

https://dspace.org/

Factors governing selective impacts of elephant on woody vegetation

Chafota, Jonas

2009-02-02T10:03:44Z
http://hdl.handle.net/10539/5990

Downloaded from a DSpace repository. https://dspace.org/

FACTORS GOVERNING SELECTIVE IMPACTS OF ELEPHANT ON WOODY VEGETATION

Jonas Chafota

A thesis submitted to the Faculty of Science,
University of the Witwatersrand, Johannesburg,
in fulfilment of the requirements of the degree
of Doctor of Philosophy

Johannesburg, 2007

DECLARATION

I declare that this thesis is my own, unaided work. It is being submitted for the Degree of Doctor of Philosophy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

_____

_____ day of _____ 2007

This thesis is dedicated to my mother for her support and encouragement from the day I went to school

ABSTRACT

This study investigated factors governing selective impacts of elephants on different tree species, size classes, and plant parts in different areas at different times of the year in the elephant range of northern Botswana. Differential impacts on woody vegetation by different age/sex classes of elephant were considered. Also, environmental factors fortuitously identified to have direct influence on habitat resources, spatial distribution of elephant and the manner in which they interacted with woody vegetation were studied. These environmental factors included frost, fire and drought.

Plant-based and animal-based data collection methods were used. The plant-based observation method involved an assessment of woody species impacts by sampling on foot, areas indicated by fresh tracks of actively feeding elephants. The animal-based observation method involved focal animal sampling whereby the feeding activities of the closest readily visible and actively feeding elephant were recorded. Due to safety problems and impassable terrain, much of the data for this study was collected from the plant-based method.

Elephant favoured the intermediate height categories, but were not narrowly selective for plant height class within these categories. In fact, they generally subsisted on commonly available shrub species and were quite narrowly selective for a few woody plant species, with only fairly minor seasonal changes in the diet of woody species included in the diet during the cool-dry and wet seasons. The favoured shrub species included *Baphia massaisensis, Bauhinia petersiana, Grewia monticola* and *Diplorhyncus condylocarpon*.

No clear distinction could be made with respect to differences in impacts between cow and bull herds on the commonly utilized shrub species. However, bulls appeared to have greater impact than cows with respect to severe impacts such as snapping of trunks, digging and uprooting plants.

The major factors found to influence elephant impacts on woody vegetation were season and height class. Thus, the impacts tended to be species and size class specific and varied seasonally. Also, availability of alternative food types in a feeding patch appeared to influence acceptability of woody species by elephant during the hot-dry

season when the diet of elephant was widened to include more woody species. This study found no evidence of a relationship between acceptance and availability of woody species.

Elephant impacts on woody vegetation were considered to be severe if feeding events involved snapping of tree trunks, debarking, uprooting or pushing over. Severe elephant impacts on canopy trees appeared to be caused by a 'restriction' in the shrub layer food. The findings of this study, although not replicated suggested a linkage of severe elephant impacts on canopy trees to episodic or occurrence of drought, frost and fire events. As elephant normally subsist on the shrub layer, severe impacts on canopy trees may be induced by non availability of this food base as a result of localised over utilization in drought years and impacts of fire and frost.

The study confirmed finding of other studies that elephant showed a relative dependence on leaves and shoots; stems and bark for a given season. However, important factors highlighted by the study are that in any given season, one or two woody species dominated by being included either jointly or alternately in elephant diet. Furthermore, an interesting observation on elephant feeding habits was that for some species, they discarded leaves in the process of consuming stems.

The study indicated that the long term consequence of elephant-vegetation interaction in northern Botswana is unclear but some management and research options were suggested. These aspects could be integrated into a long term modelling framework to assist in monitoring and decision making. A useful and interactive modelling approach could be a long term rule based qualitative model development which can continually be updated to incorporate new experience and knowledge.

ACKNOWLEDGMENTS

I would like to thank and acknowledge the support and assistance received from the following individuals and organizations during the course of the study and preparation of the thesis:

First and foremost, my supervisor, Professor Norman Owen-Smith for giving me the opportunity to study under him and for his encouragement, guidance and assistance with securing financial support. A few words from him kept me going: 'I want a good thesis' and 'Do not let it slide'.

The University of the Witwatersrand, the WWF Prince Bernhard Scholarship for Nature Conservation and the Foundation for Research and Development (FRD) for financial support. Without these sources of financial help, this study could not have been carried out.

The Department of National Parks and Wildlife Management, Zimbabwe for granting me paid study leave to carry out the study.

Maggie Taylor and all the library staff, Department of National Parks and Wildlife Management, Zimbabwe, for providing me with literature and reference materials during the initial preparation of the research proposal.

The Department of Wildlife and National Parks, Botswana, for allowing to carry out the study in the elephant range of northern Botswana as well as for giving me a 'home' by the Chobe river, at the main Kasane entrance gate to Chobe National Park. Despite the danger of crocodiles, the nuisance of baboons and monkeys I enjoyed watching the resident wildlife, including elephant and buffalo which frequented the Sidudu Island.

Heather Carr-Hartley of Kasane Enterprises and her helpful staff for logistical

arrangements including facilitating the process of obtaining a study permit. Thanks to Heather for allowing me to open a fuel account which I hope is still open, she made life possible during difficult times.

The management of Chobe Safari Lodge, particularly Louis Mynhardt for giving me an office in the Lodge at no cost. I enjoyed watching wildlife videos in the Lodge.

The management of Hunters Africa (PTY) Ltd, particularly Donald Grobler, for allowing me free use of their Kingspool Camp facilities in the Linyanti front. Tsetse flies were a nuisance, forcing me wear to overalls, and hence making the heat unbearable when I was collecting data.

Kay Moss, Department of Zoology, for managing my research funds and timely disbursements when I was in the field.

Herman Du Preez, for his assistance when I was preparing for my field trip from Johannesburg. Thanks to you Herman for assisting me with shopping for my field supplies as well as stocking my trunk with assorted food.

Jean Chafota, who later played a dual role of being a wife and field assistant. Thanks to you for your hard work and vigilance.

'Boiler' Dingalo, my Bushmen guide and first field assistant. The time we spent together was short, but we had fun moments. Despite being short in stature, I was amazed at how quickly he could locate elephant and how easily he could navigate his way back and forth through the bush in featureless terrain.

WWF-SARPO, particularly Dr. Dave Cumming and Ed Wilson for giving me the time to work on my thesis as well as using the office facilities. Dr. Cumming in particular, kept on the pressure by constantly asking when I was going to submit the thesis. Each

time the question was asked, the date of submission kept on shifting. The demands of office work made the task of thesis writing slow and stressful.

Meg Cumming for her encouragement and especially the constant reminders urging me to complete the write up of my thesis.

Kudakwashe Muhwandagara, of WWF-SARPO GIS Section for assistance with the production of study area maps.

All the individuals, friends and colleagues, who encouraged or assisted me during the field work days and preparation of the thesis, their contribution motivated my work.

Lastly I would like to thank Jaqueline Farley, for raising Takaidza and Makeda under difficult conditions during my academic pursuits.

CONTENTS

Declaration ii
Abstract iv
Acknowledgments vi
List of figures x
List of tables xiii
List of appendix tables xiv
Abbreviations xv
Introduction 1
Selective utilization of woody plant species and height classes by elephants ….....7
Composition and seasonal variation of woody plant diet of elephant 48
Seasonal variation of elephant impacts on woody vegetation 66
Conditions associated with severe impacts by elephants on canopy trees 95
A simple rule-based foraging model of elephant impacts on woody vegetation.....112
Conclusions 123
Literature cited.....129
Appendix 1 139

LIST OF FIGURES

Figure 2.1 Map of northeastern Botswana, showing study area and landuse boundaries.....12

Figure 2.2 Distribution of sampling sites for elephant feeding records during the wet, cool-dry and hot-dry seasons in the sandveld of northern Botswana……22

Figure 2.3 Mean seasonal height class site acceptances for all of woody species in the sandveld woodland of northern Botswana ……28

Figure 2.4 Seasonal woody species height class acceptances by bull and cow groups of elephant in the sandveld woodland of northern Botswana during (a) the wet season (b) cool-dry season and (c) hot-dry season ……..…….29

Figure 3.1 Relative woody species dietary importance to elephant during (a) wet season (b) cool-dry season and (c) hot-dry season in northern Botswana ……..……55

Figure 3.2 Seasonal variation of importance of woody species height class to elephant diet in Chobe National Park, northern Botswana during (a) wet season (b) cool-dry season and (c) hot dry season ……58

Figure 3.3 Overall woody species importance by height class to elephant diet in Chobe National Park, northern Botswana ……..…59

Figure 3.4 Dietary importance of plant parts by height class to elephant during (a) wet season (b) cool-dry season and (c) hot dry season in northern Botswana ..60

Figure 4.1 Impact types and frequencies on commonly utilized and other woody species by elephant during (a) wet season (b) cool-dry season and (c) hot-dry season in northern Botswana ……..……..…….73

Figure 4.2 Mean impact types and frequencies on the different height classes of woody species utilized by elephant during (a) wet (b) cool-dry and hot-dry-seasons in northern Botswana ……..……..75

Figure 4.3 Woody species and size classes suffering digging and uprooting by elephant during the hot-dry season in northern Botswana ……...……77

Figure 4.4 Wet season snapping of stems and leaf stripping elephant impacts for commonly utilised woody species in northern Botswana ……78

Figure 4.5a Cool-dry season snapping of stems elephant impact for commonly utilised woody species in northern Botswana ……79

Figure 4.5b Cool-dry season stripping of leaves elephant impact for commonly utilised woody species in northern Botswana ……..80

Figure 4.6 Hot-dry season snapping of stems elephant impact for commonly utilised woody species in northern Botswana ……..……..……81

Figure 5.1 Map of northern Botswana showing sites where severe fire and frost induced elephant impacts on canopy trees were recorded in Kazuma Forest Reserve (1992) and Kasane Forest Extension (1994) ……98

Figure 5.2 Map of northern Botswana showing the Linyanti river front area where severe elephant impacts on canopy trees were recorded during the cool-dry and hot-dry seasons of 1993 ……..……...…….99

Figure 5.3 Annual and mean rainfall recorded at (a) Maun and (b) Savuti for the period 1982-1994 ……102

Figure 5.4 Severe elephant impact involving tree felling for *Burkea Africana* on burned and unburned areas in the Kasane Forest Extension, northern Botswana (1992) ……..…105

Figure 5.5 Severe elephant impacts involving tree felling on the different diameter size classes of *Burkea africana* and *Terminalia sericea* in Kazuma Forest Reserve northern Botswana in 1994 ……106

Figure 5.6 Severe elephant impacts involving felling and debarking on the ifferent diameter size classes of *Colophospermum mopane* canopy trees in 1993 on the Linyanti river front, northern Botswana ……..107

