Non-Protected	88.98	106.72	35.57	9
13	Protected	127.12	186.93	66.09	8
13	Non-Protected	200.75	222.12	90.07	6

Long distance movement

Long distance observation for both collared bulls combined indicated that 60% of observations occurred at night and connected two core areas. The remaining observations occurred during the day and within a home sector.

The greatest daily distance collared bull 16 travelled (58.9 km) was from the Salambala Conservancy to the LPR and BNP. On two occasions bull 16 exhibited long-distance ranging behaviour while remaining within one home sector (BNP). Speeds here were much lower, averaging 1.3 km/h. Months of furthest travel included the wet season months of March (349 km travelled with an average daily distance 11.3 km) and April (572 km travelled with an average daily distance of 19.1 km).

Long distance movement for collared bull 13 occurred mostly when moving between core zones (the protected forest on the Zambezi to SNNP and the CSF, and from SNNP to BNP). A daily maximum distance of 61 km travelled in one day surprisingly occurred in October, the peak of the dry season when this bull moved from the CSF to the Nanduka Protected Forest under the cover of darkness at an average speed of 1.59 km/h. Only on one occasion did this bull move over 30 km/day within a home sector – in BNP. For Bull 13, months of greatest travel included the wet season months of April (424 km travelled with an average daily distance of 14.3 km).

For collared female 2, long distance movement occurred on five occasions during the study period, and all movements were diurnal and connected core zones within SNNP. The longest daily maximum journey was 44.8 km and occurred at her highest recorded average speed of 1.86 km, when she travelled from the south to the north of the Park during the day. One of the observations saw her returning from the Western Zambezi GMA south of Nanduka Protected Forest to the north of SNNP. For the female and her herd, the month of greatest travel was April (347 km travelled with average daily distance of 11.57 km).

2.4 Discussion

i) Home ranges

According to Hoare (2004), little is known of the elephant movements in Caprivi and elephants here are restricted by settlements and water availability, only making use of the Caprivi as part of the dry season range. This study clearly demonstrates that the Caprivi forms an important part of the wet season range for both collared bulls, with numerous

core zones recorded on the western side of the Kwandu River, the Caprivi State Forest, Bwabwata National Park and Salambala Conservancy, with home ranges extending as far as Mudumu National Park. Satellite telemetry also showed the highly migratory nature of the bulls, with wide-ranging cross-border movements recorded.
Grid square home range size of the collared elephants ranged between 1 500 and 2 000 km^2. Elephant home range size and structure has been linked to habitat heterogeneity, local rainfall, spatio-temporal distribution of water and food sources, as well as sexual segregation and intra-sexual avoidance (Stokke & du Toit, 2002; Poole & Moss 1981, Leggett, 2006, Lindeque & Lindeque, 1991). The size of home ranges reported elsewhere varies widely, ranging from less than 60 km^2 in Tanzania (Douglas-Hamilton, 1971), to 436 km^2 in Kruger National Park (Hall-Martin, 1984), 1 800 km^2 in Tsavo East in Kenya (Owen-Smith, 1988) up to 9 000 km^2 in the desert regions of Namibia (Lindeque & Lindeque, 1991). Rivers may act as home range boundaries (Shannon *et al*., 2006), and none of the home ranges in this study crossed the Zambezi River. The collared bulls are sexually competitive males, ranged much wider than the female and showed spatial overlap in the wet season only, when resources are plentiful. Bulls are known to have larger home ranges than females (Poole & Moss, 1981), and sexually active males range over larger areas and avoid intrasexual competition by temporal partitioning of resources (Wittemyer *et al.,* 2007, Douglas-Hamilton, 1972).

Collared female 2 occupied a spatially explicit home range, restricting her movements to a habitat corridor connecting a National Park and the neighbouring GMA to a forest reserve. Small home range size was also found in a study on female elephants in the Kruger National Park by Hall-Martin (1984, 1987). Although Whyte (1996) suggests that smaller homer ranges may indicate local availability of essential resources and decreased disturbance, it is presumed that collared female 2's small home range is linked to settlement densities and human disturbance on the south-western and north-eastern boundaries of the Park.

Seasonal range use

Although the fidelity of the collared elephants to their seasonal ranges can only be reasonably estimated with longer time series data, this study provided some valuable insights. Wet and dry season ranges were not spatially explicit, with dry season ranges visited at least once during the wet season, although distinct wet and dry season ranges have been described by Thouless (1995), Babaasa (2000), Shannon *et al*. (2006), Dolmia *et al*. (2007), Galanti *et al*. (2006) and Douglas-Hamilton *et al.* (2005). Results from this study however agree with Namibian surveys conducted by Rodwell *et al.* (1995), confirming that the collared elephants are making inter-annual repeated use of certain areas. Elephant impact may be accentuated when seasonal ranges overlap with the same areas being visited across seasons and years. Collared bulls remained in the teak and mopane woodlands of protected areas in the peak dry season, remaining near the Kwandu, Chobe and Zambezi Rivers. This concentration around rivers in the dry season followed by dispersal and migration in the wet season has been confirmed by other studies (Rodgers & Elder, 1977; Lindeque & Lindeque, 1991; Verlinden & Gavor, 1998). Well-wooded areas and closed woodlands supply important browse, as well as shade and cover, in the dry season (Loarie *et al.,* 2009; 2009a). No transboundary movements were recorded for the collared female. She remained in the teak woodlands and grassy floodplains of the central and northern sections of SNNP and the nearby Zambezi River. In contrast, Chase (2007) recorded transboundary movements of a family herd in the dry season in this area. Variation exists in elephant movements, with some elephants being sedentary (Leuthold & Sale, 1973), while other migrate seasonally (Thouless, 1995).

In accordance with studies conducted by Foley (2002) and Galanti *et al*. (2006), wet season range was larger than dry season range for all three collared elephants. This study was the first to document nocturnal activity of bulls in Conservancies, with collared bull 16 recorded in four agricultural areas (Kwandu, Mayuni, Mashi, Salambala Conservancies) in Namibia during the wet season, which corresponded with the harvest season for rural crops (maize, sorghum, millet). As two of the agricultural areas (Conservancies) do not form part of his usual range, it is predicted that he raided crops at this time. This behaviour was also found in studies by Osborn & Parker (2003) and

Osborn (2004), which recorded that end of wet season range expansion of bulls coincided with movements into communal lands, with the quality of wild grasses declining and maturing crops offering a higher nutrient content than locally available browse.

Core and non-core areas:

Not surprisingly, collared elephants selected core areas that lay close to protected areas, or areas with limited human activity. Other studies have reported an obvious human influence on elephant distribution, with disturbance cited as the main reason for selecting for protected areas (Graham *et al*., 2009; Wittemyer, 2007; Chase, 2007; Foley, 2002). Other factors cited for core area selection include canopy density (De Boer *et al*., 2000), higher forage quality (Loarie *et al.*, 2009), while in studies on blue wildebeest (*Connochaetes taurinus mearnsi*) by Thirgood *et al.* (2004) and African buffalo (*Syncerus caffer*) by Winnie *et al.* (2008), selection of core areas was governed by anthropogenic disturbance and predation risk. Spatial preferences of the elephants for these areas, specifically those that lay beyond protected areas, is significant as core areas can function as stepping stones within a disturbed matrix (Forman, 1995), and may consequently improve connectivity in the landscape.

This study further revealed that collared elephants selected core zones at higher elevations. Here it is interesting to note that the dune ridges of the eastern Caprivi Strip, which extend over vast areas of Angola, Zambia, Zimbabwe and Namibia (Thomas, 1984), are marked by predominantly wooded vegetation - teak *(Baikaeae plurijuga)*, kiaat *(Pterocarpus angolensis)* and wild syringa *(Burkea africana)*, which may provide important food and shade for the collared elephants.

Dry and wet season core areas:

The preference of collared elephants for dry season core areas with lowered elevations confirms results from Shannon *et al*. (2006), who suggested that elephants selected for riparian and low-lying habitats on relatively nutrient-rich soils in the dry season. Low-lying soils in the KAZA TFCA typically include seasonally flooded grasslands, including swamps, dambos, floodplains and pans. Fryxell and Sinclair (1988) showed that ungulates such as white eared kob (*Kobus kob leucotis*) also selected low-lying areas adjacent to rivers in the dry season as residual soil moisture in these areas guarantee higher quality forage than surrounding areas, while research by Pienaar *et al.* (1993) on white rhinos (*Ceratotherium simum*) revealed that core zones lay along riverbanks, with resting spots tending toward high-lying areas. Nutrient-rich areas lie close to rivers, as well as in alkaline clay soils in dune hollows that may be rich in sodium – a mineral sought out by elephants (Holdo *et al*., 2009; Sukumar, 1990). As the soils of KAZA TFCA are predominantly coarse Aeolian sands with poor water holding capacity and nutrient status (Robertson 2005), elephants much like African buffalo may be selecting the core zones as nutrient hotspots (Winnie *et al.,* 2008).

The high settlement density around KAZA TFCA's perennial rivers may explain the proximity of dry core area to settlements. It is well known that water drives elephant distribution (Chamaille-James *et al.,* 2008; Chamaille-James *et al.,* 2007; Harris *et al*., 2008; Shannon *et al.,* 2006; Viljoen, 1989; Sukumar, 1989) so the proximity of dry season core areas to rivers is not surprising. Dry season core areas are of critical conservation importance as water and food become limiting resources and elephants spend 75-80% of their time feeding and foraging, and are therefore sensitive to disturbance.

During the wet season, the energy requirements may be higher for females as the high demands of lactation have been linked to rainfall (Freeman *et al.*, 2008), while the phenology of parturition was linked to primary productivity in a study conducted by Wittemyer *et al.* (2006). For bull elephants, Shannon *et al*. (2006) found that musth was most commonly observed when resources were abundant. It was therefore expected that wet season core areas would have higher AFRI values than dry season core areas as it is broadly understood in the literature that wet season dispersal areas have higher vegetation and nutritional quality (Loarie *et al*., 2009; Foley, 2002, Verlinden & Gavor, 1998;). However no difference in AFRI was found in this study. Values measuring vegetation productivity can be masked by effects of fire and floods (Foley, 2002), both of which are significant environmental drivers in the region's ecosystem. Other measures of productivity and vegetation vigour such as EVI and NDVI may have to be investigated in order to confirm or reject the AFRI results.

Wet season core areas lay at a greater distance from rivers than dry season core areas. Besides the obvious reason that water is widely available during the wet season due to the presence of pans and waterholes, and elephants are not restricted to rivers at this time, surface flooding may play a role in avoidance of riparian areas (Fryxell & Sinclair, 1988).

ii) Land use types

The findings of this study agree with previous studies, which indicated that elephants have an awareness of risk associated with protected and non-protected areas (Graham *et al.*, 2009; Galanti *et al.*, 2006; Douglas-Hamilton *et al.*, 2005).

Unlike studies conducted by Loarie *et al.* (2009) and Foley (2002), vegetation vigour alone did not explain selection for protected areas. In this study, the collared elephants avoided non-protected areas in the dry season, which coincided with months of highest burning (runaway fires and land-clearing burns). It is well known that elephants avoid burned areas (Bell & Jachmann, 1984). Indeed, Chase & Griffin (2009) recorded a two-fold increase of elephants in Mudumu National Park between seasons, despite the fact that this increase was not evident in other areas surveyed. Inter-specific competition with humans and livestock outside of protected areas may be another significant factor in selecting for protected areas, as was reported by a study on Kenyan elephants by Wittemyer *et al.* (2008).

iii) Elephant behaviour and avoidance of humans

Few riparian zones beyond protected area boundaries are undisturbed by human settlements in the KAZA TFCA. Movement into settlement areas expose elephants to disturbance and predation by humans - poaching, hunting, fires, and competition for space and water have been mentioned in the context of KAZA TFCA (Chase & Griffin, 2009; O'Connell-Rodwell *et al.*, 2000; Hoare, 2004). The collared elephants preferred areas of decreased human disturbance and this is consistent with previous studies on elephant distribution in an anthropogenic landscape (Hoare & du Toit, 1999; Galanti *et* *al*., 2006). Disturbance may therefore be the driving factor in selecting for protected areas (Galanti *et al.,* 2006; Graham *et al*., 2009).

The collared female 2 and her herd avoided major roads, settlements and agricultural areas. Avoidance of roads and settlements was also recorded in a study by Gibeau *et al*. (2002), even if near high quality habitat.

Bulls in this study displayed behavioural plasticity by making use of an array of different land use types, including agricultural locales. As was found by Sitati *et al.* (2003), Graham *et al.* (2009) and Wittemyer *et al.* (2007), the collared elephant bulls tended to move through non-protected areas at night, suggesting that this may form part of their risk avoidance strategy when moving in disturbed areas. The collared bulls further travelled faster at night in non-protected areas, at times streaking through the matrix at speeds that were four times higher than average, with disturbance along roads a major factor (Blake *et al.* 2008). Kalemera (1987) linked faster, nocturnal travel to cooler temperatures, suggesting that elephants minimised energy expenditure by travelling at night. This may well be the case in protected areas. Streaking behaviour in this study was found to be the result of human disturbance in non-protected areas, as travel speed in protected areas was considerably slower. Previous studies describing streaking behaviour suggest that this fast travel occurs in corridors (Douglas-Hamilton *et al.*, 2005; Foley, 2002) that connect core sectors. Visual interpretation of the data confirmed that streaking occurred in what could be a potential corridor (visible on maps), however, long-term ground-based surveys would be needed to confirm its existence.

Long distance movements

In non-protected areas, long-distance travel of > 30 km occurred at night, whereas in protected areas, it occurred during daylight. This suggests that human influence outside of protected areas may affect elephant activity. Although the curtailment of elephant movement by human activity agrees with previous research (Thouless, 1995; Tchamba *et al.*, 1994), results here indicate that collared bulls will change behavioural patterns by travelling long distances at night.

Conclusion:

Long-range movements of the three collared elephants within the KAZA TFCA imply that TFCAs can succeed: Firstly, the behavioural plasticity displayed by bulls demonstrates that connectivity between refugia, and thus genetic exchange between sub-populations, can be maintained by moving at night and at speed. Connectivity between refugia improves elephant persistence across the landscape and allows elephants to respond to stochastic events such as fire, drought and poaching through the process of dispersal. Secondly, penetration of the matrix by elephants suggests fragmented landscapes are not a hindrance to elephant movement if elephants are actively protected under governmental law. Human-elephant interactions date back to the 16^{th} century (Meredith, 2001), yet increasing fragmentation due to agriculture and expanding rural populations will have to be unapologetically managed at the highest political level if elephants (and their economic spin-offs) are to persist in KAZA TFCA over the next century in the face of increasing human populations. SNNP, and the forest pockets to the west of the Zambezi are especially threatened, as most elephant populations in Zambia are declining, with few old individuals and poaching occurring at levels far higher than reported by the Zambian authorities (van Aarde, 2007).

The need to improve management of elephants beyond protected areas boundaries becomes evident from this study, which shows that elephants, especially bulls, are making use of core zones within KAZA TFCA's land use matrix. Owen Smith (2006) suggested that 'Management should be spatially differentiated, and may involve zoning some areas as elephant sanctuaries and others as tree sanctuaries with clearly specified objectives.'

Once presence and absence of elephants in core areas beyond protected areas boundaries has been established, the management of 'elephant areas' can be readily initiated by effective land use planning initiatives. Ground-based surveys and long-term scientific data are needed in order to map important core zones beyond protected area boundaries if elephants within KAZA TFCA are be allowed to persist, and the KAZA TFCA is to become the flagship TFCA for southern Africa.

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'Proboscidean trails are well used, clearly identifiable, and easy to follow. Proboscideans habitually re-use old trails seasonally, thus establishing clear networks of widely separated places connected by paths.'
Gary Haynes

CHAPTER
3

PATHWAY USE BY SAVANNAH ELEPHANTS (*LOXODONTA AFRICANA AFRICANA*) IN AN ANTHROPOGENIC LANDSCAPE

Abstract

A study on the existence and use of pathways by savannah elephants in an anthropogenic landscape was conducted in the Kwandu Conservancy, Namibia. Pathways were described, and their direction, length and width measured. Elephant activity was compared between two seasons. Results indicated that pathways existed, and lay on an E-W gradient. Selective pathway use between males and females was evident: females used pathways further away from settlements in order to access water, while males used pathways among settlements, also to launch crop raids. Crossing points on roads remained 100% constant. Pathway use decreased significantly in the dry season. Pathways were on average 4.1 km in length, and connected two protected areas. Pathways crossed a mosaic of land use types, including forest, agricultural land and protected areas. Functional connectivity of pathways was not species-specific, with a host of other species making use of the conduits, including humans, predators and ungulates. The study suggests that pathways may facilitate elephant penetration of the anthropogenic matrix and optimize foraging strategies by connecting predictable resources such as crop fields with other landscape features such as preferred shelter/ resting areas, crossing points at roads and preferred drinking spots (Kwandu River and waterholes).

3.1 Introduction

Movement has been associated with an animal's behavioural processes such as the need to find food or mates, to find shelter, to avoid predators, and to regulate inter-and intra-specific competition, to regulate contact with denuded landscapes, to make use of ephemeral resources and to expand home ranges (Bennett, 1999; Bar-David *et al*., 2009). Movement patterns have a direct impact on population dynamics and species persistence, and in the case of a megaherbivore such as the African elephant (*Loxodonta africana africana,* Blumenbach, 1797), space use has a significant impact on ecosystem dynamics (Owen-Smith, 1988). Movement is suggested to be non-random (Loarie *et al.*, 2009) with animals creating a cognitive map of their home range and the distribution of available resources within that range (Forman, 1995). Spatial and temporal distribution of resources therefore affects searching efficiency and behaviour. Foraging behaviour contributes towards understanding an animal's ecology, and movement patterns are symptomatic of which strategies individuals use to locate resources. Movement can be separated into types – with migration and dispersal occurring between patch mosaics within a home range, while shorter movements are associated with foraging between resource and habitat patches (Chetkiewicz *et al*., 2006).

On grasslands, herbivores make a trade-off between quality and quantity of their food intake. Search for areas that allow the best trade-off may induce repeat grazing in those areas (Garcia *et al.,* 2005). Repeated movement to preferred resources results in the formation of trails, which may be stable over time. Bar-David *et al*. (2009) state that pathway recursion (return to previous forage area) can be driven by a combination of abiotic and biotic factors, including food, water, shelter, commonly used travel routes, salt licks and preferred plants which could all play a potentially significant role in pathways use. Herbivores improve their searching efficiency by adapting their foraging velocity and/or path sinuosity through the perception of their feeding environment (Garcia *et al.,* 2005). Area-concentrated search is considered valuable in patchy environments (Fortin, 2003), where search mode is adapted to habitat structure and perceptions of food quality. Search modes can be either intensive (with low travel speeds and high path sinuosity), or extensive (with high travel speed along linear paths). In homogenous habitats, animals travel randomly, while in heterogeneous swards, they develop non-random search (Hobbs, 1999). In order to adapt foraging behaviour to the heterogeneity of the area, animals are often able to memorise the best areas visited, and to associate these areas with visual cues (Edwards *et al*., 1997). This cognitive ability has fitness consequences.

According to McLean (2001), natural selection favours the procurement of food at the lowest energetic cost. Taking a Darwinian approach, he suggests that foraging efficiency in complex or niche environments should have resulted from the evolution of particular cognitive abilities. In elephants, tool use has been used as a measure of higher mental ability (Povinelli, 1989; Chevalier-Skolknikoff & Liska, 1993; Hart *et al*., 2001). Studies on primates have demonstrated cognitive ability in the use of mental topological maps in least effort-route use between resources (Normand & Boesch, 2009). Higher mental ability or predictive capability has also been demonstrated by MacKinnon (1978), who showed that orang-utans (*Pongo pygmaeus*) use energy-saving routes through the forest canopy on foraging bouts. The procurement of food at the lowest energetic forms the basis of Optimal Foraging Theory (OFT). Optimal foraging is achieved in part by minimising travel distance and travel time between resources. Least-effort routes have been described in chimpanzees (*Pan troglodytes verus*) by Normand & Boesch (2009), baboons (*Papio ursinus*) by Noser & Byrne (2007) and in buffalo (*Syncerus caffer*) by Bar David *et al.,* (2009), with animals displaying a goal-directed approach to out-of-sight food and water sources. Linear paths were found to connect food, water, salt licks, preferred resting areas and travel routes.

Reference to pathway use in savannah elephants is currently largely anecdotal. The identification of pathways, and the landscape features (water, forage, refuge) they connect, may offer insights into habitat requirements in a fragmented landscape: pathways much like seasonal corridors, could facilitate daily movement of individuals, promote genetic exchange, and support ecological processes. Feeding efficiency may be increased by reducing traveling times to high-nutrient, clustered and stable food sources (crops, fruiting trees, mineral licks). Pathways, if shown to be a significant factor in the distribution of crop-raiding incidents (see Chapter 4), could form the basis of successful land use planning initiatives., as pathways and path types are predicted to be significant factors in determining spatial patterns of human-elephant conflict (HEC) (Sitati *et al.*, 2003). WWF (2008) suggest that in Kwandu Conservancy (KC), HEC is exacerbated when settlements are placed across 'well-used elephant paths'.

The understanding of pathway functionality could further contribute towards a better understanding of elephant behavioural ecology. This is relevant in fence breaking by bulls in South Africa's Kruger National Park, where mature bulls regularly break through the western boundary of the Kruger fence at the same spot along pathways, presumably to access marula (*Sclerocarya birrea*) trees (Ferguson & Hanks, 2010).

The identification of pathways in anthropogenic landscapes could therefore reduce conflict between people and elephants (Douglas-Hamilton *et al.,* 2005) by allowing safe thoroughfare between resources for both species and by promoting elephant dispersal by providing access to sink habitats in overpopulated elephant regions.

The objectives of this study are therefore to establish whether 1) elephant pathways exist in the region, 2) whether pathways differ in function, 3) whether pathway use differs between the wet and the dry season, 4) the group size of elephants using these pathways, and 5) whether sexual segregation occurs in the utilisation of pathways.

3.2 Materials and Methods

This study was conducted in the Kwandu Conservancy (KC) in the Caprivi Strip, Namibia. Results are derived from data collected over 120 observation days (March-April, and September-October) in 2008.

i) Study area

The KC lies in the centre of the Caprivi Strip, north eastern Namibia (Fig. 3.1). It extends over 190 km^2. The KC lies between two protected areas: the Bwabwata National Park (BNP) in the west, and the Caprivi State Forest (CSF) in the East. The international boundary to Zambia's Sioma Ngwezi National Park (SNNP) and Angola's Luiana Partial Reserve (LPR) forms the northern boundary (Fig. 3.2).

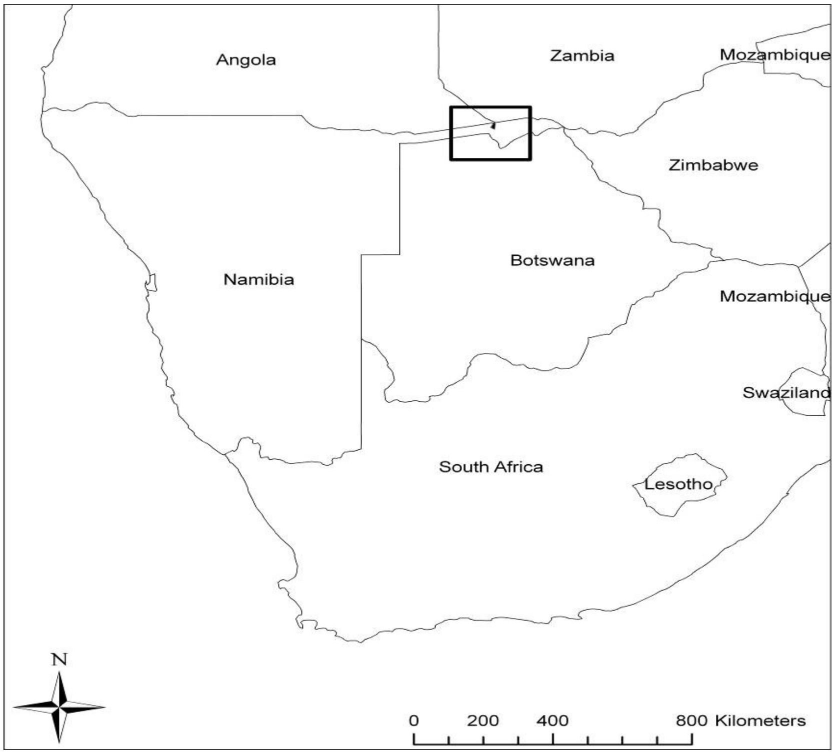


Fig 3.1. The study area within southern Africa

The greater Kwandu Basin is marked by the presence of fossil dunes where shallow seasonally flooded areas form in the dune troughs and ancient river valleys. The Kwandu River marks the western boundary of the KC, and both people and elephants rely on the river for water in the dry season (May-October). During the wet season (November-April), surface water is widely available in numerous waterholes, pans and *omurambas* (ancient river valleys) throughout the area, but by May, most of the waterholes have dried up. The region has a tropical savannah climate. Rainfall is variable, occurring mainly in summer months between November and April. Mean annual rainfall is estimated at 600 mm. The KC, the most densely populated Conservancy in Namibia, is inhabited by 4 300 people. Kongola is the largest village. Villages, agricultural fields, schools and clinics occur mostly adjacent to the main North-South gravel road. Cultivation occurs in the wet season when farmers plant maize, millet and sorghum, which is harvested in April-May.

Soil is predominantly Kalahari Sands and is nutrient poor. The landscape is flat, with an average altitude of 930 - 1 100 m a.s.l. (Mendelsohn & Roberts, 1997). Broad-leafed savannah characterises the Caprivi Strip. Mopane-*Burkea* and teak woodland, mixed shrubland and *omuramba* grassland dominate the area with mature woodlands (*Acacia* sp.) occurring in the region (Mendelsohn & Roberts, 1997).

ii) Existence of pathways

Fieldwork to locate and explore elephant pathways was initiated from the State Forest cut-line - a sand track marking the eastern border of KC (Fig 3.2), and habitual elephant crossing points on the main road within the Conservancy mapped with the assistance of local game guards. Direct field observations of elephant tracks, faeces and feeding damage confirmed pathway use by elephants, and only active pathways with floors devoid of vegetation that were used on two or more occasions were selected. Twelve pathways out of 18 were identified for observation.

iii) Pathway function

Pathways were followed from the cutline to the road and on to the Kwandu River. A Garmin GPS reading, elevation and pathway width was recorded at 100 m strip intervals. Land-use types and presence of water pans, fields, roads, crossing points and prints of other species were recorded.

iv) Pathway use across seasons

Elephant activity along pathways and crossing points was recorded over 120 observation days during two seasons. Fresh spoor was counted daily between 06h00 and 07h00.

v) Elephant group size and sexual segregation

Number of elephant prints and elephant group size was recorded. To avoid recounting old spoor, tracks were eradicated after each count, and bull and breeding herd spoor (including that of offspring) were noted. I distinguished between male and female elephant groups from the presence or absence of dung and footprints from elephants less than 6 years of age (Chiyo & Cochrane, 2005; Balasubramanian, 1995).

Note: The original map has been shrunk slightly to fit on an A4 page

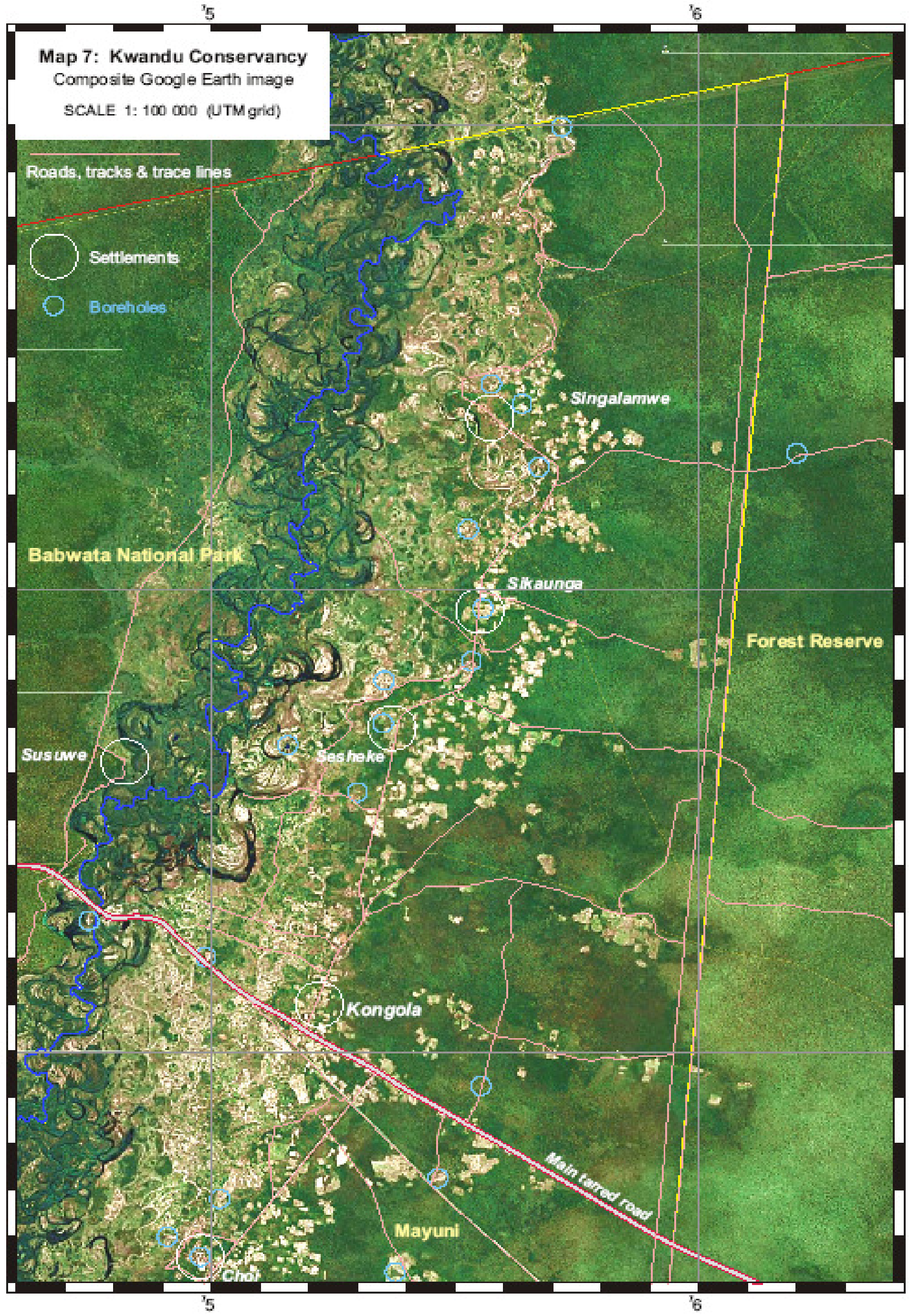


Fig. 3.2. Satellite image of study area (Martin, 2006). Note spatial configuration of landscape features within the Kwandu Conservancy, with fields and settlements along main North-South road creating a barrier between floodplains and hinterland.

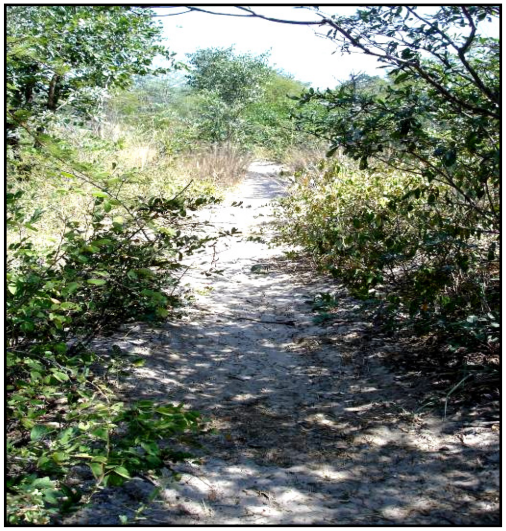
3.3 Results

i) Existence of pathways

Pathways connected the Kwandu River with the CSF and BNP, and crossed three land use types: forest, agricultural land and floodplain. Pathway floors were devoid of vegetation (Fig. 3.3), indicating repeated travel. Elephant urine and dung deposits affirmed elephant presence. Pathways were used at night, allowing elephants to traverse the anthropogenic landscape in relative safety. Pathways tended to be directional, following dune troughs lying on an E-W gradient with low curvilinearity.