Figure 5.7 Severe elephant impact involving debarking on the different diameter size classes of *Acacia erioloba*, *Acacia nigrescens* and *Terminalia prunioides* in the riparian woodland of the Linyanti river front, northern Botswana in 1993 ……...108

LIST OF TABLES

Table 2.1 Seasonal and habitat distribution of sampled sites for plant-based and animal-based observation methods …….. 20

Table 2.2 Availability and acceptance frequencies of woody species encountered by elephant in the sandveld woodland of northern Botswana ..……...25

Table 2.3 Availability and acceptance frequencies of woody species encountered by elephant in the Chobe riverine habitat of northern Botswana ..…27

Table 3.1 Seasonal importance of woody plant parts to elephants diet …..…..57

Table 4.1 Significant effects of the influence of season, plant species and height class and the interaction of these factors on elephant impacts on different woody species ……..71

Table 4.2 Digging and uprooting elephant impact and availability frequencies for some uncommon and rare woody species in the sandveld woodland of Chobe National; Park northern Botswana ……..…76

Table 6.1 Decision table of the rule-based foraging model …….……121

LIST OF APPENDIX TABLES

Appendix Table 2.1 Availability and acceptance frequencies of all woody species encountered by elephant in the sandveld woodland of northern Botswana recorded over three seasons using the plan-based method ……..……....33

Appendix Table 2.2 Availability and acceptance frequencies of woody species encountered by elephant in the Chobe riverine habitat of northern Botswana ……..38

Appendix Table 2.3a Acceptance by height class of woody species encountered by elephant in the sandveld woodland during the wet season in Chobe National Park, northern Botswana ……..……39

Appendix Table 2.3b Acceptance by height class of woody species encountered by elephant during in the sandveld woodland during the cool-dry season in Chobe National Park, northern Botswana ……..42

Appendix Table 2.3c Acceptance by height class of woody species encountered by elephant in the sandveld woodland during the hot-dry season in Chobe National Park, northern Botswana .....……45

AppendixTable 3.1 Seasonal woody plant species and plant part dietary importance to elephant in northern Botswana ……..63

Appendix Table 3.2 Dietary importance of different plant species by height classes to elephant in northern Botswana ……..……65

Appendix Table 4.1 Seasonal elephant impact frequencies (with 95% confidence intervals) for the commonly utilized woody species in northern Botswana ……..…….…….88

Appendix Table 4.2 Seasonal elephant impact frequencies by height class for the commonly utilized woody species in the sandveld of Chobe National Park, northern Botswana ……..…….…….90

Appendix Table 5.1 Diameter size class, availability and impact frequencies by elephant on the severe impact sites in northern Botswana..111

ABBREVIATIONS

%	percent
α	significance level
β	regression coefficient
df	degree of freedom
ANOVA	analysis of variance
F	function of
F	ratio of independent variables in the analysis of variance
m	metre
n	sample size
P	probability level
t	Student's t-value.
χ^2	chi-square

CHAPTER 1

INTRODUCTION

Despite many years of research by many scientists, the dynamic impact of elephant on the environment is poorly understood. Defining management policies to deal with the problem of elephant overabundance in conservation areas has been made difficult due to lack of scientific facts (Laws, 1970; Parker, 1983). Past attempts to manage elephant populations and their adverse impacts on vegetation have been targeted at keeping elephant populations at predetermined local densities in some conservation areas (Laws and Parker, 1968; Hanks, 1971; Hall- Martin, 1984; Cumming, 1981, 1983). Culling was in many ways used as a low risk strategy whereby elephant populations were held at artificially low levels while attempts were being made to understand the system dynamics of conservation areas.

Owen-Smith (1988) outlined the possible dimensions of the elephant problem as follows (a) radical modification of certain habitat types leading to perhaps the loss of species which depend upon them (b) elimination of certain sensitive plant species (c) reduced vegetation cover leading to accelerated erosion and decline in the overall productivity of the ecosystem (d) depression of the resource base for megaherbivores themselves and (e) loss of aesthetic features of landscape, such as mature trees.

Other potential management options to deal with the elephant problem included non-interference, elephant cropping adjacent to parks, augmenting water supplies to redistribute elephant away from localities of concern, and creation of dispersal sinks (Work and Owen-Smith, 1986; Owen-Smith, 1974, 1981). The adoption of one or more management options must be based on scientific facts and should be monitored to ensure that the objectives are met. As Bell (1983) put it, the role of research in decision-making is to identify the class of technically sound options, and to provide information on how to achieve the chosen option.

Botswana has the largest concentration of elephants in southern Africa, with the

elephant population estimated to be over 80 000 at the time of my study, and increasing at an annual rate of about 5 to 6% (Clef, 1991a; Craig, 1996; Gibson et al., 1998). Most of this elephant population is concentrated in the elephant range of northern Botswana (Said et al., 1995). The wet season elephant range in northern Botswana is about 100 000 km^2, but this shrinks to about 10 000 - 12 000 km^2 as seasonal pans dry up and elephant converge on the permanent water sources. The impact that this elephant population has exerted in certain localities such as the dry season concentration areas has been a source of concern. Management options including culling have continued to be considered (Hancock, 1990), but the spatial and temporal variability in the elephant impacts has made it difficult to establish justification for such intervention (Skarpe et al. 2004)

Heavy elephant impact on woody vegetation was first noticed in the dry season concentration areas such as the Linyanti/Kwando and the Chobe river fronts where elephant densities were reported to be seasonally as high as 7 km^{-2} to 12 km^{-2} (Craig, 1990; Calef, 1991a, b; Gibson et al., 1998). As a result, emphasis on specific research on the elephant vegetation interaction was focussed in the dry season concentration areas by different researchers including Sommerlatte (1976), Simpson (1978), Moroka (1984), Coulson (1992) and Wackernagel (1993). The major finding of these research activities was that elephant impacts were threatening the survival of sensitive riverine tree species such as *Acacia nigrescens, Acacia erioloba, Acacia tortilis* and *Berchemia discolor*.

At the centre of the elephant overpopulation dilemma in northern Botswana was the need for ecological justification for undertaking a specific management intervention to redress the perceived adverse habitat changes induced by elephant. There were gaps in knowledge pertaining to the consequence of elephant impacts on woody vegetation, on other mammal species and on the elephant population itself. Nevertheless, the elephant population as indicated above has continued to show a high rate of increase despite habitat changes that appeared to have been occurring.

At the time when my study commenced, very few studies have been carried out in Botswana to determine the ecological effect of elephant on other species or on the environment. However, recent studies by Skarpe et al. 2004 suggested that while elephant selectively destroyed mature trees, the density and species composition of tree regeneration could be determined by fire, and/or predation of seeds or seedlings by insects, rodents, large browsing mammals and fungal attack. The study also found no evidence of a decrease in palatable woody species in the heavily elephant impacted areas or reduction in the numbers of large herbivores including grazers, browsers and mixed feeders as a result of increasing elephant population. But Addy (1993) confirmed that the bushbuck inhabiting the riverine woodland of the Chobe river had declined in areas most severely impacted by elephant. However, bushbuck was not likely to go extinct since adequate cover remained in the form of woody species not favoured by elephant. Whether vegetation changes are detrimental to elephant or other species has yet to be fully proved scientifically as this is likely to depend more on the spatial and temporal pattern of vegetation damage, than on the severity of damage to individual trees at any one place.

There has been a lack of scientifically defined conservation objectives and the limits of acceptable vegetation changes induced by elephant have not been specified. Such limits would define the range of optimum densities for the various environmental components in relation to defined management objectives beyond which action must be taken to return the system to within the permissible range (Bell, 1983). In 1991 the Government of Botswana, through the Department of Wildlife and National Parks (DNPW), came up with a policy on elephant that suggested maintaining the elephant population at the 1990 level of around 55 000 (DNPW, 1991). In practice, no management interventions for the expanding elephant population have been adopted since the ban on elephant hunting in 1983.

The perceived vegetation changes in conservation areas may not necessarily be due to elephant impacts. For instance, Viljoen (1988) reported that vegetation changes perceived as detrimental were not prevented by keeping elephant at relatively low

levels in Kruger National Park. Other factors which may interact with elephant in relation to vegetation changes need to be taken into account. As noted by Walker (1989), the northern Botswana ecosystem is driven by external and episodic events linked to the availability of surface water, drought, fire and disease. Accordingly, these episodic external events may have overriding effects on the ecological systems and hence understanding and responding to these events may assist in the achievement of conservation goals.

The need for drinking water has been known to concentrate elephant in defined localities such as the northern Botswana river frontage (Child, 1968; Sommerlatte, 1976). Frost and fire were found to kill the above ground regrowth of woody vegetation (Rushworth, 1975). The browsing pressure of other herbivores such as giraffe and impala were reported to restrict recruitment potential of woody vegetation (Pellew, 1983; Prins and van der Jeugd, 1993).

Studies of the elephant-vegetation interaction elsewhere in southern Africa, particularly in the Sengwa Wildlife Area, Zimbabwe (Anderson and Walker, 1974), Guy (1976) and Kasungu National Park, Malawi (Jachmann and Bell, 1985), focussed in broad terms on determining the species favoured by elephant. The studies did not provide specific details of impacts suffered by individual species, and the likely consequence of such impacts to woody species dynamics. Details of the likely environmental factors or conditions under which certain plant species may suffer specific impacts were not provided.

The objectives of the present study were centred on determining the factors governing selective impacts of elephant on woody vegetation in northern Botswana. The full range of factors considered in the study therefore included plant species, size classes, plant parts, spatial regions, seasons, age/sex classes of elephant as well as environmental factors which had direct influence on the habitat resources which therefore affected the spatial distribution of elephant and the manner in which they interacted with woody vegetation.

The primary objectives were therefore broadly defined as:

(1) To establish factors governing differential impacts of elephants on different tree species, size classes, spatial regions and times of the year.

(2) To determine the differential impacts of the different age/sex classes of elephant on woody vegetation.

(3) To develop a rule-based model to predict elephant impacts on woody vegetation under different conditions.

The chapters of this thesis are organized in a logical sequence designed to address issues related to the objectives. Chapter 2 considers the factors which influenced the selective utilization of woody species by elephant in the absence of the identified adverse environment factors such as frost, fire and droughts. Chapters 3 and 4 are related to Chapter 2 as follows: Chapter 3 takes into consideration the seasonal contribution of different plant species, size classes and plant parts to the diet of elephant. Chapter 4 focuses on determining the seasonal variation of elephant impacts on woody plant species and size classes. Chapter 5 describes the elephant-induced impact types suffered by canopy trees under specific environmental conditions fortuitously identified during the study period.

Chapter 6 pools together the study results detailed in chapters 2 to 5 in a modelling framework. Thus, this chapter presents a simple prototype rule-based foraging model to predict elephant impacts on woody vegetation under different conditions in space and time.

Chapter 7 presents the overall conclusions and synthesis of the whole study, and the direction of future elephant related research. The possible management options available to the Botswana Government in view of the expanding elephant populations are also critically reviewed in this concluding chapter.