Teak wood and shrubland constituted the major vegetation type in the forest, and included tree species important to elephant diet in the wet, as well as in the dry, season (Appendix 3.1). Agriculture fields were a mixture of fallow and planted fields, with maize being the dominant crop type. Pathways became less defined upon entering agricultural fields, becoming linear again upon approaching the crossing points of the road and leading down to the river. Crossing points remained 100% consistent with elephants always crossing at the same point along the road for all 68 observations. Pathways were found to traverse areas of low to high human disturbance, traversing all three land use types.

Four of the northern pathways (pathway 18, 19, 22 and 25) were found in less densely settled areas. Pathway 19 joined pathway 22 at the same drinking/crossing spot on the Kwandu River approximately 4km to the west. Pathway 25 – the northern boundary and cutline of the KC was frequently used by elephants moving from the SNNP and the CSF into BNP (*see* Chapter 2 satellite maps). Pathway 16 led to a maize field, which according to the KC Office records had been raided repeatedly by elephants over the previous four years. Pathway 6 was active for a short while in the wet season, yet elephant activity along this pathway ceased as road construction disrupted movement. Pathways were used by other wildlife, including hyaena (*Crocuta crocuta*), hippopotamus (*Hippopotamus amphibius*), leopard (*Panthera pardus*), jackal (*Canis mesomelas*), wild cat (*Felis libyca*), duiker (*Sylvicapra grimmia*), kudu (*Tragelaphus* *strepsiceros*) and bushpig (*Potamochoerus larvatus*) especially in the north, in areas of decreased human disturbance.



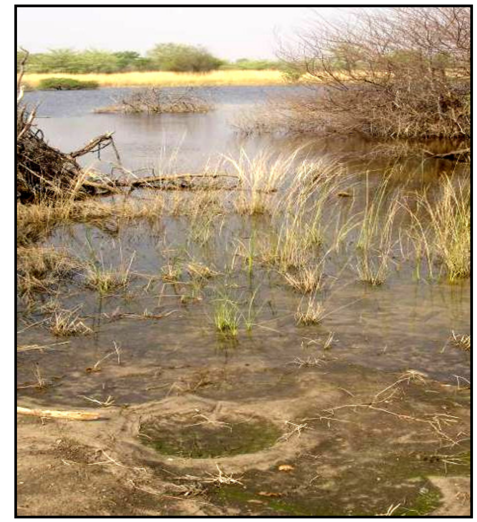
a)

b)

c)

d)

e)



f)

Fig. 3.3 (a-f): Elephant pathways within the Kwandu Conservancy were linear with floors devoid of vegetation (Figs. a, b, e). Pathways connected habitat and resource patches such as waterholes (c), preferred drinking spots on the river (f) with crossing points on the Kwandu Conservancy road (d).

ii) Pathway function

Elephant pathways connected resource patches such as 1) preferred drinking/crossing points on the Kwandu River 2) waterholes, and 3) maize fields with crossing points on the main N-S road. Waterholes were found along 54 % of the pathways. However, 83% of these waterholes were dry by mid-May (end of wet season and harvesting season), suggesting that pathway use after this time occurred in order to access the Kwandu River and the protected areas beyond. Pathways followed a E-W direction, averaged 67 cm in width and 4.1 km in length. Average elevation was 985 m.

Table 3.1: Spatial features and use of elephant pathways

Pathway No	Settlement density along pathway	Pathway length (km)	Pathway width (m)	Elevation (m)	No of branches off pathways	Waterpan	Elephant sex	Pathway use by elephants across seasons
2	high	5.7	0.6	973	6	no	Male	wet and dry
3	high	4.7	0.5	978	2	no	Male	wet and dry
6	high	3.6	0.7	980	6	no	Male	Wet
12	medium	2.5	0.5	988	6	1	Male	Wet
13	medium	6.8	1.1	993	8	3	Male	Wet
14	medium	3.4	1.3	993	2	4	Male	Wet
16	medium	3.3	0.5	990	4	no	Male	Wet
18	low	3.3	0.7	972	2	1	Both	wet and dry
19	low	4.6	0.5	985	0	no	Male	wet and dry
22	low	4.4	0.5	986	0	no	Both	wet and dry
new 3	low	2.3	0.5	989	2	1	Male	Wet
25	low	4.3	1	988	0	8	Male	wet and dry

iii) Pathway use across seasons

Pathway activity was significantly higher in the wet season months of March and April (records, n = 60) than in the dry seasons months of September/October (records n = 8), with peak pathway activity in April. September/October was marked by intensive burning and smoke cover. Rural farmers clear their land of vegetation by burning at this time, and runaway bushfires are common. Bulls were responsible for five out of eight pathway records on pathways 2 and 3 in the south of the KC during the dry season observations. Pathway use by bulls was most intensive in the wet season and occurred across the spectrum of settlement densities. The two records for female activity again occurred exclusively on the northern pathways (18 and 22), the same pathways used by females in the wet season. All elephant activity along pathways within the KC occurred under cover of darkness.

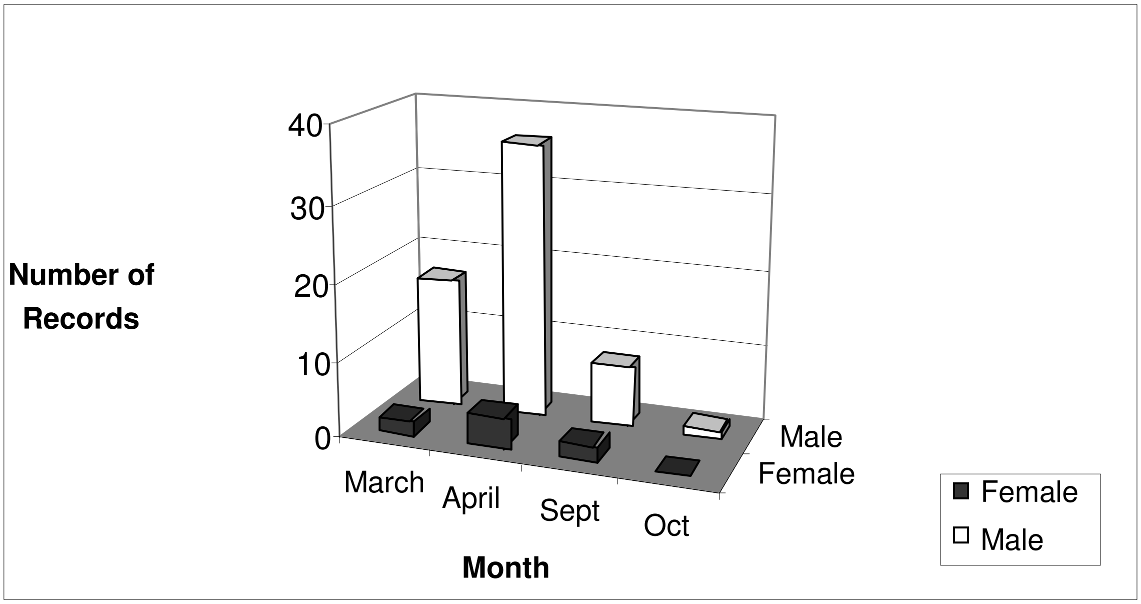


Fig 3.4 Pathway use in the wet (March/April) and dry (September/October) season.

iv) Elephant group size and sexual segregation

Although no sexual segregation was recorded (Table 3.1), females exclusively used pathway 18 and pathway 22 in the northern sections of the KC, in areas of low human densities. Pathway 22, and pathway 19, led to a drinking spot and crossing point on the Kwandu River in a sparsely populated, well-forested area. Females frequented a waterhole on Pathway 18, which was the only recorded waterhole in KC that carried water past the end of April. Females avoided pathways in medium to high settlement densities areas in the south. Average group size of females was 7.1 and did not vary from wet to dry season. As the number of observations for females was low (n = 8), it is presumed that the same herd made occasional use of the northern section of the Conservancy during its monthly movements between the Caprivi State Forest and SNNP. Average group size for the males increased from 1.5 bulls in March to 2.5 bulls in April. The largest bull group constituted seven individuals.

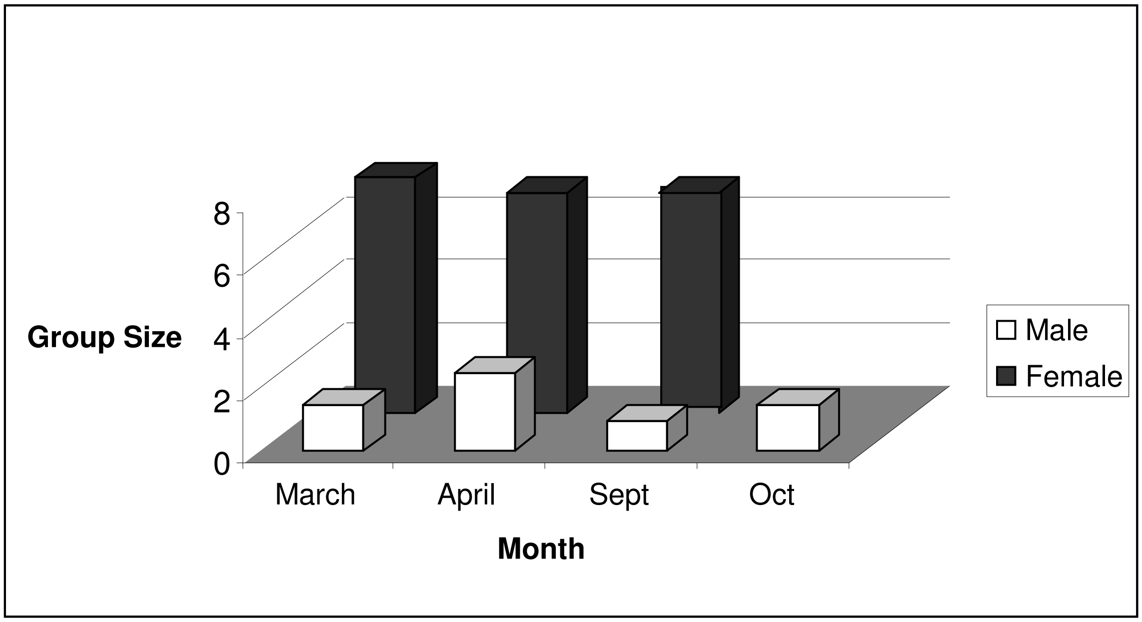


Fig. 3.5: Average group size of elephants utilising pathways.

3.4 Discussion

i) Existence of pathways

Pathways in KC were linear, devoid of vegetation and actively maintained by repeated movement. Elephants traveled in single file along pathways, and appeared to adopt a goal-directed approach to certain resources such as preferred drinking spots, crop fields and crossing points on roads in heterogeneous environments with high disturbance. Non-random movements were also found by Wittemyer *et al.* (2008), who found elephant movement tended to be more directional when resources were limited or habitat heterogeneity was high. Elephant movement is consequently non-random (Loarie *et al.,* 2009; Wittemyer *et al.,* 2008), demonstrating navigational ability and spatial memory. Spatial awareness was further demonstrated in this study by the fact that crossing points on the N-S road remained 100% consistent. The utilisation of spatial memory rather than cue-directed search during foraging was found to be a significant factor in foraging efficiency (Garcia *et al*., 2005; Thiele & Winter, 2005).

In the popular literature, little information can be found on elephant pathways. Campbell (1995) proposes that elephant pathways may be of great antiquity. Research on how Proboscideans affect the landscape suggests that elephants make and use pathways, some of which are predicted to be 50 years old (Haynes, 2006). Williamson (1975) also recorded elephant trails following the troughs of Pleistocene dunes in Zimbabwe. In Botswana, Child (1968) observed that seasonal movement by elephants was reflected by well-defined elephant paths, especially those leading to pans. Pathways or trails have further been anecdotally mentioned by previous authors in connection with watering holes or drinking areas (Payne 1998; Moss, 1988). A recent report on crop-damage caused by elephants in the Okavango Delta mentions that conflict may occur along 'established elephant pathways' (NRP, 2006). Leggett (*pers. communication*) confirms that desert elephants use pathways, and that elephants used these pathways seasonally between feeding areas, as well as daily in order to access preferred drinking spots along the Hoanib and Hoarusib Rivers.

Some scientific information exists regarding elephant paths or trails in forest elephants (*Loxodonta africana cyclotis*): in the equatorial forests of central Africa, forest elephants play an important role in ecosystem dynamics by opening up clearings, structuring tree species composition through seed deposition and by creating paths within the forest, which are subsequently used by other animals and humans (Weinbaum *et al*., 2007).
Van Leeuwe and Gautier-Hion (1998) indicated that elephant trails connect forest clearings, which are important social gathering sites and areas containing high mineral deposits. They also recorded different size pathways had different functions with larger trails used for long-distance faster travel and smaller more sinuous pathways used for foraging as well as accessing resources. Forest elephants use trails that can continue for tens of kilometres and these may be several metres wide (Blake, 2004). Pathways also connected waterholes and clearings. It is further suggested that migrations in forest elephants may follow regular tracks in the forest rather than being random movements (Turkalo & Fay, 1995). White (1992) and Short (1983) suggested that elephant trails may link important fruiting trees,.

Many species, from ants to hippos, make use of pathways for a host of different reasons: Hölldobbler and Lumsden (1980) show that foragers of the harvester ant (*Pogonomyrmex* spp) use a trunk route foraging system to facilitate exploitation of patchily distributed yet stable food resources. Ants travel on well-defined trunk trails before diverging on individual excursions, and trunk trails are used for homing after foraging. Similarly, in this study, narrower and smaller pathways joined up with the main pathways. This seems to suggest that a network of pathways may exist, and that smaller pathways connect the larger "highways". This was suggested by van Leeuwe and Hion (1989) in a study on forest elephants. Mapping the entire pathway network did not form part of this study, but would certainly be an important next step in understanding the spatial arrangement of resources.

These trunk trails have been shown to be consistent over time, with chemical and visual cues along trails contributing to trail persistence. Hippopotamii maintain various types of paths with those in back-swamp areas being aligned with the prevailing slope which develop into channel systems that keep channel systems open. These trunk trails are connected to lateral trails that lead to grazing areas (McCarthy *et al*., 1998). A Global Information System (GIS) analysis by Ganskopp *et al*. (2000) showed that cattle establish least-effort routes between frequented areas of their pasture, reducing energy expenditure between high gain foraging areas by their searching behaviour.

Spatial memory allowing for the return to preferred food patches has been termed 'path recursion' in a study on buffalo. Bar-David *et al*. (2009) found that recursion occurred both in the wet and in the dry season and occurred within time intervals of 10-16 days. An early study on black rhino *(Diceros bicornis*) in East Africa notes that the animal moves along the 'same well worn paths' when moving to and from drinking spots. These paths were 20 inches (50.8cm) wide, were well graded and did not follow contours (Ritchie, 1963). The rock hyrax (*Procavia capensis*), the closest relative of the elephants, has been shown to use foraging trails within its home range (Estes, 1992).

ii) Pathway function

Bar-David *et al*., (2009) state that pathway recursion can be driven by a combination of abiotic and biotic factors such as food, water, shelter, salt licks, preferred plants and commonly used travel routes. In KC, pathways were marked by dung and urine deposits. Forest elephants are known to play an important ecological role in tropical forests as seed dispersers. Pathways could not only aid seed dispersal by elephants in savannah ecosystems, but could also serve as chemical highways, providing more naïve elephants with olfactory cues to access resources and provide information on members of a sub-population (Holldöbbler & Lumsden, 1980). Pathways in KC were predicted to: 1) facilitate movement in a disturbed matrix, 2) link predictable resources such as crop fields with other landscape features such as preferred shelter/ resting areas, crossing points at roads and preferred drinking spots 3) serve to maximise optimal foraging.

1) Facilitate movement in a disturbed matrix

Principles of landscape ecology state that corridors serve five functions: habitat, conduit, filter, source and sink. Pathways here are interpreted as conduits for short-range daily movements, with elephants moving inside the pathway or alongside it. Habitat connectivity and quality are the two primary variables determining conduit function (Forman, 1995). The KC is a densely settled and highly disturbed area with three land use zones: riparian, agricultural and secondary forest. Habitat and pathway connectivity between the CSF, the Kwandu River and BNP is patchy due to the presence of agricultural fields. The spatial configuration of the N-S road, settlements and random crop fields create a barrier to wildlife movement, with spaces between fields too small to qualify as habitat (Martin, 2006). Elephants with core zones in CSF and BNP (see Chapter 2) would have to circuit a stretch of 30 km or more in order to avoid settlements or roads. An environmental gradient of habitat quality therefore existed along pathways, which should decrease animal movement (Forman, 1995). In this study, temporal segregation of pathway use permitted elephant to traverse the anthropogenic matrix safely: elephants and other species were active along pathways at night, with human activity occurring during the day. Forman (1995) refers to pathways as ‘animal trails’, noting that these act as conduits for native mammals or as ‘travel lanes for movement’. Forman (1995) states that human use of trails with that of native cattle and dogs may eliminate all conduit use by wild animals. Human trails were avoided by forest elephants in Central African Republic (Fay & Agnana, 1991) due to intense poaching pressure in the region. Elephants are protected under Namibian law, and elephant avoidance of human pathways was not evident. Pathway use by elephants and humans has also been noted by Carroll (1988), with forest elephants and Aka pygmies utilising the vast network of elephant pathways connecting marshy clearings high in mineral and water content.

Animals are known to have sinuous pathways in good quality terrain, whereas they tend to move farther and faster in unfavorable terrain (Crist *et al.*, 1992). Fidelity to pathways in disturbed areas could further be an effective behavioural strategy when speedy escapes and spatial awareness of shelter areas are required - farmers in KC chase elephants from the area in April/May, using a combination of traditional methods as well as by firing shots at them. For example, meerkats (*Suricata suricatta*) have been shown to use spatial memory rather than olfactory or visual cues in quickly locating boltholes when exposed to predation threat (Manser & Bell, 2003). Furthermore, the escape behaviour of Virginia opossums *(Didelphis virginiana*) indicates that they are highly spatially aware, selecting the closest temporary refuge when escaping from threat (Ladine & Kissel, 1994).

2) Link predictable resources

Pathways connected preferred habitat and resource patches in BNP with those in CSF, as elephants moved along pathways both from the west to east, and vice versa, crossing the KC N-S road and the Kwandu River. Satellite data from bull 16 confirmed results from ground surveys – with movements from core zones in BNP to CSF, crossing KC and the Kwandu River on numerous occasions (Chapter 2). Undisturbed riparian habitat, with preferred food sources such as fruiting trees (*Sclerocarya*, *Garcinia*, *Diospyros*, *Bauhinia* and *Acacia* sp.) and minerals, is available on the western side of the Kwandu River within BNP. Salt licks are made available around pans in BNP (*pers. observation*), providing an important source of sodium. In the savannahs of the Central African Republic, elephants were shown to seek out salt-rich soils around termitaria and waterholes and that these areas are connected by trails (Ruggiero & Fay, 1994). Holdo *et al*. (2009) showed that elephants, especially females, exercised geophagy in response to sodium deficiency in Kalahari Sand Habitats.

Some pathways were used by elephants to launch crop raids in the wet season. Maize is non-randomly distributed in the landscape and often the same field is planted from one year to the next (see Chapter 4). This provides elephants with a clumped and stable, high nutrient resource at the end of the wet season, when nutritional demands are highest with bulls coming into musth and females into oestrus with the onset of the rains (Poole, 1984). Crop-raiding has been described as an extension of the elephant's optimal foraging strategy, with bulls making use of heightened nutritive content (protein, calcium and sodium) of crops at the end of the wet season (Sukumar, 1990).

3) Maximize optimal foraging

Least effort routes between food sources and resting areas are used by a host of other species (buffalo, baboons, chimpanzees, sheep), and minimising travel distance between resources seems like an obvious strategy to maximise the cost-benefit balance (Noser & Byrne, 2007). Elephants foraged randomly while in homogeneous maize patches, yet when traveling through a heterogeneous environment (entering or leaving agricultural locales), movements were linear and non-random. Ganskopp *et al*. (2000) showed that pathways between frequented pasture areas were a significant factor in improving foraging efficiency in sheep. Pathways of least resistance were maintained by domestic sheep in order to maximise net nutritional gain.

iii) Pathway use across seasons

Short, non-seasonal movements can include travel between preferred feeding and watering sites, as well as evasive movements avoiding disturbance (Bar-David *et al*., 2009). In KC, pathway use was significantly higher in the wet than in the dry season. Dry and wet season dispersal areas may be spatially segregated and the shift in seasonal range reflects the shift in diet. Elephants disperse in the wet season so pathway use in disturbed areas during the wet season may seem counter-intuitive with water and food widely available in undisturbed areas. However, peak pathway use in April coincided with end of wet season range expansion, the fruiting of certain plant species (crops, marulas) and the drying up of water holes. Waterholes in the KC had dried up by the end of April, forcing elephants to the Kwandu River at the end of the wet season. Although African elephants are generalist herbivores that rely on widely distributed resources (Owen-Smith, 1988), elephants may exhibit selection for preferred plant types in particular habitats and have been known to travel long distances in search of their favourite food. Trail distribution of forest elephants in tropical forests has been linked to high nutrient food sources such as fruit and mineral deposits (Blake & Inkambu-Nkulu, 2004). In Botswana, Child (1968) recorded trails leading to fruiting trees such as marula and mugongo (*Schinsiophyton rautaneii*). In the KC and adjacent areas, numerous species of fruiting trees favoured by elephants occur, including marula, Transvaal gardenia (*Gardenia volkensii*), camelthorn (*Acacia eriloba*), candlepod acacia (*Acacia hebeclada*), jackalberry (*Diospyrus mespiliformis*) and rosewood (*Guibourtia coleosperma*). Trees fruit between November and April, coinciding with the wet season. As some of these trees grow in the greater KC area, and many of these riverine areas are densely settled, human elephant interactions are inevitable.

Monthly raiding frequency has been attributed to elephant movement, with elephants following their seasonal migration pattern encountering crops *en route* (Adjewodah *et al*., 2005; Sukumar, 1990). Not all bulls in a population are crop-raiders with Balasubramanian *et al.* (1995) maintaining that bulls that have lost part of their home range to crop fields become crop-raiders. At the end of the wet season, range expansion of bulls coincided with movements into communal lands (Osborn & Parker, 2003) as quality of wild grasses declined and maturing crops offered higher nutrient content than locally available browse. Recent field research indicates that crop raiding appears to be initiated by bulls (Douglas-Hamilton *et al*., 2005; Moss & Poole, 1983). Williams *et al.* (2001) showed that elephants only damaged fields that fell within their home range, and that crop-raiding bulls had home ranges twice as large as bulls that did not raid crops..
Elephants moved through settled areas at night and at speed (Douglas-Hamilton *et al*., 2005; Graham & Ochieng, 2008; Galanti *et al*., 2006; Osborn, 1998; Sitati *et al*., 2003). Females did not raid crops in KC, although they have been recorded to do so elsewhere. Sitati *et al*. (2003) found that females crop-raiding incidents were determined by % area under cultivation and the associated travel cost – pathways may reduce travel costs in other HEC locations.

Optimal foraging theory (Krebs & Davies, 1991) could explain this high-risk behaviour as elephants, although wary of human disturbance, target nutrient-rich crops in a risk/fitness trade-off. Mosojane (2004) noted that in Botswana resident bulls raided all year round, but that raiding peaked at the end of the wet season when crops matured. Crops, much like fruit, may provide higher nutrient content for bulls as they come into musth, as well as for lactating females, satisfying higher energy requirements before the onset of the dry season. Savannah elephants, much like the forest-dwelling subspecies, may well be pursuing the same foraging strategy by using pathways of least resistance to high quality nutrient resources such as crops or fruiting trees.

Dry season pathway use was heavily disrupted by burning in the KC and surrounding areas, suggesting that in years with minimal bushfires, pathway use in KC may be significantly higher than was reported for this study. Water is a limiting factor in the dry season and elephants in Caprivi tend to spend the dry season in National Parks (Chase & Griffin, 2009), where they have unrestricted access to the Kwandu River. Well-resourced National Parks are safe from human-induced disturbance (fire, competition with humans and cattle for water). In KC, females used the same pathways in the wet and in the dry season (pathways 18 and 22) in the least disturbed area of KC, while moving between BNP, CSF and SNNP. Bulls utilised six out of twelve pathways in the dry season, two of which were heavily used in the wet season (pathways 2 and 3) and were found in the most densely settled area of KC. This finding agrees with Osborn (1998), where elephant bulls were still present in communal lands after all crops had been removed. This could suggest that pathway use by bulls in KC is not wholly explained by optimal foraging on crops, but that pathways may serve as least effort routes to the Kwandu River, when water becomes limiting, in a highly disturbed environment. This may indicate that pathways are of some antiquity (Haynes, 2006). Pathways 25, the northern boundary of KC, was also used by bulls in the dry season for movement between dry season core zones.

iv) Elephant group size and sexual segregation

Sexual segregation in pathways use was not recorded here. Leggett (*pers. communication*) confirmed that elephants mixed freely along pathways in Western Namibia. In this study, females showed a preference for two pathways located in the less densely settled areas to the north, whereas males moved in the north as well as the heavily disturbed south. The female's avoidance of densely settled areas agrees with research on female ranging behaviour (Hoare, 1999), which suggested that females avoid disturbed areas, whereas risk-tolerant bulls may be found near settlement areas. Of 68 observations of pathways use, only eight pathways observations were those of females. Risk aversion to human disturbed areas has also been noted in grizzly bears (*Ursus arctos*) by Gibeau *et al*. (2002).

In KC, bulls made heavy use of pathways in the peak of the wet season, with activity recorded on twelve pathways. Bull group size ranged from single individuals to seven bulls (including juveniles). Average bull group size increased in April. Douglas-Hamilton (1972) classified bulls into three categories: retired males, sexually competitive males between 25-20 years of age and males younger than 25. Single large bulls moving through the area were most commonly observed in KC. However at the height of the harvesting season, bull groups consisting of two to seven individuals of varying age classes were recorded, with serious crop-raiding incidents attributed to groups of bulls foraging in the area together (*see* Chapter 4). Bull areas have been described by various authors, and it is possible that disturbance-tolerant bulls may be found near settlement areas (Hoare, 1999). Crop raiding may be a learned behaviour (Osborn, 2002) with loose relationships between males being common (Hanks, 1979).

3.5 Conclusion

O'Connell–Rodwell *et al*. (2000) suggests that increasing human settlement density along the Kwandu River and along the main road network in the area may restrict elephant movement. Indeed, Martin (2006) notes that the concentration of fields along the main Kwandu Road, while practical from a farming perspective, creates a barrier of movement for wildlife between the Kwandu Floodplain and the hinterland. However, this study suggests that although habitat quality in KC is low, pathway function is not completely compromised. Instead, pathways facilitate movement between habitat and resource patches in a heterogeneous environment, with risk-averse females utilising pathways in less disturbed areas, and bulls making use of pathways in both disturbed and undisturbed areas. Behavioural plasticity in elephants moving near disturbed areas has been well documented in other studies (Hoare, 1999). Elephants responded to human disturbance by using KC pathways at night. It is not known whether pathways were utilised more heavily by both sexes in the distant past.

The use of pathways suggests that elephants, especially bulls, penetrate the anthropogenic landscape if protected by law. Bulls in this study used pathways to launch crop raids at the peak of the wet season when crops mature. Movement pathways may also be of conservation significance to other taxa with broadly different life histories, as shown by Haddad *et al.* (2003). In the Mudumu North Complex in the Caprivi Strip, Hanssen (*pers. communication*) confirms that carnivores such as hyaenas use pathways to enter settlement areas. The role of pathways with regard to the extent and locality of human wildlife conflict, and specifically human-elephant conflict, necessitates further investigation.

If humans and elephants are to co-exist, precise land use planning is required across multiple land use types. Local land use planning initiatives zoned elephant pathways and widened elephant crossing areas in Mayuni Conservancy to the south, decreasing HEC incidents significantly. These pathways cross from the hinterland to the Kwandu River, and are heavily used by breeding herds and bulls at night in the dry season (*author pers. observation*), suggesting that wider and undisturbed pathways increase conduit function (Forman, 1995).

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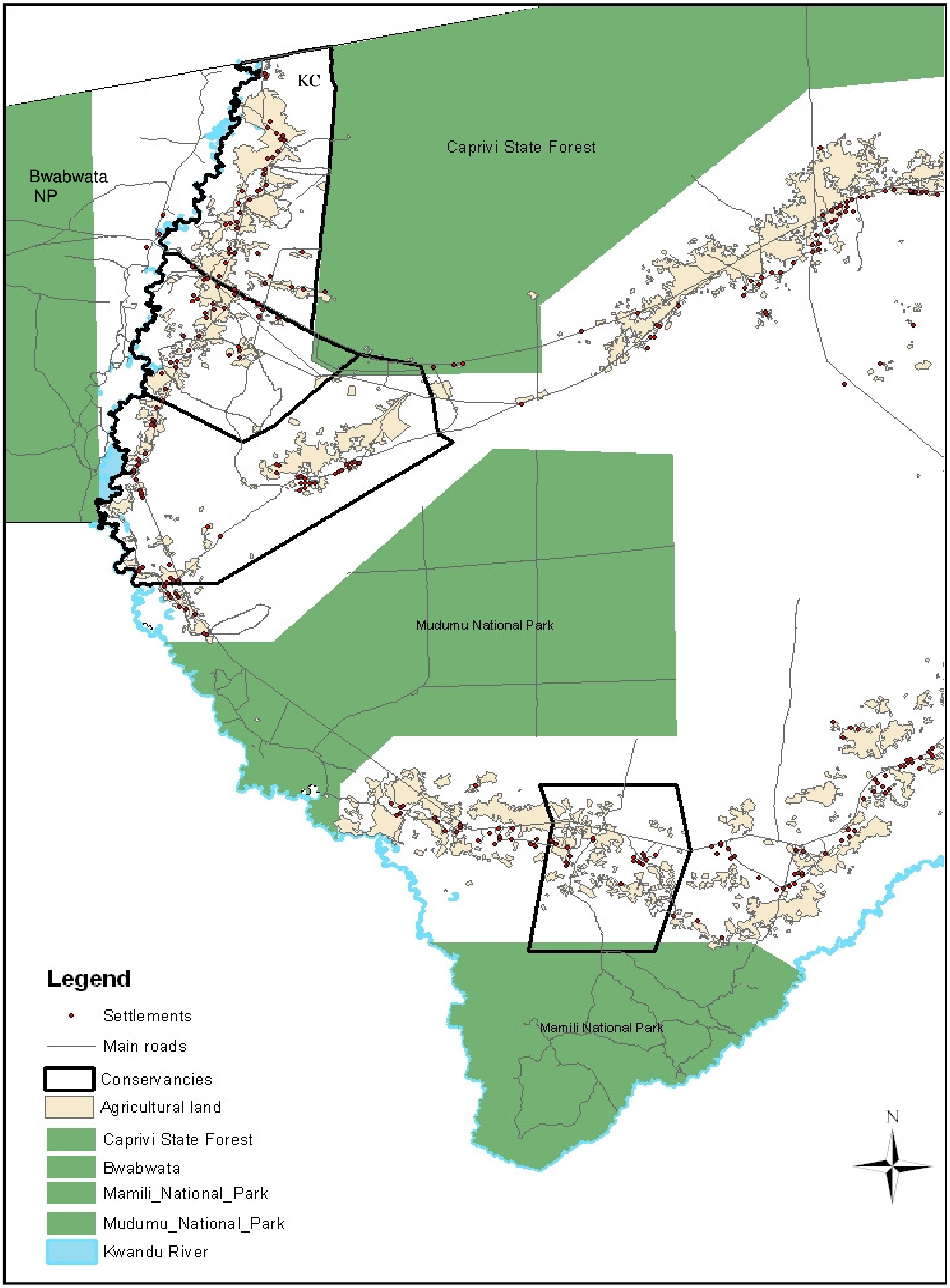
Appendix 3.1: List of tree species recorded in the Kwandu Conservancy (Kamwi, 2003).