The chapters of this thesis are organized in self-contained chapters to facilitate publications of the research findings as each chapter may be published independently.

This form of presentation has however resulted in some unavoidable duplication in the introduction and method sections of some chapters.

CHAPTER 2

SELECTIVE UTILIZATION OF WOODY PLANT SPECIES AND HEIGHT CLASSES BY ELEPHANTS

2.1 Introduction

The African elephant (*Loxodonta africana,* Blumenbach 1797) exerts a major impact on woody vegetation by selectively felling, debarking, snapping stems, breaking leader shoots, or otherwise damaging trees and shrubs (Owen-Smith, 1988). '*Selective utilization*' as used here refers to the relative acceptance of different woody species and size classes by elephant in order to consume specific plant parts such as leaves, bark, roots, stems and twigs to satisfy dietary requirements. The term '*acceptance*' reflects the likelihood of an animal commencing feeding on a species when that species is available nearby (Owen-Smith and Cooper, 1987, 1989).

Selective herbivory influences competitive interactions among plant species and growth forms, leading to changes in community composition and physiognomy (Owen-Smith and Danckwerts, 1997). As a result, herbivory may shape plant morphology, growth patterns and resource allocation in interacting with other environmental factors. Hence, a full knowledge of factors influencing selective utilization of woody plant species by elephant is fundamental to the management of both elephant and their habitats.

Previous studies on elephant feeding habits (Bax and Sheldrick, 1963; Field, 1971; Field and Ross, 1976; Barnes, R.F.W., 1980; Jachmann and Bell, 1985) showed that (a) elephant altered their diet in relation to season, i.e some plants were favoured while others were neglected, and some assumed importance at certain times of the year and (b) woody species were utilized for different plant parts e.g. bark, leaves, or twigs during different times of the year.

Tree species found to be almost invariably favoured by elephant included *Acacia spp*. (Child, 1968; Croze, 1974b; Sommerlatte, 1976; Leuthold, 1977; Mwalyosi, 1990), *Adansonia digitata* (Barnes, R.F.W., 1979, 1980, 1982), *Commiphora spp*.(Leuthold,

1977; Barnes, R.F.W.,1982) and *Brachystegia boehmii* (Anderson and Walker, 1974; Thompson, 1975; Guy, 1981). Tree species neglected by elephant included *Combretum mossambicense, Crossopteryx febrifuga, Diospyros senensis, Baikiaea plurijuga and Erythrophleum africanum* (Child, 1968; Sommerlatte, 1976; Guy, 1981; Moroka, 1984).

Elephants were reported to utilize woody species in proportion to their relative abundance (Croze, 1974b; Anderson and Walker, 1974; Barnes, R.F.W., 1983; Jachmann and Bell, 1985). Elephants were observed to prefer small size classes of woody plants (Wing and Buss, 1970; Laws et al., 1975; Caughley, 1976; Barnes, R.F.W., 1979, 1980), and large trees were selected only when preferred small size classes were not available (Laws et al., 1975).

The preferred feeding level of elephant appeared to be between 1 and 2 m (Guy, 1976; Caughley, 1976; Jachmann and Bell, 1985). Individual plants < 1 m of favoured woody species were reported to be infrequently utilized by elephant (Croze, 1974b; Caughley, 1976; Leuthold, 1977; Pellew, 1983; Mwalyosi, 1990). However, Dublin et. al. (1990) reported that elephant alone appeared to prevent woodland regeneration in the Serengeti-Mara by feeding on small seedlings because there were fewer trees in larger height classes. Impact of elephant on saplings was also observed for *Acacia tortilis* in Lake Manyara National Park, Tanzania (Mwalyosi, 1987) but sufficient saplings survived and reached maturity.

Bull elephants were reported to have a higher impact on vegetation than females with respect to debarking and tree felling (Croze, 1974b; Guy, 1976; Barnes, 1980, 1982). Guy (1976) found that bulls were responsible for 80% of all the trees observed pushed over and uprooted as compared to 20% by females. Recent studies by Stokke (1999) and Stokke and du Toit (2000) within Chobe National Park found no evidence of feeding height stratification between family units and male groups. However, the authors confirmed that the preferred feeding level was about 2 m. Adult males were found to have the least diverse diet in terms of woody plant species included in the diet

but consumed more plant parts than family units. This was reflected in feeding site selection whereby family units selected patches with a higher diversity of plant species than males. In Ruaha National Park, Tanzania, Barnes (1982) reported that bulls and cows generally utilized a similar diet in terms of plant parts except during the dry season when cows tended to eat a diet containing significantly more woody browse than leafy browse.

The present study was carried out in Chobe National Park, Northern Botswana, and was concerned with quantifying selective utilization of different woody species and size classes by elephant over the annual cycle. Early studies on elephant-vegetation interaction in Chobe National Park by Child (1968), Simpson (1975), Sommerlatte (1976), Moroka (1984), Coulson (1992) and Wackernagel (1993) focussed mostly on the riverine woodlands of the Chobe and Linyanti rivers and provided limited details of seasonal and differential woody species and size class selection in the rest of the park. Commonly utilized woody species in the riverine woodlands were observed to be *Acacia spp., Berchemia discolor, Terminalia prunioides* and *Peltophorum africanum.* Within the sandveld woodland, heavily utilized woody species were mostly shrubs, i.e. *Diplorhynchus condylocarpon, Combretum collinum, Baphia massaiensis, Bauhinia petersiana* and *Terminalia sericea*. All size classes of *Colophospermum mopane* and *Burkea africana* were reported to be utilized by elephant in the Kalahari sandveld woodland.

The objective of the study was to determine which factors influenced the selective utilization of woody species by elephant during the seasonal cycle. The specific questions addressed by this study were:

(i) Which species were consistently favoured?
(ii) Which species were consistently neglected or rejected?
(iii) Which species were favoured seasonally?
(iv) Did availability influence acceptability?
(v) Did size influence acceptability?
(vi) Did acceptability differ among habitats?

(vii) Did acceptability differ between male and female elephants?

(viii) How did plant parts influence acceptability?

The specific hypotheses to be tested were as follows:

2.1.1 H_0: Selection is unrelated to availability.

The basis for testing this hypothesis stems from the fact that earlier studies on elephant-vegetation interaction elsewhere (see Croze, 1974b; Guy, 1976; Barnes, R.F.W., 1983; Jachmann and Bell, 1985; Stokke, 1999) indicated that woody species appeared to be utilized in quantities proportional to their abundance.

2.1.2 H_0: Acceptance frequencies are independent of the availability of other species

This hypothesis was applied to the highly favoured woody plant species and it was assumed that if some or all of these plants were available in a feeding patch, selective utilization of one of them could affect the acceptances of the others.

2.1.3 H_0: There is no difference in acceptance between height classes of the same species.

This hypothesis was formulated to assess if there were differential acceptances of height classes within woody species.

2.1.4 H_0: Bull herds and family groups do not differ in their acceptances of different woody species and size classes.

This hypothesis was formulated to assess the differential acceptances of bull and family groups on different size classes of woody species.

2.2 Study Area

The study area was located in the north-eastern corner of Botswana within Chobe National Park and Kasane Forest Reserve and Kasane Forest Reserve Extension (Fig. 2.1) and lies between 24˚43′ and 25˚15′E and 17˚46′ and 18˚15′S. The study area extended from Kazungula to Ngoma and the southern limit was about 40 km from the Chobe river.

Based on 49 years (1945-1993) rainfall data and 13 years (1982-1994) temperature data for Kasane, provided by the Botswana Meteorological Services, the area receives a mean annual rainfall of 700 mm and experiences an annual average temperature of 22°C. Most of the rain falls between November and March. October is the hottest month with a mean maximum temperature of 35°C. The coldest month is June with a mean minimum temperature of 10°C. The only source of perennial water is the Chobe river.

The area is primarily flat to gently undulating with elevations above 1000 m. The majority of the soils are derived from Kalahari sand while others are formed from lacustrine and alluvial soils which are found on the Chobe flood plain (Sommerlatte, 1976).

The following description of vegetation types is based on localised and broad studies by Child (1968), Simpson (1975), Sommerlatte (1976) and Moroka (1984). The vegetation was broadly categorized into the riparian fringe, the alluvial terrace and sandveld woodlands.

The riparian fringe woodland extends for an average distance of 70 m from the Chobe river. Representative woody plants are *Diospyros mespiliformis, Croton megalobotrys, Capparis tomentosa, Acacia nigrescens* and *Combretum mossambicense.* The alluvial terrace woodland extends southwards from the riparian fringe woodland. This woodland is of variable width but extends for no more than 500 m at the widest point from the riparian fringe. Common woody plants in this woodland are *Combretum elaeagnoides, Dichrostachys cinerea, A. nigrescens, C. megalobotrys, Lonchocarpus nelsii, C. mossambicense* and *Securinega virosa*.