Species
1. *Acacia ataxacantha*
2. *Acacia erioloba*
3. *Acacia fleckii*
4. *Acacia nebrownii*
5. *Acacia nilotica*
6. *Acacia tortillis*
7. *Baikiaea plurijuga*
8. *Bauhinia petersiana*
9. *Berchimia discolor*
10. *Boscia albitrunca*
11. *Burkea africana*
12. *Combretum collinum*
13. *Combretum imberbe*
14. *Combretum molle*
15. *Combretum psidioides (psidioides)*
16. *Combretum zeyheri*
17. *Commiphora angolensis*
18. *Croton gratissimus*
19. *Dichrostachys cinerea (Setulosa)*
20. *Erythrophleum africanum*
21. *Guibourtia coleosperma*
22. *Lonchocarpus capassa*
23. *Lonchocarpus nelsii*
24. *Ochna pulchra*
25. *Peltophorum africanum*
26. *Pterocarpus angolensis*
27. *Terminalia sericea*
28. *Ziziphus mucronata*

Appendix 3.2: Barriers (roads, settlements, fields) along the eastern boundary of the Kwandu River.



'When we are hungry, elephants are food. When we are full, elephants are beautiful.'
Zimbabwean Rural Farmer

CHAPTER
4

SHORT-RANGE ELEPHANT MOVEMENTS: PATHWAYS AS SPATIAL VARIABLES AFFECTING CROP-RAIDING

Abstract
Short-range daily elephant movements were recorded in the Kwandu Conservancy, Namibia in peak wet and dry season months. Spatial correlates of crop-raiding were investigated, with specific focus on the impact of elephant pathways on raiding location. One hundred fields within the Conservancy were randomly selected and geo-referenced. Spatial correlates recorded included field distance to nearest pathway, protected area, settlement, river and road. In Kwandu Conservancy, 168 elephant incidents were logged in the wet season months of March/April. Results indicated that actual crop-raids (more than one quarter of field destroyed) constituted less than 25% of all reported incidents. Bulls were responsible for 100% of all crop-raiding incidents. Bulls preferred foraging in crop fields that lay near pathways than on fields that lay at a distance from pathways. This study suggests that 1) crop-raiding from pathways may maximize foraging efficiency by reducing time spent and distance travelled while foraging, 2) elephants foraged randomly while in homogenous crop patches, but when travelling through a heterogeneous environment (entering or leaving agricultural locales), movement was directional and non-random, and 3) crop attractiveness may be enhanced by water availability. Pathways and crossing points to the Kwandu River, as well as crop palatability, should be considered in elephant management and Human-elephant conflict reduction strategies.

4.1 Introduction

Human-elephant conflict (HEC) is widespread in Africa, with rural subsistence farmers incurring agricultural losses and damage from crop-raiding elephants. Although crop-raiding can be traced back to the 16^{th} century (Meredith, 2001), it is increasingly being reported in Africa and in Asia. The resolution of conflict has become a political challenge as rural chiefdoms may exert strong political influence (Parker & Osborn, 2001, Osborn & Parker, 2003), which could threaten conservation efforts (Hoare, 1999; Sitati & Walpole, 2006). Conflict is exacerbated by the conversion of former elephant range into agricultural land, increasing the human-elephant interface, especially along perennial rivers and near protected area boundaries. This has given rise to community-based natural resource management (CBNRM) in and near protected areas. However community participation in conservation activities within the Kavango Zambezi Transfrontier Conservation Area (KAZA TFCA) is highly variable, with some countries more developed than others. Research is looking for solutions to crop-raiding and numerous studies have focused on the consequences of HEC (Osborn & Parker, 2003, Parker *et al.*, 2006, Sitati *et al.*, 2005), yet no one single mitigation measure has proven to be effective due to the adaptive behaviour of the pachyderms to traditional deterrents. Active defense methods (crop guarding, drum beating, burning fires, hurling rocks) and passive methods (fences, alarm bells) suggest that elephants are capable of adaptive behaviour in response to spatio-temporal variability in habitat conditions.

Research in the last two decades has increasingly turned to investigating the causes of HEC. Sitati *et al*. (2005) suggested that conflict is clustered, and not distributed equally among farms, but is a result of local physical and geographical factors. Spatial variables of HEC have been correlated to human population density, elephant density, proximity to nearest elephant refuge, distance to nearest settlement and distance to roads and rainfall. The most comprehensive study on HEC in Africa (Hoare, 1999) failed to find significant spatial correlates for crop-raiding. Research at finer spatial scales however revealed that HEC was significantly correlated to distance to water, mean elevation and length of protected area frontage, field size, distance to nearest elephant refuge (Graham *et al.*, 2009; Mosojane, 2004). The availability and distribution of food and water are known to underlie elephant spatial use (Harris *et al.*, 2008). Sitati *et al*. (2003) found that males and females incidents in HEC displayed different spatial correlates with female incidents being determined by % area under cultivation and the associated travel cost, while bulls were more impacted by the proximity to the nearest settlement and hence mortality risk In Kenya, Smith and Kasiki (2000) reported a significant correlation between HEC incidents and distance to permanent water, as well as with mean elevation and length of protected area frontage. Parker and Osborn (2001) and Naughton-Treves (1997) reported from Zimbabwe and Uganda respectively that HEC was clustered, increasing significantly in farms close to protected areas. Summarising recent research efforts, Jackson *et al.* (2008) stated that the present understanding of factors governing HEC is fragmented, with site-specific studies varying in spatial scale. Consequently, HEC is said to be irregular and unpredictable in nature (Hoare, 1999; Osborn, 2002).

The Kwandu Conservancy (KC), centrally placed within the KAZA TFCA, forms part of an important corridor for movement of elephants between Botswana, Namibia, Angola and Zambia, with elephant movements increasingly being reported into Angola's south-eastern Luiana Partial Reserve (Chase & Griffin, 2009). HEC is a growing concern within the KAZA TFCA (Gadd, 2005; Mosojane, 2004; Cumming & Jones, 2005; NRP, 2006). Recent research into the KAZA TFCA revealed that HEC in southern Africa is increasing (Diggle *et al*., 2006), where elephants are moving into areas of human settlement and out of protected areas, damaging crops, raiding food-stores and damaging water sources, occasionally killing or injuring people in the process.

Rural subsistence farmers whose food security is threatened by crop raiding elephants make up 80% of the human population of the KAZA TFCA. Crop raiding reduces the tolerance of farmers to elephants, as well as towards wildlife managers and conservation agencies tasked with their protection.

Studies have noted that elephants 'are a convenient medium for widespread and persistent complaint from rural communities against wildlife initiatives' (Dublin & Hoare, 2004).

Settlements (Fig. 4.2) may act as a barrier to elephants accessing Kwandu River (Chase & Griffin, 2005) and rural communities have been identified as the central starting point for participation in natural resource and mitigation management (Conservation International, 2006:Graham & Ochieng, 2008). This study sets out to 1) test above-mentioned, traditional spatial correlates of raided fields for significance, particularly distance to nearest a) settlement, b) refuge, c) road d) protected area and e) river and 2) specifically, for the first time in the HEC literature, test whether pathways are a significant variable in crop-raiding locality. The study offers new insights into spatial variables of HEC, and results are hoped to be of use to land use planning initiatives and conservation managers.

4.2 Materials and Methods

i) Study area

KC, the most densely populated Conservancy in Namibia, is inhabited by 4 300 people. Kongola is the largest village. Villages, agricultural fields, schools and clinics occur mostly adjacent to the main North-South gravel road. Cultivation occurs in the wet season when farmers plant maize, millet and sorghum, which is harvested by April/May. Soil is predominantly Kalahari Sands and nutrient poor. Mean annual rainfall is estimated at 600 mm, with rainfall occurring mainly in summer months between November and May. The landscape is flat with an average altitude of 930 ± 1 100 m a.s.l. (Mendelsohn & Roberts, 1997).

The KC is situated in the Caprivi Strip (Fig. 4.1), and extends over 190 km^2. It is wedged lies between the Bwabwata National Park (BNP) and the Caprivi State Forest (CSF) in the East. The Kwandu River marks the western boundary of the Conservancy, and both people and elephants rely on the River for water in the dry season, when there is no other perennial water in the region. Surface water is widely available in numerous waterholes, pans and *omurambas* (ancient river valleys) during the wet season, but by May most of the waterholes have dried up.

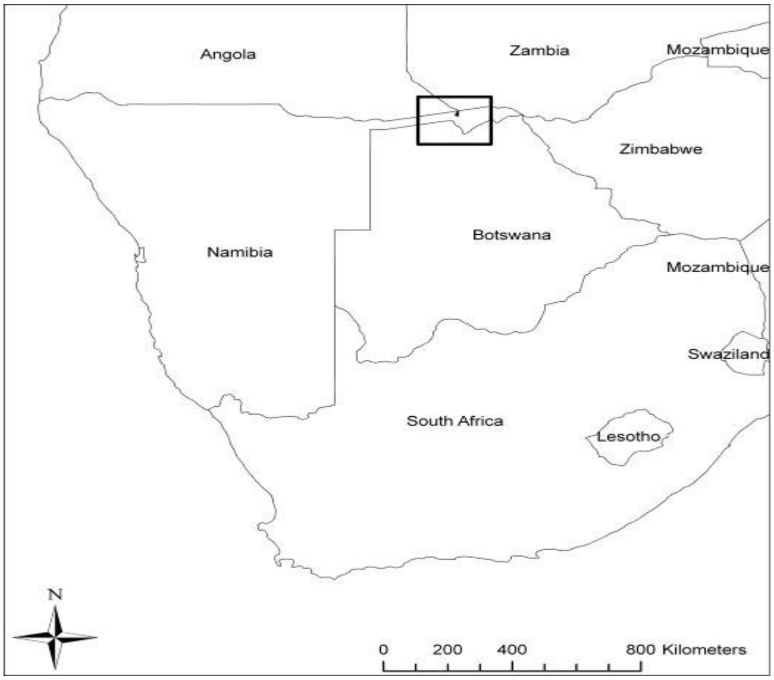


Fig. 4.1: The study area within southern African region.

Of all Conservancies, the KC has the highest number of reported HEC incidents in Namibia (Hanks, 2006). Elephants are protected under Namibian law and move freely between preferred foraging areas. KC practices CBNRM, with a minimal number of elephant bulls removed through trophy hunting each year. The Conservancy receives a percentage of the hunting fees as well as the meat from the animal. Problem Animal Control (PAC) is exercised by the Ministry of Environment and Tourism (MET), but frequently it falls to the local Professional Hunter to expediently eliminate the 'problem elephant'. Compensation for crop-raiding incidents is paid to farmers who comply with compensation regulations. Reports of crop-raiding are confirmed by a team of ten Conservancy Game Rangers.

Table 4.1: Elephant numbers 1980-2005 in West and East Caprivi, with *Forest Reserve* representing elephant numbers in the Caprivi State Forest adjoining the Kwandu Conservancy (Source: Chase & Griffin, 2009).

	West Caprivi				East Caprivi				
Year	Mahango NP	Buffalo NP	WCGR[a]	Susuwe	Mudumu NP	Mamili NP	Forest Res.	Total	Source
1980					0	32	1509		Rodwell *et al.* (1994)
1981				410					Rodwell *et al.* (1994)
1982					193	135	1936		Rodwell *et al.* (1994)
1983	53				539	100	1550		Rodwell *et al.* (1994)
1984					149	57	1768		Rodwell *et al.* (1994)
1985	0	1			310	72	1353		Rodwell *et al.* (1994)
1986	0				158	136	567		Rodwell *et al.* (1994)
1987	169	868							Rodwell *et al.* (1994)
1988	0			884	143	169	1075	2271	Rodwell *et al.* (1994)
1989	82	92		728	387	179	335	1468	Rodwell *et al.* (1994)
1990	319	1085			534	491		2429	Rodwell *et al.* (1994)
1991	208								Martin (2005)
1993	298	1209	0	2825	405	187		4924	Rodwell *et al.* (1994)
1994	248	1532	0	2953	433	638		5804	Rodwell *et al.* (1994)
1995	252				821	1457			Martin (2005)
1998	292	1227	0	1549	175	1333	0	4576	Craig (1998)
2000	238								Martin (2005)
2002	250								Martin (2005)
2003		1438	944	1754	623	524	35	5318	This study
2004	340	1927	38	2563			0	7671	MET (2004)
2005	64	1116	292	1984	1254	532		5242[b]	This study

[a]West Caprivi Game Reserve.
[b]This total does not include an estimated 1232 elephants in the north and south conservancies.

i) Pathways as spatial variables affecting crop-raiding

Ground-based surveys were used to record all reported crop-raiding incidents. Two hundred and fifty fields were geo-referenced, and each field was assigned a random number drawn form a uniform distribution. Fields were sorted according to the random number, and the first one-hundred fields were selected as a random sample. Fields were placed into three categories: 1) raided 2) non-raided (elephant absence) and 3) non-raided (elephant presence - no raid). If more than one quarter of a field was destroyed, it was considered a raid (KC Office protocol). If less than one quarter of the field was affected, it was categorized as ‘elephant presence- no raid’.

Field center point was calculated in Arc GIS. The following spatial correlates were tested in previous studies, and were included in this study for comparative purposes: field proximity to nearest 1) road, 2) village, 3) protected area, 4) forest refuge and 5) river (Hoare, 1999; Sitati *et al.*, 2003, 2005; Smith & Kasiki, 2000, Naughton-Treves, 1997).

Elevation and rainfall were also included. Pathways were mapped (*see* Chapter 3) and field proximity to nearest pathway calculated.

ii) Crop-raiding in Kwandu Conservancy

All reported crop-raiding incidents for March and April of 2008 were recorded, and the name of the farmer, village, date, crop type and maturity of crop involved noted. For each incident, number and sex of elephants involved were logged. As per Chiyo & Cochrane (2005) and Balasubramanian (1995), I distinguished between male and female elephant groups raiding crops from the presence or absence of dung and footprints from elephants less than 6 years of age. Sitati *et al*. (2005) proposed that fields that were raided in the past were more likely to be raided again, so all raided farms in 2007 were recorded prior to the 2008 cropping season. Raided and field with elephant present, but not raided, were tested for significant differences in crop type and crop maturity.

iv) Analyses

The Kruskal-Wallis test was used to test the significance of field position to eight spatial variables, while the Chi-Square test was used to compare nominal variables to other nominal input variables (crop age, crop type and raiding status). This test statistic was also used to compare bull group size across seasons.

4.3 Results

i) Pathways as spatial variables affecting crop-raiding

This study statistically tested for significant spatial correlations in distance to 1) protected areas, 2) nearest forest refuge, 3) road, 4) village, 5) river, 6) elevation and 7) pathways. Field distance to protected area, forest refuge, road and river as well as elevation proved to be insignificant as spatial variables in explaining field-raiding position (Table 4. 2).

Table 4.2: Eight variables tested against field position (Kruskal Wallis) for significant spatial correlates.

Distance to	F value	p value
Settlement	2.55	0.08
Protected area	1.09	0.34
Forest Refuge	1.10	0.34
Tar Road	1.45	0.24
Gravel Road	0.10	0.9
River	1.33	0.33
Pathway	6.01	**< 0.01**
Elevation	0.77	0.47

Distance of fields to nearest settlement (Fig. 4.2, $p = 0.08$) suggested that fields close to settlements tended to be raided less frequently than fields that lay further away, although this was not significant. Fields that lay close to pathways (Fig. 4.3, $p < 0.01$) were raided significantly more often than fields that lay further away.

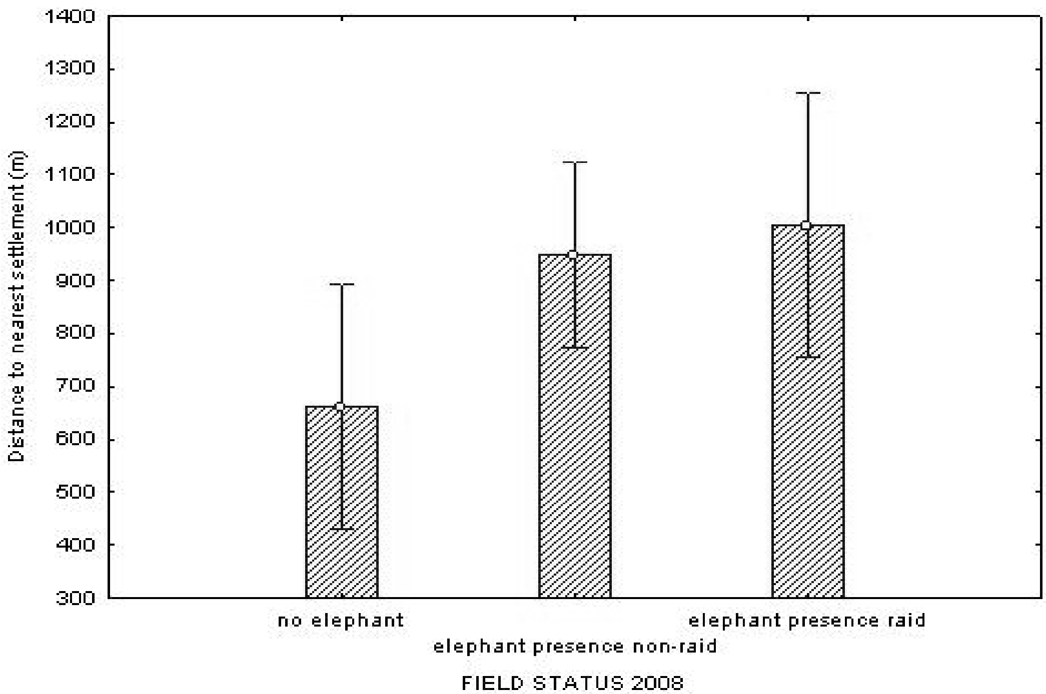


Fig. 4.2: Average distance of field to nearest settlement. Error bars indicate 95% Confidence Intervals. p = 0.08.

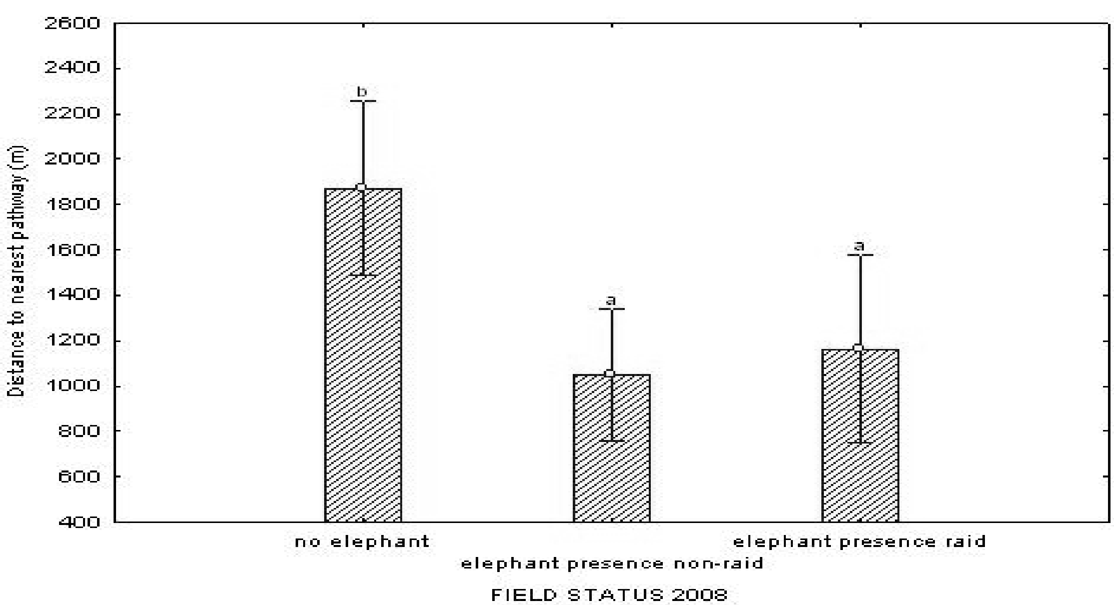


Fig. 4.3: Average distance of field to nearest pathways. Significant differences at p < 0.01 indicated by different letters.

ii) Crop-raiding in Kwandu Conservancy

2007 showed the highest number of recorded incidents for the KC (Fig. 4.4). In 2008, 168 incidents were recorded between February 13 and April 17. Crop raiding occurred as crops ripened towards the end of the rainy season, from March until May, with a peak in elephant incidents in April (Fig 4.5). Of these, 76% constituted "elephant presence-no raid" incidents (less than 25% of field destroyed) with 24% of elephant incidents constituting actual raids (more than 25% of field destroyed).

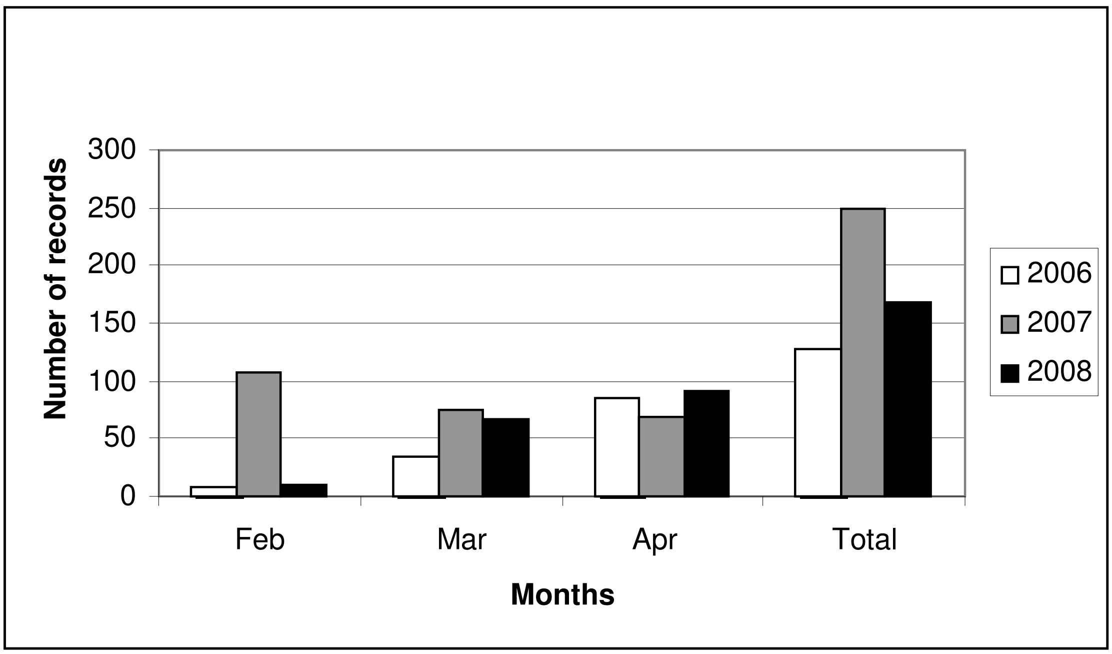


Fig. 4.4: Number of elephant incidents during the wet season, 2007-2008.

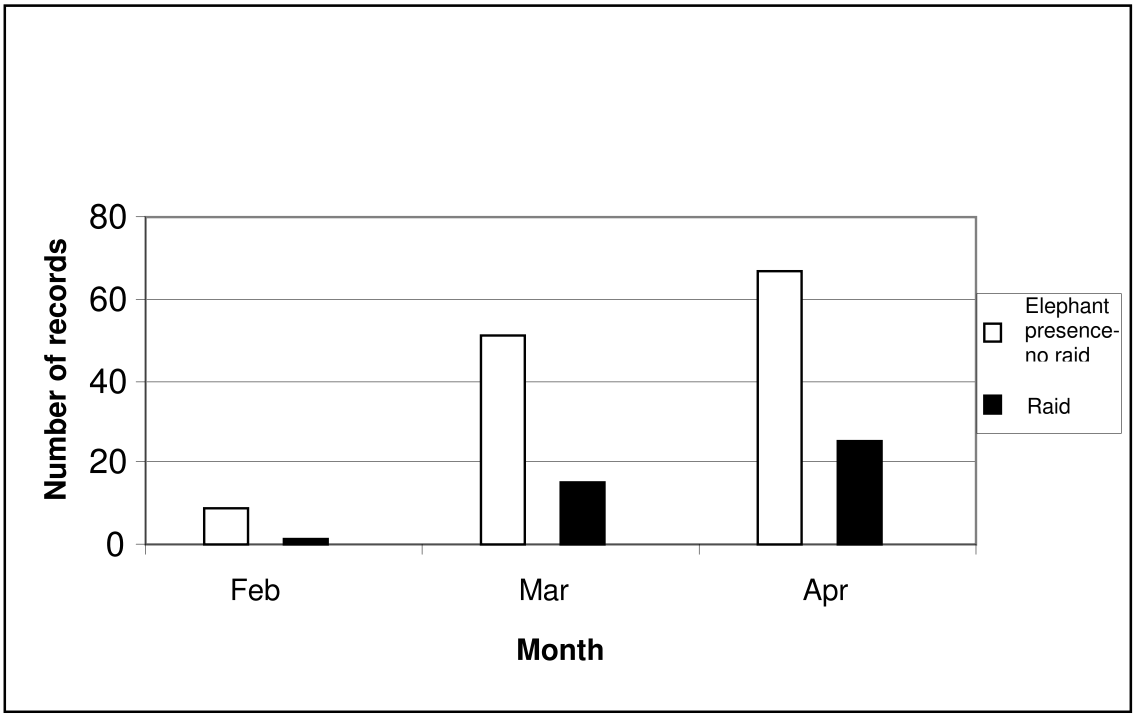


Fig. 4.5: Number of elephant incidents in the Kwandu Conservancy in the wet season, 2008, with a peak in activity in April. Of all recorded elephant incidents, only 25% constituted actual raids.

Maize was the most frequently planted crop among farmers (n = 100), and the most affected by elephant incidents (Fig. 4.7). Mature crops were raided more frequently than interim or immature crops (Fig. 4.6., Chi-Square Test, $p = 0.00392$). Bulls were responsible for 100% of reported incidents, and all incidents occurred at night. Bull group size increased with incident type (Fig. 4.8), with larger bull groups responsible for raids. Seventy-five percent of fields raided in 2007 were targeted again in 2008 (Fig 4.9, Chi-Square Test, $p = 0.01774$).

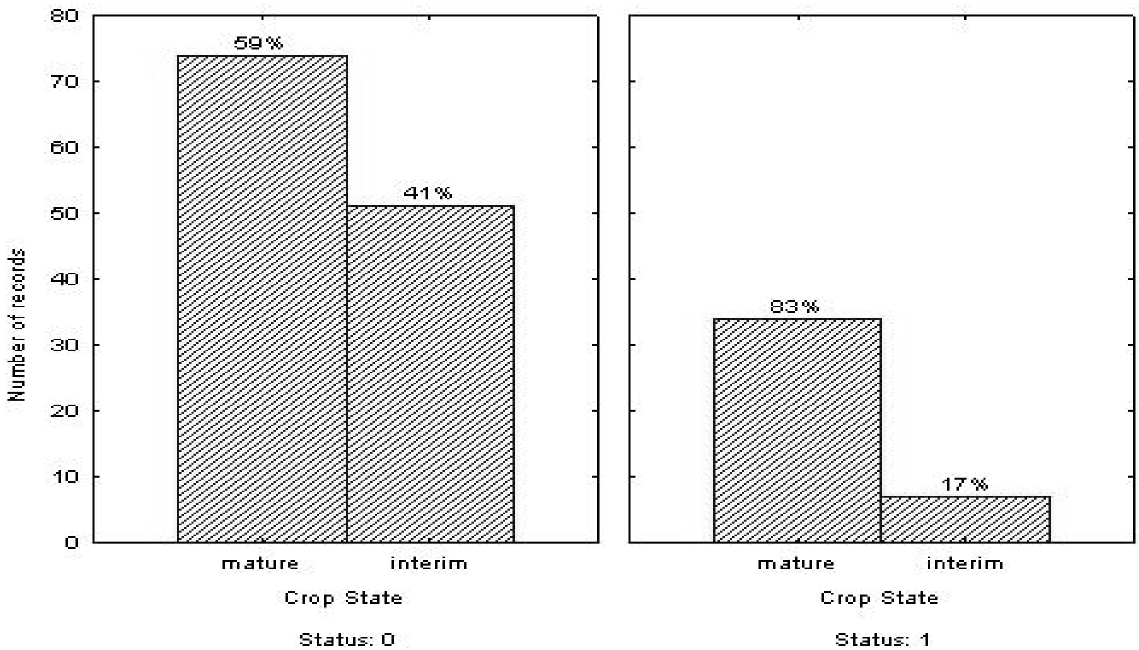


Fig. 4.6: Correlation between crop status and raiding frequency (Chi-Square Test, p = 0.00392), with Status 1 = raided field.

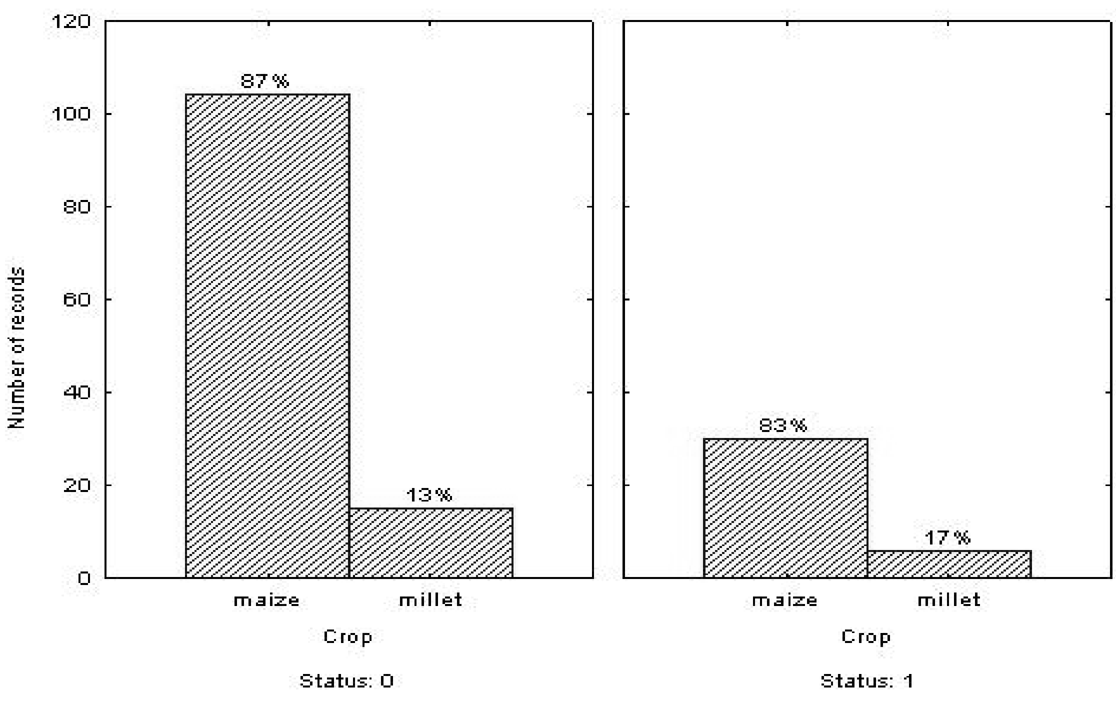


Fig. 4.7: Maize was the most frequently planted crop among farmers (n = 100), and the most affected by elephants, whether Feeding While Moving (Status 0) or raided (Status 1).