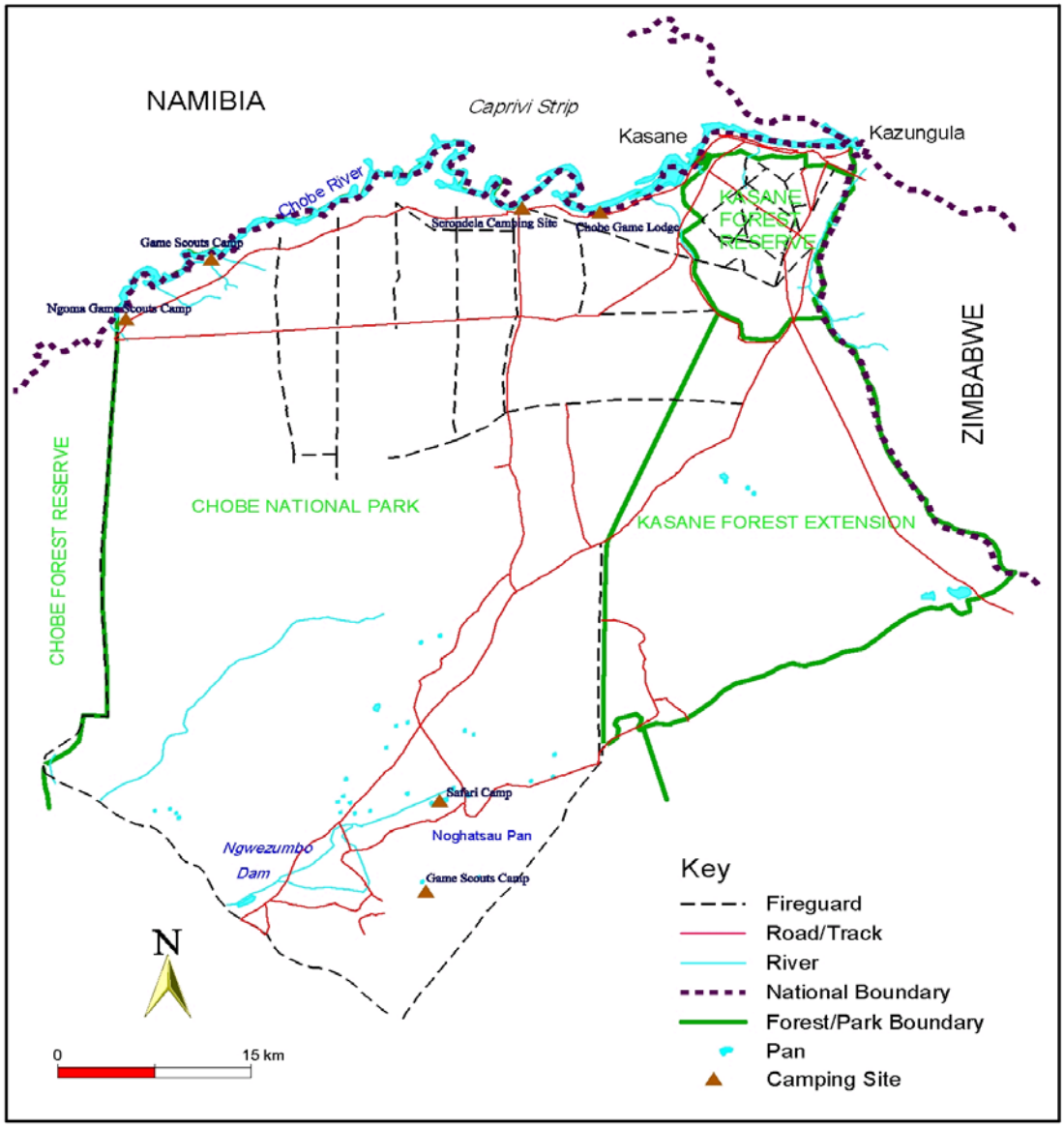

Figure 2.1 Map of northern Botswana, showing the study area and land use boundaries.

Some species described by Simpson (1975) and Sommerlatte (1976) as common in the riparian fringe and alluvial terrace woodlands have been devastated by elephant. These include *Acacia erioloba, Acacia tortilis, A. nigrescens* and *B. discolor*. Remaining plants of these species are restricted to the shrub layer by elephant.

The sandveld woodland of the study area may be broadly divided into the *B. plurijuga* and *B. africana* woodlands. The *B. plurijuga* woodland occurs in pure stands on deep Kalahari sands. The *B. plurijuga* woodland may be found in association with *B. africana, E. africanum, Guibourtia coleosperma, Brachystegia boehmii* and *Pterocarpus angolensis* in the tree layer. The shrub layer which also includes the regeneration of the canopy layer is dominated by *Ochna pulchra, D. condylocarpon, T. sericea, B. petersiana, B. massaiensis, Combretum apiculatum, C. collinum, Combretum fragrans* and *Combretum zeyheri*.

The *B. africana* woodland occurs on less deep sandy soils and is mostly found on the southern part of the study area. Similar woody species as listed for the *B. plurijuga* woodland occur in the understorey.

In this study, the different sandveld woodland associations were treated as one habitat because specific communities have not been mapped.

2.3 Methods

Data collection started in August, 1992 and ended in July, 1993. Three seasons were distinguished, based on rainfall and temperature patterns: (a) wet (November-April) (b) cool-dry (May-July) (c) hot-dry (August-October).

2.3.1 Observation and data recording

Both animal-based and plant-based observation methods were used for recording woody vegetation acceptances by elephant. A Psion Organiser hand-held computer was used for direct data capture in the field using a data capture program 'Jumbo' (Appendix 1). The data capture program was coded by the author and field tested

before carrying out the full scale data collection process. Computerized data recording had the following advantages: (a) data entry was faster, (b) data entry was accurate because safeguards and editing controls could be built into the program, (c) certain keys could be programmed so that identical foraging activities could be replicated, (d) necessary computations were done automatically, (e) the data was transferred directly into a micro computer and required minimum editing and (f) laborious error-prone transcription of check sheet data to a micro computer was avoided (Unwin and Martin, 1987; Whiten and Burton, 1988).

The recorded feeding activities or feeding events included feeding actions such as branch breaking, uprooting or pushing over trees, digging for roots, debarking, leaf stripping, snapping of small stems and trunks, snapping of shoots or any manipulation of a food item which may or may not have been followed by consumption of a plant part. Woody plants were classified into 5 height classes: 0-0.5 m, 0.5-1 m, 1.0-2.5 m, 2.5-5 m and >5 m.

2.3.2 Animal-based observations

The animal-based method involved focal animal sampling (Altmann, 1974). Groups or individual animals were located by searching while driving a 4-wheel drive vehicle along the park tracks. Searching and encounters of different groups of elephant were opportunistic as there was no prior set pattern by day or area to be searched. When a group of actively feeding elephants was encountered, the closest readily visible and actively feeding elephant was the focal animal. The place where a group of actively feeding elephant was encountered and hence sampled was defined as a feeding site.

The foraging activities of the focal elephant were recorded continuously but for a period not exceeding one hour as long as the animal was in view for proper data collection. All feeding actions which may or may not have been followed by consumption of a plant part were recorded by plant species and height class. All woody species not selected but occurring within a 10 m radius of the feeding position of a focal elephant were recorded by height class as well. The area defined by the 10m

radius of the feeding position of the focal elephant was referred to as a feeding patch. A new feeding patch was defined if the distance travelled by the focal elephant from the centre of the previous feeding patch was ≥20 m. A radius of 10 m was selected to represent 2 body lengths of an adult elephant. All woody plants in this radius were considered to be available to a feeding elephant.

A new focal elephant was observed if the animal under current observation (a) stopped feeding, (b) engaged in other activities i.e. standing, lying, drinking, travelling, wallowing, social interactions etc. (c) became obscured or (d) was disturbed by the presence of the observer. Where possible a maximum of five patches would be sampled at a feeding site over all the focal animals of the same group.

Focal elephant were categorized by sex and age classes as follows: (a) immature (juveniles and sub-adults), (b) adult male and (c) adult female. It was difficult to sex immature elephants in the field, hence only the sexes of adults were recorded. Field aging criteria described by Laws (1966) were used where elephants were assigned to age categories by relative body sizes. This became possible after observing several groups of elephants especially adult females with juveniles and sub-adults.

The elephant group, of which the focal elephant was part, was categorized as bull herd or family unit. A bull herd refers to an all-male group while a family unit comprises adult females, juveniles, immature males and females, and sometimes also sexually mature males.

The animal-based method was used mostly in the riparian and alluvial terrace woodlands where elephant could be observed at close range from a vehicle. Elsewhere, the road network was poor and off the road observations from a vehicle were limited by deep sands and thick vegetation. For security reasons, no direct observations were done by following elephants on foot.

The riparian and alluvial terrace woodlands were sampled as a single habitat and will be referred to as the riverine woodland. This was necessary because (a) it was usually

difficult to define the boundary between the riparian fringe and alluvial terrace woodlands and (b) data were limited because the elephant hardly utilized the woodland types during the wet and cool-dry seasons.

2.3.3 Plant-based observations

Plant-based observations involved an assessment of woody species acceptances by sampling on foot areas indicated by fresh tracks of actively feeding elephants. In the event that a group of feeding elephant was encountered, observations of foraging habits were done by either backtracking or following elephant feeding tracks forwards. As for the animal-based method, feeding tracks or groups of elephant were opportunistically located by searching while driving a 4-wheel drive vehicle along different park track roads in the sandveld or riverine woodlands. A feeding track was considered fresh if discarded plant parts such as leaves or small twigs had not dried up.

Over 90% of data using the plant-based method was collected from the sandveld woodland in any one season. Most feeding activities also occurred in the sandveld as favoured woody species and size classes in the riverine woodland quickly got depleted due to elephant concentration close to the river. The plant-based observation method provided a way of recording data on (a) night foraging habits of elephants if elephants or fresh tracks were located at dawn and (b) foraging habits of elephants which could not be followed by vehicle due to impassable terrain, thick vegetation, elephant aggression or elephant which were wary of the presence of the observer.

The sampling procedure was started by selecting a feeding patch of 10 m radius. This was done by multiplying a random number generated from a scientific calculator by 200 m, which appeared to be the average length of sites of active feeding. Each woody plant in the patch was examined and a record was made of impact type and plant part consumed for each height class.

A total of 5 feeding patches were sampled and the area sampled was defined as a feeding site. Four of the patches were systematically placed on either side of the first

and spaced at equidistances of about 50 m, but within the 200 m length of the feeding site. The distance between patches was determined by pacing and each pace averaged 0.95 m.

A distinction was made as to whether the track belonged to a bull herd or family unit. Family unit tracks could easily be distinguished by the presence of small footprints of juveniles and immatures. Bull footprints could be confirmed by hind footprint measurements i.e. adult bulls generally have footprints measuring >45 cm (Western et al., 1983). The number of elephant in the group was determined by direct counting of elephant (if seen) or estimated approximately from spoor count.

2.3.4 Data analysis

Feeding tracks or a group of elephants were located by searching, hence the sightings or feeding sites sampled were assumed to be independent in data analysis. Each group or individual elephant sighted or feeding tracks located had the same probability of being sighted at a particular day and time as for any other.

SYSTAT statistical package (Wilkinson et al., 1992) was used for statistical analysis and graphical presentations. A significance level test of 95% (α=0.05) was used

2.3.4.1 Acceptability and availability frequencies

As already defined, *acceptance* reflects the likelihood of an animal commencing feeding on a species when that species is available nearby (Owen-Smith and Cooper, 1987.). Site based acceptability frequencies were calculated for each species by dividing the number of patches where a plant species or height class was utilized by the number of patches per site where this plant species or height class was available. Acceptability frequencies were calculated separately for the riverine and sandveld woodlands for each season.

A woody plant species was considered to be available to an elephant if it occurred within a feeding patch. Availability frequencies for each woody species were

calculated by site by dividing the number of patches in which it occurred by the total number of patches sampled. The availability frequencies were calculated separately for the riverine and sandveld woodlands for each season.

2.3.4.2 Linear regression analysis

The linear regression analysis was carried out using Systat statistical package (Wilkinson et al., 1992) on acceptance versus availability over all sites to determine if woody species acceptance by elephant was influenced by availability. This analysis was done for each season for accepted woody species where sample sizes for site availabilities were ≥ 10.

2.3.4.3 Multiple Regression analysis

Multiple regression analysis was used to test the hypothesis that a species was less likely to be accepted when other highly acceptable species were available than when such species were absent from the feeding site. The analysis was restricted to highly accepted species of intermediate to common availability each season. A stepwise (backward, interactive) multiple regression analysis (Sokal and Rohlf, 1981; Draper and Smith, 1981) was carried out using Systat statistical package (Wilkinson et al., 1992).