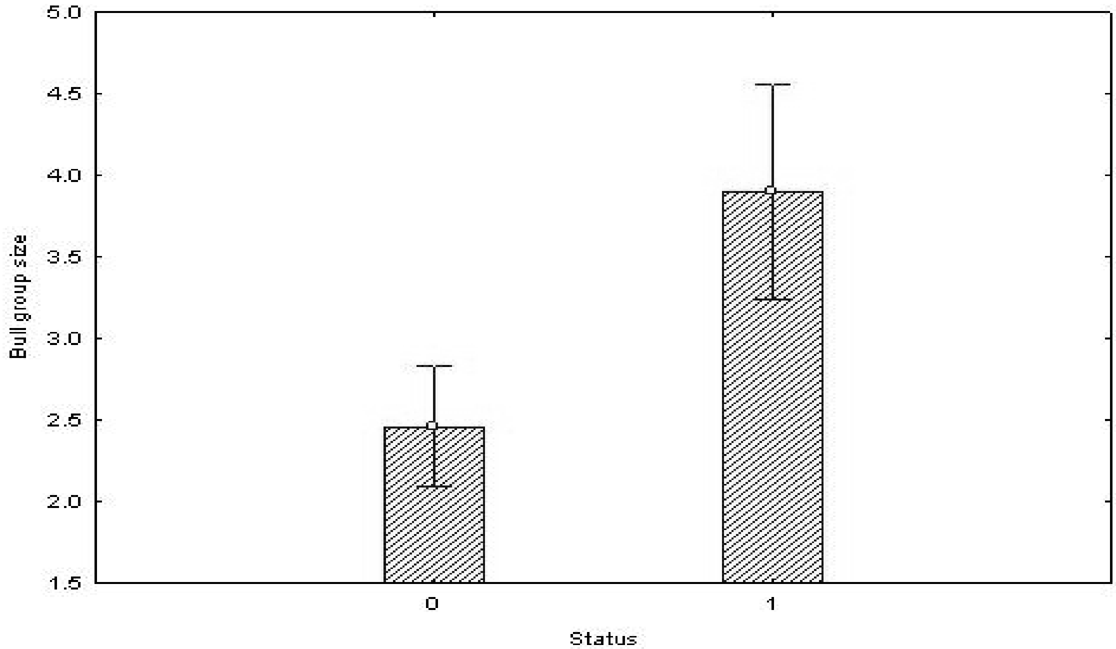


Fig. 4.8: Average bull group size and raiding status), with Status 1 = raided, 0 = not raided. Error bars indicate 95% Confidence Intervals. $p < 0.01$.

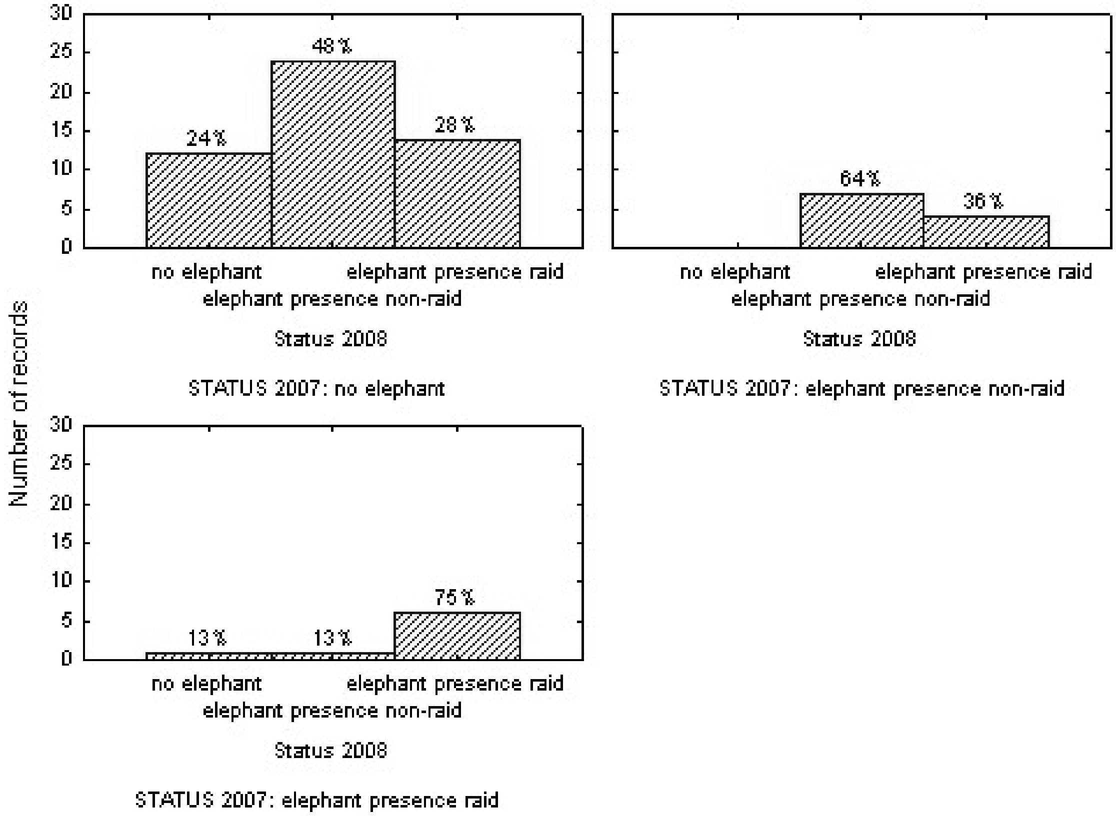


Fig. 4.9: Relationship between field position and raiding status (Chi-Square Test, p = 0.01774)**.** Each graph consists of three panels, which give results for 2007, while the percentage given provides information of what occurred in 2008.

4.4 Discussion

i) Pathways as spatial variables affecting crop-raiding

Previous studies and reports have made reference to the existence of pathways, and suggested they may play a role in HEC (Smith & Kasiki, 2000; Sitati *et al*., 2003), although this has never been scientifically documented. In fact, Sitati & Walpole (2006) tested non-electrified barriers over 'well-used elephant crop-raiding routes' as a mitigation measure, but this proved ineffective as elephants pushed over or circumvented the barrier. A human-wildlife conflict (HWC) report by the Worldwide Fund for Nature suggests that in Conservancies such as KC, conflict is exacerbated when settlements are placed across 'well-used elephant paths' to and from the Kwandu River (WWF, 2008). In Botswana's Okavango Delta, Mosojane (2004) further noted that most of the raided fields were situated in the proximity of segments frequently crossed by elephants, and part of his recommendations to the Botswana Government stated that areas with 'traditional elephant paths' should be avoided in land allocations for agricultural purposes.

In this study, pathways were found to be significant spatial variables in crop-raiding location in KC, with bulls preferring to forage in fields that lay closer to pathways than on fields that lay further away. Fields close to pathways may provide a clustered and stable high quality nutrient source, where feeding rates and nutrient intake can be maximised, which in turn determines time invested in other non-feeding activities (Spalinger & Hobbs, 1992) such as resting or searching for mates. Field proximity to pathway may also explain inter-annual HEC incidents on the same field, with elephants using the same pathways to and from the Kwandu River between years. Traditional and repetitive elephant movement along elephant routes has been noted by Sitati & Walpole (2006), who showed that any barriers along elephant routes failed to arrest elephant movement as such barriers were regularly challenged by elephants. Fields, much like barriers, can thus expect to be regularly challenged by elephants, elephants traversed fields lying on pathways during nocturnal movements between resource and habitat patches.

Pathways in KC were linear and led through fields, becoming less obvious in the homogenous crop patch. Similarly, in Uganda, elephants used entry and exit paths into crop fields (Chiyo *et al*., 2005).

Dai *et al.* (2007) proposed that directional persistence increases optimal searching success. Optimal foraging theory assumes that animals are adapted to make least effort routes between resources – for example, Noser & Byrne (2007) found that baboons (*Papio ursinus*) planned their foraging journeys, and approached them in a goal-directed manner. Spatial orientation in goal-directed approaches to resources was also found in forest chimpanzees (*Pan troglodytes)* (Normand & Boesch, 2009). Elephants too may use traditional 'least effort' routes between refuges and the Kwandu River as spatial organization of landscape features such as available forage, refuges and water can drive repetitive elephant movement (Wittemyer *et al*., 2008). Surface-water availability is known to affect the distribution and abundance of elephants (Chamaille-James *et al.*, 2007), and waterholes in KC and CSF were found to be dry by end April. Pathways in KC were consequently also used by elephants between seasons to access the Kwandu River (Chapter 3). Martin (2006) notes that the spatial configuration of fields in Kwandu: '…although in theory the spaces between fields could qualify as wildlife habitat, they are so small that any wild animal attempting to use them would automatically become a problem animal'.

As with Hoare's (1999) study of HEC in the Sebungubwe region in Zimbabwe, no significant spatial correlation in distance to nearest protected area and settlements, as well as to road and river KC could be found. This may be due to a problem with spatial scale: For example, Sitati *et al.* (2003) indicated that data at 1 km^2 resolution exhibited too much noise and autocorrelation to identify spatial correlates reliably, and that 25 km^2 resolution yielded statistically significant results with greater confidence.

ii) Crop-raiding in Kwandu Conservancy

The KC has been termed a HEC 'hotspot' (Hanks, 2006). Extent of HEC along the Kwandu River has been investigated by Mulonga *et al.* (2003), O'Connell-Rodwell *et al*. (2000), Evans (2004) and Suich (2003). Data vary according to sources and methods used, and are highly variable spatially and temporally.

KC is a narrow, highly populated area, sharing boundaries with protected areas to the west, north, and east. Smallholder farms near protected area boundaries, such as those near BNP, SNNP, CSF and LPR, are likely to experience high levels of crop depredation by elephants (Barnes, 1996; Osborn & Parker, 2003, Naughton-Treves, 1997, O'Connell-Rodwell *et al*., 2000,). The Kwandu River frontage is extremely exposed to wildlife movements, and high incidents of HEC have been reported. Attitudes of communities towards elephants are consequently negative (Scovronick *et al.,* 2007).

In KC, temporal crop-raiding peaks were positively correlated with periods of high rainfall that incorporated a lag period. Rainfall determines food availability, distribution and quality, and is suggested to be a significant factor in elephant seasonal movements (Loarie *et al*., 2009; 2009a, Wittemyer *et al.*, 2008). Crop palatability and phenological stage has been linked to crop-raiding (Sukumar, 1990). In KC, crop-raiding was therefore found to be a function of season, with incidents only recorded by the Conservancy Office in the wet season, although elephants cross the Conservancy in the dry season to access the River and BNP.

In KC in 2008, crop-raiding was not severe: of all reported incidents, only 24% constituted actual crop raids. As in Uganda, elephant forays into agricultural fields in KC were rare and localized, but disastrous to the individual farmer (Naughton-Treves, 1997). In KC, fields that were raided in 2007 were targeted again in 2008, agreeing with a study of spatial correlates of HEC by Sitati *et al*. (2003). Bulls were responsible for 100% of elephant incidents recorded (Thouless, 1994; Barnes, 1996, O'Connell-Rodwell *et al.*, 2000). All incidents occurred at night. Bull areas have been described by various authors, and it is possible that disturbance-tolerant bulls may found near settlement areas (Hoare, 1999). Bull group size increased with incident type, where bulls of differing age classes joined together when moving through KC. Sukumar (1991) also found that males appeared to form larger groups in response to risk during raiding. Chiyo's *et al.* (2005) study in Uganda further suggested that crop raiding was initiated at an age when male elephants leave their families and a large proportion of elephants raid when they are approaching reproductive competition. Crop raiding may further be a learned behaviour (Osborn, 2002).

Mature maize was the dominant crop type affected. Mosojane (2004) noted that in Botswana locally resident bulls raided all year round, but that raiding peaked at the end of the wet season when crops mature. Breeding herds of elephants also raided at this time. Seasonal changes to food availability may play a role in crop raiding behaviour. Osborn (2003) noted that bull elephants moved into Zimbabwean crop fields when the quality of wild grasses decreased below the quality of crop species. Crop-raiding has been described as an extension of the elephant's optimal foraging strategy (Krebs & Davies, 1991) with bulls making use of heightened nutritive content (protein, calcium and sodium) of crops at the end of the wet season. This 'Male behaviour hypothesis' has been supported by empirical data from the field (Sukumar, 1991, Osborn, 1998). In polygynous mammals with marked sexual dimorphism, males display risky behaviour that will increase reproductive success (Sukumar, 1991).

4.5 Conclusion

HEC has been attributed to natural elephant movements being disrupted through human encroachment into elephant range, competition for water as elephants traverse fields to get to scarce water sources, reduction of natural habitat resulting in elephant movement becoming impeded to such an extent that human elephant interactions become inevitable, degradation of natural habitat, as well as to the nutritive value of crops as energy maximising strategies in elephant foraging behaviour (Sukumar, 1990).

This study suggests that daily elephant movements along elephant pathways play a significant role in patterns of HEC. Smith & Kasiki (2000) noted a similarity in pattern of HEC and the position of elephant 'migration routes', proposing that elephants may be a) using old routes out of habit, b) elephants use old routes as they connect crops and water points and c) elephants use routes to move between protected areas. The authors suggest that a study of migration routes and testing the above would be of enormous value to land use planning initiatives. As is the case with studies on the movement among wide-ranging species in fragmented landscapes such as cougars (*Felis concolor*) by Beier (1995) and grizzlies (*Ursus arctos*) by Wielgus *et al*. (2002), elephants frequently used sand tracks within the greater KC (*pers. observation*) as they may serve similar functions to pathways (wildlife movement conduits) in a fragmented habitat.

In KC, reported elephant incidents were partly a function of elephant movement, with some bulls passing through KC during their daily movements, while other bulls launched crop-raids. Sukumar (1991) suggested that the removal of habitual crop-raiding males could reduce crop-damage in high conflict areas. Elephant persistence in settlement areas is relevant to the socio-economic well-being of the Conservancies in Namibia, where financial returns from trophy hunting are often the only sustained income. The removal of males through trophy hunting should, however, be approached with caution as hunting may affect the male hierarchy (De Villiers & Kok, 1997), as well as effect the loss of genetic contact between sub-populations, as mature bulls with large home ranges, such as bull 16, use communal lands.

Poole (1996) predicted that the blockage of traditional routes around human settlements and protected areas will increase HEC. Crop raiding by wildlife can be regarded as a negative result of monotonous land use due to the loss of ecological functions (Agetsuma, 2007). Success of conservation efforts on communal lands within a TFCA context is therefore determined by the relationship between people and wildlife. For example, Fernando *et al.* (2005) found that mosaics of settlements, agriculture and remnant forest patches with ill defined human-and elephant usage areas encouraged HEC in Sri Lanka. His study further proved that land use planning and agricultural practice encourages coexistence between humans and elephants, if usage for each species is clearly segregated and well defined in a protected area complex. Successful land use planning, leading to the relocation of people and crops away from floodplains used by elephants may result in a reduction in HEC. For example, in the Mayuni Consrevancy in the Caprivi Strip, people moved away from the Kwandu floodplain, with elephant movement zones and crossing points over the main road were clearly signposted – both of which led to a clear reduction in HEC (Fig. 4.15, from NRP, 2006). Agriculturists should therefore be discouraged to settle in high-risk areas, as was concluded in Kenya by Gadd (2005). Local land use planning initiatives would do well to consider Owen Smith *et al.* (2006), who suggested that 'Management should be spatially differentiated, and may involve zoning some areas as elephant sanctuaries and others as tree sanctuaries with clearly specified objectives'. Elephant pathways may well provide the first step in identifying such areas as elephant sanctuaries.

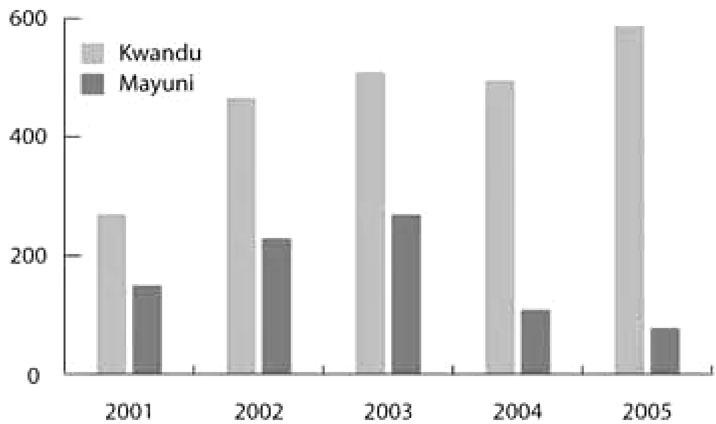


Fig 4.10. Changing trends in the number of incidents of crop damage by wildlife in two neighbouring Conservancies in east Caprivi between 2001 and 2005. Source: Jones (2006)

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'When we plan, when we conserve, when we design, when we manage, and when we make wise decisions for landscapes, and especially for regions, we manifest sustainable thinking and act for human generations'.
Richard T. T. Forman

CHAPTER 5

MAIN RESEARCH FINDINGS AND CONSERVATION APPLICATIONS

5.1 Main Research Findings

Landscape scale

What are elephant movement patterns in the Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA)?
Results suggested that collared elephants had distinct home ranges with preferred core areas that they frequented throughout the year. The female and her herd restricted their movements to a contiguous area – a National Park (NP) and a forest fragment next to the Zambezi River. A distinct habitat corridor for the female and her herd was identified, with the herd avoiding the central portions of the Nampiu Forest, with anthropogenic disturbance a possible factor. The collared bulls on the other hand ranged widely within the KAZA TFCA making use of a mosaic of land-use types. Multiple Resource Areas (MRAs) and Conservancies adjoining protected area boundaries nevertheless played an important role, constituting 35 - 45% of the total range. Conservancies in Namibia and the west Zambezi Game Management Area (GMA) have a crucial role to play in elephant dispersal.
Elephants spent the dry season in protected areas near the Kwandu and Zambezi Rivers. Wet season range expansion occurred for all three elephants, with collared bulls ranging across four countries, while the female and her herd remained in the National Park and adjoining areas.