The basic multiple regression model was of the form:

$$A(S_i) = f(A(S_{i+1}), A(S_{i+2}), A(S_{i+k}\text{-}1))$$
$$= ß_0 + ß_1.A(S_{i+1}) + ß_2.A(S_{i+2}) + ... + ß_k.A(S_{i+k-1}) + \in_i , \; i = 1, k.$$

where k = number of highly selected species in any one season and habitat

f = '*function of*'

$A(S_i)$ = acceptance index of the *i*th species

$ß_0$- $ß_k$ = regression coefficients

$\in$ = random error term

The procedure was as follows: if the acceptance of the *i*th species was used as the dependent variable, acceptances of other species were taken as independent variables. This approach was used in order to find out how changes in acceptances of independent variables affected the acceptances of the dependent variables. In this analysis, the distinction between dependent and independent variables was

interchangeable and this was acceptable as recommended by Draper and Smith (1981) depending on the nature of the study.

Selecting the best acceptance model by stepwise (*backward, interactive*) is an iterative procedure which starts by computing a regression equation containing all predictor variables followed by removing all insignificant variables (Draper and Smith, 1981; Rohlf and Sokal, 1981; Wilkinson et al., 1992). The partial F-test value was calculated for every predictor variable and each F-value was associated with a test of H_0: $\beta_i=0$ versus H_1: $\beta_i\neq0$ and all insignificant variables, in this case, with $P\geq0.05$ were dropped. A possibility of interaction between response variables and any departure from the basic model formulation was investigated by residual analysis (Draper and Smith, 1981; Box et al., 1978).

2.3.4.4 Analysis of Variance

Within and between season differences in acceptances of size classes of commonly accepted woody species were determined by a one way analysis of variance (Wilkinson et al., 1992). Differences in acceptance between seasons and size classes were determined by the Bonferroni pairwise comparisons or contrast (Steel and Torrie, 1980; Wilkinson et al., 1992).

2.3.4.5 Student's t-test

A two sample t-test (Steel and Torrie, 1980; Wilkinson et al., 1992) was used to test differences in acceptances of woody species between habitats and between seasons. The samples for comparison were the woody species acceptances over all sites. As discussed above, the site based acceptances were considered independent and equality of variances was not assumed.

2.4 Results

2.4.1 Seasonal and habitat distribution of records

The plant-based method was the major form of data collection and represented 61% of all sites sampled in all habitats over the three seasons (Table 2.1). This method could

be used in all woodland types and particularly in the sandveld where elephants could not be followed by vehicle due to impassable terrain. The animal-based method was restricted to the riverine area with access roads where elephant could be observed at close range. Due to limited data collected in the riverine woodland, the following results are restricted to data from the sandveld, unless otherwise indicated. Limited data was collected in the riverine area during the wet and cool-dry season due to the fact that elephant concentrated their feeding activity on the sandveld (Figure 2.2).

2.4.2 Woody species availability

Woody species were arbitrarily categorized by their availability at feeding sites into rare (0-0.05), uncommon (0.05-0.25), intermediate (0.25-0.5) and common (>0.5). Within the sandveld, a total of 73 woody species was recorded as available to elephant and of these, 7 were classified as common, 8 intermediate, 21 uncommon and 37 rare.

Table 2.1 Seasonal and habitat distribution of sampled sites for plant-based and animal-based observation methods. Figures outside parenthesis represent number of sites and figures in parenthesis represent the number of patches.

SEASON	**METHOD**	**SITES** ***(patches in parenthesis)***	**DISTRIBUTION BY HABITAT**	
			Riverine	**Sandveld**
Hot-dry	Plant-based Animal-based	66(330) 79(98)	6(30) 79(98)	60(300) 0
Wet	Plant-based Animal-based	27(135) 0	0 0	27(135) 0
Cool-dry	Plant-based Animal-based	37(177) 4(6)	3(13) 4(6)	34(164) 0
Total		**213(746)**	**92(147)**	**121(599)**

Commonly available woody species included *B. massaiensis, B. petersiana, B. plurijuga, O. pulchra, C. apiculatum, C. collinum, D. condylocarpon.* Woody species falling in the intermediate category included *B. africana, C. fragrans, C. zeyheri, Commiphora mossambicensis, E. africanum, Grewia monticola, Pseudolachnostylis maprouneifolia,* and *T. sericea.*

Details of availabilities frequencies of all woody species encountered in the sandveld woodland are shown in Appendix Table 2.1, in which woody species are presented in descending order of mean availability frequencies over the annual cycle.

About 95% of the sites in the riverine habitat were sampled using the animal-based method. In this habitat, 30 species were recorded as available to elephant and of these, 3 were classified as common, 3 intermediate, 12 uncommon and 12 rare. The most common woody species were C. *mossambicense, C. megalobotrys* and *S. virosa* and in the intermediate category were *C. elaeagnoides, C. tomentosa,* and *D. cinerea*. Details of availability frequencies for the different categories of woody species encountered in the riverine habitat are presented in Appendix Table 2.2.

2.4.3 Woody species acceptability

Woody species acceptance values were arbitrarily categorized into three classes: low (<0.2), intermediate (0.2-0.4) and high (>0.4). Appendix Tables 2.1-2.2 provide details of acceptability frequencies for all woody species encountered in the sandveld and riverine areas respectively while Tables 2.2-2.3 provide details of accepted woody species with availability frequencies ≥10 for the two habitats.

2.4.3.1 Wood species consistently favoured

A woody species was considered to be consistently favoured if it had high acceptance values over all three seasons. *G. monticola* was the only consistently highly accepted woody species in the sandveld woodland ANOVA $F_{(2,74)}$=2.93, P=0.06) (see Table 2.2).

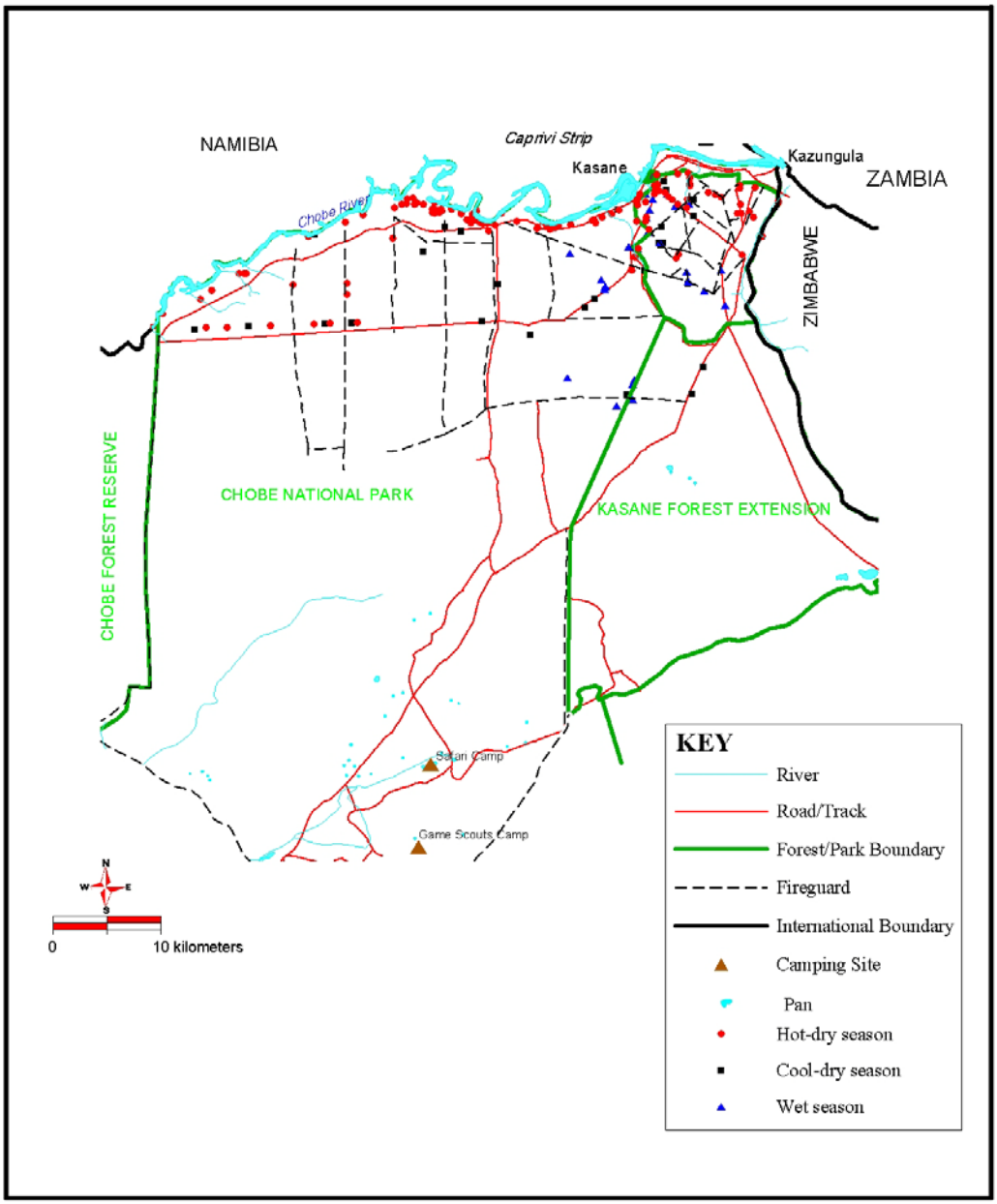

Figure 2.2 Distribution of sampling sites for elephant feeding records during the wet, cool-dry and hot-dry seasons in the sandveld of northern Botswana.

Other woody species with high acceptance values in at least 2 seasons were *B. massaiensis* (hot-dry and wet seasons) and *B. petersiana* (cool-dry and wet seasons), *C. fragrans* (hot-dry and cool-dry seasons). *D. condylocarpon* was highly accepted during the cool-dry season only while *C. collinum*, *C. zeyheri* and *T. sericea* were highly accepted during the hot-dry season. *C. fragrans* was highly accepted during the hot-dry and wet seasons.

Favoured woody species in the riverine woodland during the hot-dry season were the two common species *C. megalobotrys* and *S. virosa;* and two intermediate species *C. elaeagnoides* and *D. cinerea.*

2.4.3.2 Woody species consistently rejected or neglected

A woody species was considered to be consistently rejected if it was never recorded as accepted in any one season and neglected if it was lightly accepted. Within the sandveld, rejected common species were *B. plurijuga* and *O. pulchra.* Neglected woody species were all in the intermediate category and these included *E. africanum* and *P. maprouneifolia.*

2.4.4 Influence of availability on acceptance

The results of the regression analysis on acceptance versus availability for accepted woody species with $n \geq 10$ for availability for each season showed no evidence of linear relationships between the two parameters as follows: (a) wet season (ANOVA, $F_{(1,10)} = 1.36$, $P = 0.270$ (b) cool-dry season (ANOVA, $F_{(1,14)} = 0.508$, $P = 0.488$ and (c) hot-dry season (ANOVA, $F_{(1,18)} = 3.508$, $P = 0.08$.