Does human disturbance have an impact on elephant movement beyond protected area boundaries?
The study confirmed that elephant movements were disturbed by human activities. Elephants had more than 50% of their range in protected areas, and communal land was used least, with nocturnally activity for both males recorded in Conservancies in Namibia. Bulls travelled significantly faster in non-protected areas than in protected areas, with speeds recorded in the matrix being up to four times higher. This streaking behaviour occurred under cover of darkness. Long distance ranging behaviour of > 30 km

tended to occur at night, with bulls travelling between two core areas within their range, which included various land-use types. Interestingly, the female's long-range movements were all diurnal, occurring within the NP.

Which core areas beyond protected area boundaries are of conservation importance to elephant persistence within the KAZA TFCA?
Fragmented range beyond protected area boundaries contained core zones that are of conservation significance. These core zones could ensure species persistence in landscape. For the female and her herd, a habitat corridor was identified. This corridor connects the northern sections of Sioma Ngwezi National Park (SNNP) in Zambia with Nampiu Forest to the north.

For the bulls, core zones of conservation importance beyond protected areas include:

In Namibia:
- Salambala Conservancy
- Mayuni Conservancy
- Mashi Conservancy
- Maningimanzi Channel and floodplains
- Nabulongwe pan south of Katima Mulilo
- Forest pockets east of Gunkwe and Kapanda

In Zambia:
- Sections of the Zambian GMA north of the Caprivi State Forest (CSF)
- Nampiu, Shokosa, Chiobe, Lusu Forest in Zambia (Forest Reserves with limited wildlife management)

In Botswana.
- Sections of NG 14 adjoining the Kwandu River, opposite Mudumu NP.

Protected areas used by the bulls include LPR (Angola), SNNP and Forest Pockets on west Zambezi in Zambian GMA (Nampiu, Shokosa, Chiobe, Lusu), Caprivi State Forest, Bwabwata NP and Mudumu NP in Namibia, and Chobe NP in Botswana. For detailed mapping of core zones, please refer to Chapter 2.

Which environmental or spatial variables explain elephant selection of areas?
Core areas were found at higher elevations than non-core areas, and near protected areas, or areas with decreased disturbance. Human disturbance was considered a prime factor, although nutrients and minerals in the soil are known to be important, although no difference in AFRI values were found. Not surprisingly, dry season core areas tended to lie close to settlements and rivers.

Regional scale

Do elephant pathways exist in the Kwandu Conservancy (KC)?
Elephants used pathways in KC to move between important habitat and resource patches. Pathways identified in this study connected two protected areas (BNP and Caprivi State Forest). Pathway floors were devoid of vegetation. Pathways lay on an E-W gradient, with elephants crossing the major N-S road in KC as well as the Kwandu River.

Does human disturbance have an impact on elephant movement along pathways?
Elephant activity along pathways was nocturnal for 100% of observations.

Does pathways functionality differ across seasons?
Pathway use decreased significantly in the dry season. This is attributed to extensive anthropomorphic burning regimes used to clear agricultural land in preparation for planting crops. Fires often penetrated protected areas, including the Caprivi State Forest. Pathways were used in both seasons to access the Kwandu River and the protected areas to the west and east. Only in one instance was a pathway found to connect directly to a crop field. Resources such as water, and access to rivers, relevant to elephant persistence in the matrix, must be considered by land-use planning initiatives, especially as many of the observed waterholes dried up mid wet season - by the end of April, all but one of the waterholes were devoid of water.

What is the group size of elephants using these pathways?
Average group size for females was seven, while for bulls, group size increased from 1.5 bulls in March to 2.5 bulls in April. The largest bull group constituted seven individuals.

Does sexual segregation occur in the utilisation of these pathways?
Females only used pathways in the northern section of KC as these lay further away from settlements, and crossed no agricultural fields. Bulls made use of all recorded pathways.

Are elephant pathways significant spatial factors influencing the intensity and frequency of HEC and specifically crop-raiding incidents?
Spatial correlates of crop-raiding were investigated for 100 randomly selected fields. Spatial correlates for raiding included field distance to nearest pathways, nearest road, nearest settlement, nearest protected area and to the Kwandu River. Environmental variables such as rainfall and elevation were also tested. Only pathways proved to be significant spatial variables in crop-raiding location. It has to be noted that only one quarter of all reported incidents constituted actual raids, with elephants utilising pathways (and hence the fields they traverse) in order to access the Kwandu River and BNP beyond. Crop attractiveness may therefore be enhanced by water availability.

Is crop-raiding in KC initiated by bulls only?
Bulls were responsible for 100% of all crop raiding incidents in KC.

5.2 Conservation applications

1. Collared bulls displayed characteristics consistent with the concept of metapopulation theory, ranging widely across countries and various land use and habitat types. This is encouraging for species persistence as genetic flow between sub-populations from different countries, and refuges, can be maintained.

2. Independent ground surveys during this study revealed that human-elephant conflict (HEC) was not as grievous as previously assumed from community data. Only 24% of all HEC incidents recorded constituted actual raids. Possible financial benefits from local compensation schemes, or individual projects, may contribute to exaggerated claims by community members. Conflict with people on protected area borders, not population size, was found to be the most salient factor driving extinction in wide-ranging species (Woodroffe & Ginsberg, 1999). Conflict may lead to an increase in elephant populations in protected areas. For example in Uganda's Murchison Falls National Park, a relatively sudden and permanent increase in the elephant population was caused by increased intensity of local land use in surrounding areas (Rodgers & Elder, 1977). As management and mitigation of this conflict is a significant factor in elephant conservation and related policy issues (Dublin & Hoare, 2004), independent scientific ground-surveys specific to each HEC locale should be encouraged.

3. Although communal land was the least preferred land use type, increased fixes from satellite data in this study indicated that collared elephants penetrated the anthropogenic matrix, including the most heavily populated Conservancy in Namibia (KC). This is especially relevant as previous research seems to suggest that elephants avoid KC (Chase, 2007), although this is not the case. Researchers are therefore encouraged to increase the number of satellite fixes, in order to obtain a more complete picture of elephant movements within a 24 hour cycle. Satellite data alone is also an insufficient method in determining elephant absence/presence in or near agricultural locales: localised, scientific ground surveys showed that elephants crossed KC on numerous occasions in just one month (Chapter 4).

4. Land use planning initiatives are required that address elephant movement types across a range of land uses.
   a. At local and regional scale, pathways connecting habitat and resource patches should be identified as *the* linear landscape element underpinning land use planning around HEC (e.g. the pathways identified in KC).
   b. At a landscape scale, pathways connecting two protected areas (e.g N-S pathway that elephants use seasonally, and which connects the Caprivi State Forest with Mudumu NP in Namibia) should form the basis of metapopulation management in the area.

5. This study has demonstrated that repetitive movements of elephants along pathways may contribute significantly to HEC. Conflict may be exacerbated by

competition between elephants and people for water. The relationship between spatial features, such as protected areas, settlements, rivers and elephant pathways, if integrated into community land use planning initiatives, could lead to significant conservation successes. The prime factor governing elephant numbers across a variety of land use types was effective wildlife management (Stokes *et al*., 2010), rather than land use type.

6. Elephant movement through agricultural fields, and their impact on HEC require closer analysis. Although not the focus of this work, movement patterns gleaned from elephant spoor suggested that actual crop raids may be confirmed through the analysis of movement types. If elephant movement is directional, the incident cannot be qualified as a raid as the elephant is using a goal-directed approach to a resource, and may just be passing through. If elephant movement is sinuous, within a field with a high number of turning angles indicating searching behaviour, the incident can be recorded as a raid. This however, requires further evaluation at a number of HEC sites.

7. Research has shown that elephants require access to heterogeneous landscapes in order to access optimal forage across seasons and years (Murwira & Skidmore, 2005; Wittemyer *et al.*, 2008). Yet within KAZA TFCA, little is known about how much rangeland remains available to elephants outside of protected areas. The study has put forward possible core zones beyond protected area boundaries that may be worth managing as elephant sanctuaries once elephant presence has been established. Potential zonation plans need to consider clear separation and management of elephant refuges and corridors, and agricultural zones, including buffer zones to mitigate against edge effects (Woodroffe & Ginsberg, 1999).

8. For the metapopulation metaphor to hold, Samways (2007a) recommends the metapopulation trio of 1) large patch size, 2) good patch quality 3) and low patch isolation. Some protected areas in KAZA TFCA will inevitably be excluded from this management approach as their spatial positioning within the matrix may preclude effective dispersal due to excessive disturbance (settlement densities, illicit poaching etc). However, isolated subpopulations may not be doomed to extinction if their habitat can be protected from humans (Simberloff *et al*., 1992).

'The KAZA TFCA promises to be southern Africa's premier tourist destination with the largest contiguous population of the African elephant in the continent. The key objective of the proposed KAZA TFCA is to join fragmented wildlife habitats into an interconnected mosaic of protected areas and transboundary wildlife corridors, which will facilitate and enhance the free movement of animals across international boundaries.'

Peace Parks Foundation

Conclusion

Hailed as the most ambitious of Africa's Peace Parks (Fox, 2009), the Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA) has vast potential to succeed as a megapark, and to attain its goal in encouraging elephant dispersal from source habitats. The importance and urgency of the KAZA TFCA to succeed is emphasised by the current situation in Asia, where Asian elephant decline is linked to habitat fragmentation, expanding human populations and growing resource demands (Sukumar, 1989; 1990). Once a continuous population, Asian elephants are now highly fragmented into isolated habitat fragments in 13 countries (Leimgruber *et al.*, 2003). The possibility of successful emigration and immigration within KAZA TFCA is demonstrated by the recolonisation of the Kruger National Park in South Africa, where elephants from Mozambique repopulated the Park over a 70 year period. Dispersal may adjust elephant populations to the changing carrying capacity of their habitats (Owen-Smith, 1988) and opportunities for movement must therefore be created. Dispersal and movement of individual elephants will however be affected by the quality of the surrounding matrix, as well as the spatial arrangement of habitat fragments beyond protected areas (Cumming, 2010). The quality of the surrounding matrix is determined by effective land-use planning, which in turn is governed by socio-political agendas.

Metapopulation theory underpins the management goal for the KAZA TFCA's network of protected areas. Such ecological networks may be a sustainable mitigation measure against habitat isolation, provided that network design and management is optimised, and the spatial arrangement of landscape elements considered. Natural ecosystems (such as protected areas) have been set aside for this purpose, but it is in the surrounding matrix that the truth of KAZA TFCA's effectiveness will be told: landscape elements such as nodes (waterholes/pans) and stepping stones (remnant forest pockets/forest reserves) in the surrounding matrix need to be identified and of high enough quality to encourage elephant movement among patches. This will be especially relevant for herds of risk-averse females and their offspring. These nodes and stepping stones remain to be identified.

The KAZA TFCA consequently cannot be seen as an African panacea of elephant conservation - without adequate design and management, political commitment and the accord of the rural populace, protected areas and habitat fragments within its boundaries continue to be susceptible to habitat degradation. For example, in Asia, only 16% of unfragmented wildland is protected, according to the IUCN (Leimgruber *et al*., 2003). They warn against protected areas that are 'paper parks', affording elephants little protection in reality. Craigie *et al.* (2010) record a worrying decline in protected area performance in Africa, while the social complexities of establishing the KAZA TFCA are well recorded by Hanks (2003) and Metcalfe & Kepe (2008). Obstructions to long-term successful establishment of the KAZA TFCA include rapid rural population growth, said to be doubling every 30 years (Hanks, 2003), rampant poverty (Mendelsohn & Roberts, 1997; Hanks, 1979), socio-political mismanagement and the unchecked expansion of settlements along the only permanent water sources: the Kavango, Kwandu, Chobe and Zambezi Rivers. These, coupled with land clearing and burning for subsistence farming in the dry season, subsistence hunting, illegal logging and the removal of so called 'problem-elephants' constitute the socio-political issues that will have to be addressed. A high demand and price for ivory in China, the consequent illegal ivory trade increasing in Angola (CITES, 2007) and political instability in Zimbabwe may further hinder effective transboundary elephant management planning. Biodiversity loss has been linked to political corruption and bad governance (Smith *et al*., 2003) – Zambia in particular has been named a major source and conduit of illegal ivory, and efforts are underway to prevent down-listing of the CITES elephant conservation status (Wasser *et al.*, 2010), which would prevent opening a legal market for ivory.

Research has shown that elephants are able to gauge levels of risks (Graham, 2006), and avoid areas of illicit hunting. This study, and other research, has indicated that elephants can co-occur with humans in agricultural areas where elephants are effectively protected by law. As such, research, and international donor funding for the KAZA TFCA should initially encourage elephant projects, and CBNRM initiatives, in countries like Namibia and Botswana that have capable wildlife departments in place.

Recommendations

Access to water: Restricted access to rivers due to riparian settlements will magnify the impacts of global warming, so that the spatial configuration of, and access to, nodes such as waterholes in KAZA TFCA (e.g. Nabulongwe Pan) in relation to protected areas and habitat fragments will become increasingly significant in future. Waterholes and pans currently used by elephants that carry water as of April/May need to be mapped, and position within the matrix with distances to nearest protected area, stepping stone and settlement area assessed. Access zones to riparian areas will have to be managed in order to avoid localised increases in elephant densities during the dry season (Smit & Ferreira, 2010), and the cascading effect on other aspects of biodiversity (Samways & Grant, 2008).

Stepping stones: Forest pockets of the west Zambezi for example are managed as forest reserves, yet are disturbed by logging, harvesting and hunting. Some of these forests should be considered for management as elephant sanctuaries, as they provide much needed dry season access to sections of the Zambezi River that are as of yet unoccupied by humans.

Compression effects of human disturbance: These are yet to be recorded. Locally abundant, and seemingly healthy elephant populations such as those in Chobe, Mudumu NP and BNP area may need to be closely monitored as they could serve as a warning of increased disturbance outside protected area boundaries. For example, little or no current data exist on elephant saturation levels for protected areas such as LPR (Angola), SNNP (Zambia), and Mudumu NP, BNP and Mamili NPs in Namibia, which have been shown to be important dry season refuges for elephants moving between Angola, Zambia and Botswana (van Aarde, 2007). According to O'Connell-Rodwell *et al*. (2000), reserves in Caprivi are inadequate for sustaining increasing numbers of elephants. Long-term data would allow managers to measure levels of disturbance, especially fire, beyond park boundaries, so as to preclude biodiversity loss through high elephant numbers within protected areas.

Fire and CBNRM: From a rural perspective, it is worth noting that local communities in Conservancies such as those in Namibia depend heavily on the sustainable use of wildlife (notably elephants) from ecotourism and trophy hunting, which may often constitute their only source of income. This income too may be compromised if connectivity between protected areas decreases through anthropogenic disturbance with bull movements becoming disrupted in dispersal sinks such as Conservancies and MRAs. Human-modified disturbance regimes, such as fire, contributes to fragmentation: local sports hunting operations in 2008 were affected by fire, as elephants in MRAs were only noted by hunters by their absence. CBNRM initiatives are encouraged to address management surrounding dry season burning.

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