2.4.5 Influence of the presence of preferred food types on acceptance

Acceptance of individual woody species by elephant appeared to be influenced by availability of alternative woody species in a feeding patch particularly during the hot-dry season and to a lesser extend during the cool-dry season. Hence, the hypothesis that woody species acceptances by elephant is influenced by alternative food types available appeared to hold during the hot-dry season when the number of woody species included in the diet of elephant was widened. For instance, the

extent to which *G. monticola* was accepted during the hot-dry season depended on or could be predicted from the acceptances *B. massaiensis, C. fragrans* and *C. zeyheri* when they were all available in a feeding patch as these species tended to be highly favoured during this season.. The most influential species therefore appeared to be *G. monticola* followed by *C. zeyheri, B. massaiensis* and to a lesser extend *B. petersiana* and *C. fragrans*. As noted in section 2.4.3.1 *G. monticola* was the only consistently highly accepted woody species in the sandveld woodland and being of intermediate availability was comparatively highly favoured during the hot-dry season.

2.4.6 *Influence of size class on acceptance*

There were no within season differences in height class acceptances during the hot-dry (ANOVA, $F_{(4,134)}$=1.56, P=0.19) and wet season (ANOVA, $F_{(4,106)}$=0.891, P=0.472). For the cool-dry season, the height class interval >5m was excluded due to insufficient data, while the remaining height class intervals as defined above showed a significant difference in acceptance (ANOVA, $F_{(3,105)}$=0.891, P=0.042, with the height class interval 0-0.5 m metres being the least accepted. Overall, it would appear that the height class interval 1-2.5 m was the most preferred over all the three seasons (Fig. 2.3). Details of the different height class availabilities and acceptances for woody species encountered by elephant in the sandveld woodland are presented in Appendix Tables 2.3a-c.

2.4.7 *Differences in woody species acceptance between habitats*

There was not much overlap in woody species found in the riverine and sandveld habitat (Tables 2.2 and 2.3). Woody species with adequate data to determine differences in acceptances between the two habitats were *B. massaiensis*, *C. elaeagnoides* and *D. cinerea.* The acceptance of *B. massaiensis* was greater in the sandveld than in the riverine woodland (t=5.6, df=24, P≤0.001) while the acceptance of *D. cinerea* was greater in the riverine woodland, (t=3.29, df=37, P≤0.01).

Table 2.2. Availability and acceptance frequencies of woody species encountered by elephant in the sandveld woodland of northern Botswana recorded over three seasons using the plan-based method. The 'n' represents number of sampling sites for availability and acceptance frequencies which were calculated by site of five patches per site. Woody species included were those with availability sample sizes ≥ 10 in at least one season.

CATEGORY	SPECIES	SEASONAL AVAILABILITY							SEASONAL ACCEPTANCE						
		Mean availability	n	Hot	n	Cool	n	Wet	Mean acceptance	n	Hot	n	Cool	n	Wet
Common	*Baphia massaiensis*	0.777	54	0.85	29	0.76	20	0.72	0.450	49	0.66±0.09	12	0.21±0.12	16	0.48±0.09
	Bauhinia petersiana	0.767	57	0.82	34	0.86	24	0.62	0.483	39	0.34±0.08	29	0.57±0.13	16	0.54±0.08
	Baikiaea plurijuga	0.643	57	0.74	28	0.65	19	0.54	0.0	0	0.0	0	0.0	0	0.0
	Ochna pulchra	0.617	47	0.52	31	0.78	22	0.55	0.0	0	0.0	0	0.0	0	0.0
	Combretum apiculatum	0.613	51	0.59	29	0.55	26	0.70	0.150	29	0.25±0.08	7	0.08	7	0.12
	Diplorhynchus condylocarpon	0.597	40	0.41	30	0.90	21	0.48	0.363	20	0.23±0.10	26	0.71±0.07	8	0.15
	Combretum collinum	0.583	57	0.61	28	0.60	24	0.54	0.213	44	0.43±0.09	5	0.06	8	0.15
Intermediate	*Burkea Africana*	0.497	39	0.39	30	0.69	19	0.41	0.170	18	0.19±0.08	3	0.03	7	0.15
	Terminalia sericea	0.490	48	0.53	27	0.44	23	0.50	0.170	31	0.39±0.11	6	0.12	0	0.0
	Commiphora mossambicensis	0.413	42	0.37	22	0.31	23	0.56	0.260	19	0.30±0.13	3	0.11	14	0.37±0.17
	Combretum zeyheri	0.380	39	0.34	28	0.53	18	0.27	0.307	29	0.57±0.14	7	0.15	5	0.20
	Grewia monticola	0.353	34	0.35	23	0.34	20	0.37	0.470	27	0.61±0.13	13	0.39±0.08	13	0.41±0.10
	Pseudolachnostylis mapreuneifolia	0.313	37	0.28	27	0.48	13	0.18	0.137	13	0.20±0.08	5	0.09	2	0.12
	Combretum fragrans	0.310	39	0.41	13	0.16	16	0.36	0.543	33	0.54±0.12	13	0.80±0.100	5	0.09
	Erythrophleum africanum	0.277	31	0.23	28	0.51	12	0.09	0.02	4	0.06	0	0.0	0	0.0

CATEGORY	SPECIES	SEASONAL AVAILABILITY							SEASONAL ACCEPTANCE							
		Mean availability	n	Hot	n	Cool	n	Wet	Mean acceptance	n	Hot	n	Cool	n	Wet	
Uncommon	*Croton gratissimus*	0.230	32	0.27	11	0.12	14	0.30	0.0	0	0.0	0	0.0	0	0.00	
	Vitex payos	0.177	32	0.25	14	0.16	16	0.12	0.037	7	0.11	0	0.0	0	0.0	
	Markamia acuminate	0.133	27	0.24	0	0.11	7	0.05	0.003	1	0.01	0	0.0	0	0.0	
	Combretum elaeagnoides	0.130	14	0.14	6	0.12	4	0.13	0.487	11	0.53	3	0.56	3	0.37	
	Pterocarpus angolensis	0.130	25	0.13	14	0.16	10	0.1	0.207	7	0.20	4	0.14	4	0.28	
	Dichrostachys cinera	0.093	12	0.06	6	0.09	7	0.13	0.023	2	0.08	1	0.17	3	0.36	
	Psydrax livida	0.083	8	0.05	11	0.13	6	0.07	0.093	2	0.10	3	0.14	1	0.04	
	Acacia fleckii	0.070	12	0.09	3	0.27 8	0	0.0	0.143	3	0.15	2	0.28	0	0.0	
	Dialium engleranum	0.063	3	0.02	10	0.15	3	0.02	0.230	2	0.56	3	0.13	0	0.0	
	Ximenia Americana	0.050	21	0.07	5	0.04	4	0.04	0.343	9	0.48	2	0.30	1	0.25	
Rare	*Guibourtia coleosperma*	0.046	6	0.03	10	0.07	5	0.04	0.123	1	0.17	2	0.2	0	0.0	
	Vangueria infausta	0.040	12	0.05	4	0.02	7	0.05	0.0	0	0.0	0	0.0	0	0.0	

Table 2.3. Availability and acceptance frequencies of woody species encountered by elephant in the Chobe riverine habitat of northern Botswana recorded during the hot-dry season using the animal-based method for woody species with n≥10 for availability sampling sites.

CATEGORY	SPECIES	AVAILABILITY		ACCEPTANCE	
		N	Hot	n	Hot
Common	*Combretum mossambicense*	53	0.65	0	0.0
	Securinega virosa	42	0.53	16	0.38±0.15
	Croton megalobotrys	44	0.53	18	0.41±0.15
	Caparis tomentosa	39	0.49	0	0.0
Intermediate	*Combretum elaeagnoides*	32	0.4	18	0.56±0.18
	Dichrostachys cinera	27	0.32	13	0.48±0.22
Uncommon	*Markamia acuminate*	17	0.19	0	0.0
	Baphia massaiensis	16	0.2	2	0.13
	Colophospermum mopane	12	0.16	6	0.54
	Strychnos potatorum	11	0.13	2	0.18
	Acacia erioloba	12	0.08		0.15

2.4.8 *Differences in height class acceptance between bulls and cows*

Sufficient data to estimate differences in woody species acceptances between bulls and cows was available from the plant-based method over the three seasons. Results of height class acceptances for the intermediate to highly accepted woody species generally showed no significant differences in height class acceptances between cow and bull groups. The only two exceptions were during the cool-dry season when selection utilization of the height class interval 2.5-5m was greater for bulls than for cows ($t=2.35$, $df=11$, $P=0.040$) and hot-dry season when the utilization of the height class interval 0.5-1 m was greater for cows than bulls ($t=2.79$, $df=9$, $P=0.020$) (Fig. 2.4).

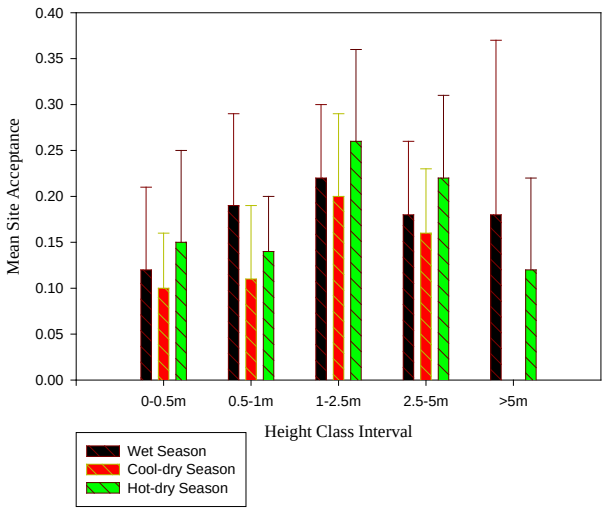

Figure 2.3 Mean seasonal height class site acceptances for all of woody species in the sandveld woodland of northern Botswana.

2.4.9 *Influence of plant part use on woody species acceptance*

The influence of different plant parts on woody species acceptance was determined where there were adequate sample sizes of acceptances of woody plant species in two or more seasons. Details of woody species acceptance by plant parts will be fully discussed in Chapter 3.

Acceptance of *B. massaiensis* was greater during the hot-dry season when stems and bark were utilized than the wet season when leaves were utilized (t=2.07, df=33.9, P=0.046). There was no significant difference in the acceptance of *B. petersiana* during the cool-dry and wet seasons when stems and leaves were utilized (ANOVA, $F_{(1,113)}$=0.285, P=0.59). However, when root was predominantly utilized during the hot-dry season, the acceptance of *B. petersiana* was less than that of the wet season (ANOVA, $F_{(1,113)}$=5.39, P=0.022) or cool-dry season (ANOVA, $F_{(1,113)}$=10.53, P=0.002). The acceptance of *G. monticola* was greater during the hot-dry season when bark of stem was utilized than during the cool-dry season when leaves were utilized (t=2.1, df=45, P=0.041.

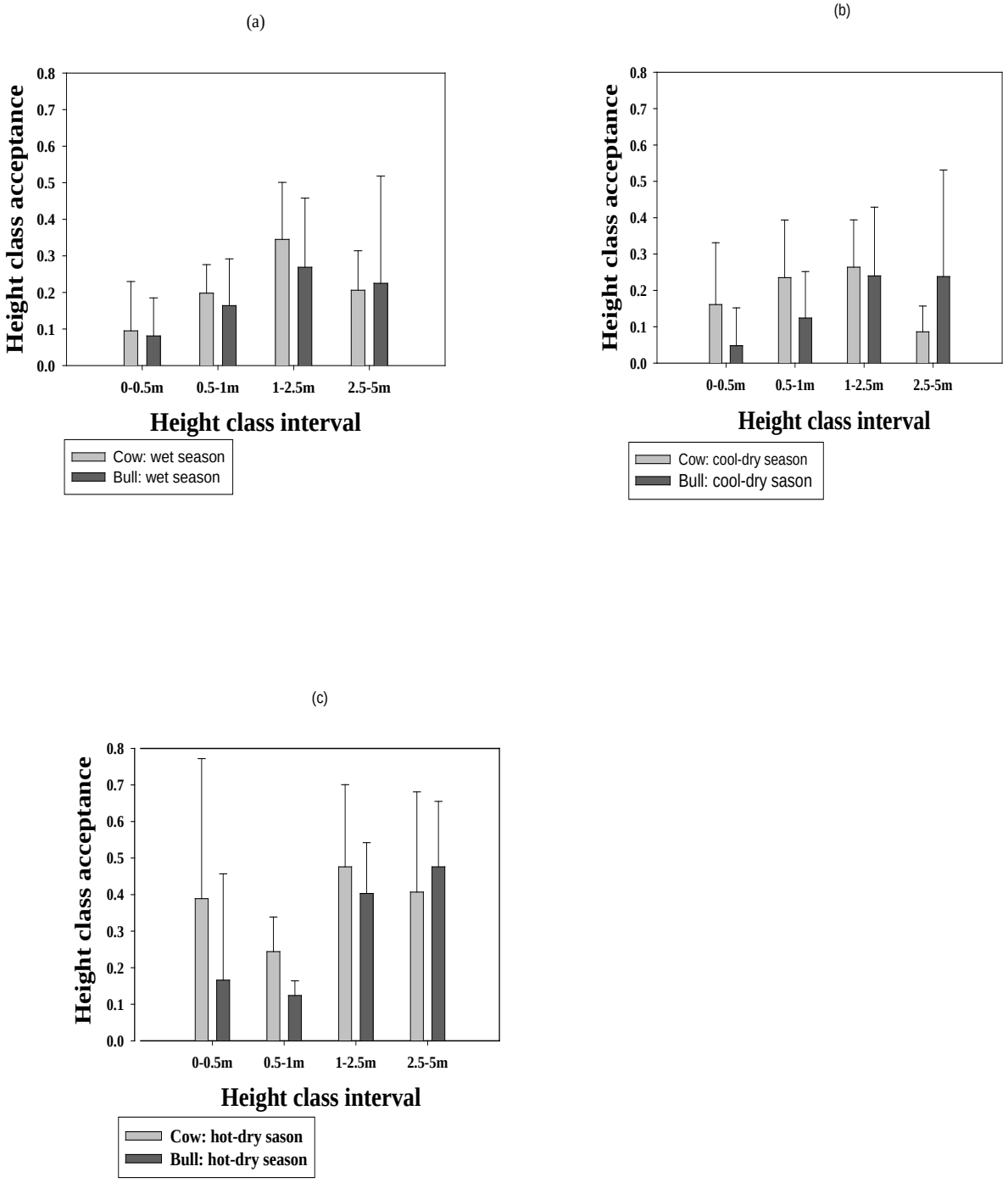

Figure 2.4. Seasonal woody species height class acceptances by bull and cow groups of elephant in the sandveld woodland of northern Botswana during (a) the wet season (b) cool-dry season and (c) hot-dry season.

2.5 Discussion

Elephants were quite narrowly selective for a few woody plant species, with only fairly minor seasonal changes in the diet of woody species included in the diet during the cool-dry and wet seasons. The number of woody species included in the diet of elephant was widened to include more woody species during the hot-dry season than any other season. Elephant favoured the intermediate height categories, but were not narrowly selective for plant height classes. Bulls and cows differed to some extent in their selection for plants of different height classes. Important factors that influence acceptance by elephant therefore appeared to be woody species and season with the degree of species acceptances being influenced by the type of plant part included in the diet by season and height class. In general, the most highly favoured woody species were those that existed in the shrub layer such as *B. massaisensis, B. petersiana, G. monticola* and *D. condylocarpon*.

Within the intermediate and common categories of availability, ≤five woodyspecies were highly favoured by elephant and this gave the impression that elephant subsisted on a narrow range of woody species. i.e they sought out a few common species. However, the results showed no evidence of a relationship between acceptance and availability of woody species. But the availability of alternative food types in a feeding patch appeared to influence acceptability of woody species by elephant during the hot-dry season when the diet of elephant was widened to include more woody species.

A comparative analysis of within season height class acceptances of the commonly utilised woody species showed no differences in height class acceptances during the hot-dry and wet seasons. As for the cool-dry season, the smaller size class 0-0.5 was the least accepted. While the results showed a broader acceptance across size classes, the finding of studies in Kasungu National Park, Malawi, (Jachmann and Bell, 1985), Luangwa Valley, Zambia (Caughley, 1976), and Sengwa Area, Zimbabwe (Guy, 1976) indicated that the preferred elephant feeding level was 1-2.5 m.

It was interesting to note that the smaller size classes ≤ 1 m of the commonly

available and preferred woody species such as *B. massaiensis, B. petersiana, C. collinum, C. fragrans, C. zeyheri, D. condylocarpon* and *G. monticola* were also accepted in one or more seasons. This is contrary to what has been reported in the literature that individual plants ≤ 1 of favoured woody species were infrequently accepted by elephant (Croze, 1974b; Caughley, 1966; Leuthold, 1977; Pellew, 1983; Mwalysi, 1990. Also, Dublin et al. (1990) reported that elephant alone appeared to prevent woodland regeneration in the Serengeti-Mara by feeding on small seedlings because there were few trees in larger size classes.

The results of this study indicated that differences in acceptance values between seasons for some woody species may have been influenced by the seasonal utilisation of specific plant parts. But detailed analysis of the influence of plant parts will be the subject of Chapter 3 of this thesis.

The results of this study also suggested no differences in acceptance of size classes of woody species although bulls appeared to neglect size classes < 1 m over the annual cycle. Similarly, Stokke (1999) and Stokke and Du Toit (2000) reported no evidence of feeding height stratification between male and female groups in the same study area.

2.6 Conclusions

2.6.1 Acceptance of woody species by elephant was such that some woody species were either consistently favoured, neglected or rejected in one or more seasons.

2.6.2 Within the sandveld woodland, elephants were very selective of woody species included in the diet with ≤five woody species being highly favoured in any one season.

2.6.3 Elephant generally showed no differences in within season and among season height class acceptance of woody species.

2.6.4 Availability of alternative food types appeared to influence acceptance of woody species in a feeding patch and this factor was more pronounced during the hot-dry season when relatively more woody species were included in the

elephant diet than the wet and cool-dry seasons.

2.6.5 The results of the study provided evidence of seasonal differences in woody species size class acceptance between bulls and cows for the commonly favoured woody species.

Appendix Table 2.1. Availability and acceptance frequencies of all woody species encountered by elephant in the sandveld woodland of northern Botswana recorded over three seasons using the plan-based method. The 'n' represents sampling sites where a woody species were available or accepted.

AVAILABILITY CATEGORY	SPECIES	AVAILABILITY							ACCEPTABILITY						
		Mean	n	Hot	n	Cool	n	Wet	Mean	n	Hot	n	Cool	n	Wet
Common	*Baphia massaiensis*	0.777	5	0.85	29	0.76	20	0.72	0.450	49	0.66∀0.09	12	0.21∀0.12	16	0.48∀0.0
	Bauhinia petersiana	0.767	5	0.82	34	0.86	24	0.62	0.483	39	0.34∀0.08	29	0.57∀0.13	16	0.54∀0.0
	Baikiaea plurijuga	0.643	5	0.74	28	0.65	19	0.54	0.0	0	0.0	0	0.0	0	0.0
	Ochna pulchra	0.617	4	0.52	31	0.78	22	0.55	0.0	0	0.0	0	0.0	0	0.0
	Combretum apiculatum	0.613	5	0.59	29	0.55	26	0.70	0.150	29	0.25∀0.08	7	0.08∀0.03	7	0.12∀0.0
	Diplorhynchus condylocarpon	0.597	4	0.41	30	0.9	21	0.48	0.363	20	0.23∀0.10	26	0.71∀0.07	8	0.15∀0.1
	Combretum collinum	0.583	5	0.61	28	0.6	24	0.54	0.213	44	0.43∀0.09	5	0.06	8	0.15∀0.1
Intermediate	*Burkea Africana*	0.497	3	0.39	30	0.69	19	0.41	0.170	18	0.19∀0.08	3	0.03	7	0.29∀0.2
	Terminalia sericea	0.490	4	0.53	27	0.44	23	0.50	0.170	31	0.39∀0.11	6	0.12	0	0.0
	Commiphora mossambicensis	0.413	4	0.37	22	0.31	23	0.56	0.260	19	0.30∀0.13	3	0.11	14	0.37∀0.1
	Combretum zeyheri	0.380	3	0.34	28	0.53	18	0.27	0.307	29	0.57∀0.14	7	0.15∀0.12	5	0.20
	Grewia monticola	0.353	3	0.35	23	0.34	20	0.37	0.470	27	0.61∀0.13	13	0.39∀0.08	13	0.41∀0.1
	Pseudolachnostylis	0.313	3	0.28	27	0.48	13	0.18	0.137	13	0.20∀0.08	5	0.09	2	0.12
	Combretum fragrans	0.310	3	0.41	13	0.16	16	0.36	0.543	33	0.54∀0.12	13	0.80.0∀0.10	5	0.09
	Erythrophleum africanum	0.277	3	0.23	28	0.51	12	0.09	0.020	4	0.06	0	0.0	0	0.0

AVAILABILITY CATEGORY	SPECIES	AVAILABILITY							ACCEPTABILITY						
		Mean	n	Hot	n	Cool	n	Wet	Mean	n	Hot	n	Cool	n	Wet
Uncommon	*Croton gratissimus*	0.230	3	0.27	11	0.12	14	0.30	0.0	0	0.0	0	0.0	0	0.00
	Vitex payos	0.177	3	0.25	14	0.16	16	0.12	0.037	7	0.11	0	0.0	0	0.0
	Markamia acuminata	0.1333	2	0.24	8	0.11	7	0.05	0.003	1	0.01	0	0.0	0	0.0
	Combretum elaeagnoides	0.130	1	0.14	6	0.12	4	0.13	0.487	11	0.53	3	0.56	3	0.37
	Pterocarpus angolensis	0.130	2	0.13	14	0.16	10	0.10	0.207	7	0.20	4	0.14	4	0.28
	Dichrostachys cinera	0.093	1	0.06	6	0.09	7	0.13	0.203	2	0.08	1	0.17	3	0.36
	Psydrax livida	0.083	8	0.05	11	0.13	6	0.07	0.093	2	0.10	3	0.14	1	0.04
	Brachystegia boehmii	0.073	0	0.0	3	0.05	5	0.17	0.270	0	0.0	1	0.11	5	0.70
	Grewia flava	0.073	7	0.05	4	0.05	5	0.12	0.147	3	0.24	0	0.0	1	0.20
	Diospyros batocana	0.073	3	0.02	8	0.12	3	0.08	0.163	2	0.42	0	0.0	1	0.07
	Acacia fleckii	0.070	1	0.09	3	0.278	0	0.0	0.143	3	0.15	2	0.28	0	0.0
	Lonchocarpus nelsii	0.067	3	0.03	2	0.04	7	0.13	0.050	1	0.08	0	0.0	1	0.07
	Dialium engleranum	0.063	3	0.02	10	0.15	3	0.02	0.230	2	0.56	3	0.13	0	0.0
	Friesodielsia obovata	0.057	0	0.0	9	0.12	7	0.05	0.103	0	0.0	3	0.31	0	0.0
	Colophospermum mopane	0.053	0	0.0	0	0.0	6	0.16	0.180	0	0.0	0	0.0	6	0.54
	Combretum celastroides	0.053	6	0.06	5	0.09	2	0.01	0.127	3	0.38	0	0.0	0	0.0
	Combretum schumannii	0.050	6	0.08	3	0.06	1	0.01	0.217	4	0.38	1	0.27	0	0.0
	Ximenia Americana	0.050	2	0.07	5	0.04	4	0.04	0.343	9	0.48	2	0.30	1	0.25

AVAILABILITY CATEGORY	SPECIES	AVAILABILITY							ACCEPTABILITY						
		Mean	n	Hot	n	Cool	n	Wet	Mean	n	Hot	n	Cool	n	Wet
	Strychnos pungens	0.047	4	0.02	6	0.11	2	0.01	0.0	0	0.0	0	0.0	0	0.0
	Guibourtia coleosperma	0.047	6	0.03	10	0.07	5	0.04	0.123	1	0.17	2	0.2	0	0.0
	Hippocratea buchananii	0.0467	2	0.01	2	0.04	5	0.09	0.0	0	0.0	0	0.0	0	0.0
Rare	*Vangueria infausta*	0.040	1	0.05	4	0.02	7	0.05	0.0	0	0.0	0	0.0	0	0.0
	Strychnos cocculoides	0.040	4	0.01	10	0.11	0	0.0	0.0	0	0.0	0	0.0	0	0.0
	Commiphora africana	0.037	0	0.0	3	0.04	4	0.07	0.193	0	0.0	1	0.33	1	0.25
	Amblygonocarpus andongesis	0.037	3	0.02	7	0.09	0	0.0	0.137	1	0.17	2	0.24	0	0.0
	Commiphora pyracanthoides	0.033	5	0.02	1	0.01	2	0.07	0.483	1	0.10	1	1.0	2	0.35
	Erythroxylum zambesiacum	0.030	7	0.02	1	0.01	7	0.06	0.0	0	0.0	0	0.0	0	0.0
	Kirkia acuminate	0.027	8	0.03	4	0.03	3	0.02	0.083	2	0.25	0	0.0	0	0.0
	Pteleopsis myrtifolia	0.027	8	0.08	0	0.0	0	0.0	0.137	4	0.41	0	0.0	0	0.0
	Ximenia caffra	0.020	5	0.02	0	0.0	3	0.04	0.123	1	0.20	0	0.0	1	0.17
	Baissea wulfhorstii	0.020	4	0.05	0	0.0	2	0.01	0.0	0	0.0	0	0.0	0	0.0
	Paropsia brazzeana	0.020	0	0.0	5	0.06	0	0.0	0.0	0	0.0	0	0.0	0	0.0
	Dalbergia melanoxylon	0.020	4	0.02	3	0.02	3	0.02	0.0	0	0.0	0	0.0	0	0.0
	Crosspteryx febrifuga	0.017	6	0.03	2	0.01	7	0.10	0.0	0	0.0	0	0.0	0	0.0
	Combretum hereroense	0.017	0	0.0	1	0.01	3	0.04	0.0	0	0.0	0	0.0	0	0.0
	Commiphora mollis	0.017	0	0.0	3	0.05	0	0.0	0.0	0	0.0	0	0.0	0	0.0

AVAILABILITY CATEGORY	SPECIES	AVAILABILITY							ACCEPTABILITY						
		Mean	n	Hot	n	Cool	n	Wet	Mean	n	Hot	n	Cool	n	Wet
	Markamia obtusifolia	0.017	6	0.05	0	0.0	0	0.0	0.0	0	0.0	0	0.0	0	0.0
	Xerophis obovata	0.013	2	0.01	1	0.01	3	0.02	0.0	0	0.0	0	0.0	0	0.0
	Xeroderris stuhlmannii	0.013	6	0.02	1	0.01	1	0.01	0.0	0	0.0	0	0.0	0	0.0
	Pterocarpus rotundifolius	0.010	0	0.0	1	0.02	2	0.01	0.0	0	0.0	0	0.0	0	0.0
	Peltophorum africanum	0.010	0	0.0	1	0.03	0	0.0	0.0	0	0.0	0	0.0	0	0.0
	Securidaca longipedunculata	0.010	0	0.0	1	0.02	1	0.01	0.0	0	0.0	0	0.0	0	0.0
	Euclea divinorum	0.010	0	0.0	0	0.0	3	0.03	0.057	0	0.0	0	0.0	1	0.17
	Tricalysia cacondensia	0.007	0	0.0	2	0.02	0	0.0	0.083	0	0.0	1	0.25	0	0.0
	Schrebera tricholada	0.007	2	0.01	0	0.0	1	0.01	0.167	1	0.50	0	0.0	0	0.0
	Lonchocarpus capassa	0.007	2	0.01	0	0.0	2	0.01	0.0	0	0	0	0.0	0	0
	Jasminum stenolobum	0.007	0	0.0	0	0.0	3	0.02	0.0	0	0	0	0.0	0	0
	Terminalia mollis	0.007	0	0.0	1	0.02	0	0.0	0.0	0	0	0	0.0	0	0
	Combretum imberbe	0.007	0	0.0	1	0.01	1	0.01	0.0	0	0	0	0.0	0	0
	Strychnos madacariensis	0.003	0	0.0	0	0.0	1	0.01	0.0	0	0	0	0.0	0	0
	Ziziphus macronata	0.003	0	0.0	0	0.0	1	0.01	0.0	0	0	0	0.0	0	0
	Ancylanthes bainesii	0.003	0	0.0	2	0.01	0	0.0	0.0	0	0	0	0.0	0	0
	Clerodendrum glabrum	0.003	0	0.0	0	0.0	1	0.01	0.333	0	0	0	0.0	1	1.0
	Vangueriopsis lanciflora	0.003	0	0.0	1	0.01	0	0.0	0.0	0	0	0	0.0	0	0
	Pavetta schumanniana	0.003	0	0.0	1	0.01	0	0.0	0.0	0	0	0	0.0	0	0

AVAILABILITY CATEGORY	SPECIES	AVAILABILITY							ACCEPTABILITY						
		Mean	n	Hot	n	Cool	n	Wet	Mean	n	Hot	n	Cool	n	Wet
	Lannea discolour	0.003	0	0.0	0	0.0	1	0.01	0.0	0	0	0	0.0	0	0
	Adansonia digitata	0.003	4	0.01	0	0.0	0	0.0	0.250	3	0.75	0	0.0	0	0
	Sclerocarya burrea	0.003	0	0.0	0	0.0	1	0.01	0.0	0	0	0	0.0	0	0

Appendix Table 2.2. Availability and acceptance frequencies of woody species encountered by elephant in the Chobe riverine habitat of northern Botswana recorded during the hot-dry season using the animal-based method. The 'n' represents sampling sites where a woody species were available or accepted.

CATEGORY	SPECIES	AVAILABILITY		ACCEPTANCE	
		n	**Hot**	**n**	**Hot**
Common	*Combretum mossambicense*	53	0.65	0	0.0
	Securinega virosa	42	0.53	16	0.38±0.15
	Croton megalobotrys	44	0.53	18	0.41±0.15
Intermediate	*Capparis tomentosa*	39	0.49	0	0.0
	Combretum elaeagnoides	32	0.40	18	0.56±0.18
	Dichrostachys cinera	27	0.32	13	0.48±0.22
Uncommon	*Baphia massaiensis*	16	0.2	2	0.13
	Markamia acuminata	17	0.19	0	0.0
	Colophospermum mopane	12	0.16	6	0.54
	Strychnos potatorum	11	0.13	2	0.18
	Acacia nigrescens	9	0.09	3	0.33
	Boscia albitrunca	7	0.09	1	0.14
	Acacia erioloba	12	0.08	5	0.15
	Canthium frangula	7	0.08	2	0.29
	Ziziphus macronata	5	0.06	3	0.6
	Berchemia discolor	4	0.05	0	0.0
	Lonchocarpus nelsii	4	0.05	2	0.5
	Acacia tortilis	4	0.05	3	0.75
Rare	*Strychnos madacariensis*	3	0.03	1	0.33
	Friesodielsia obovata	3	0.03	3	1
	Gardenia spatulifolia	2	0.03	0	0.0
	Combretum apiculatum	2	0.02	1	0.5
	Terminalia sericea	2	0.01	0	0.0
	Vangueria infausta	2	0.01	1	0.5
	Maytenus senegalensis	1	0.01	0	0.0
	Lonchocarpus capassa	1	0.01	1	1
	Vitex payos	1	0.01	0	0.0
	Ximenia Americana	1	0.01	1	1
	Acacia schweinfurthii	1	0.01	1	1
	Hippocratea buchananii	1	0.01	1	1

Appendix Table 2.3a Acceptance by height class of woody species encountered by elephant in the sandveld woodland during the wet season in Chobe National Park, northern Botswana.

AVAILABILITY CATEGORY	SPECIES	SIZE CLASS																		
		0-0.5 m				0.5-1 m				1-2.5m				2.5-5 m				>5 m			
		n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bilty	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance
Common	*Baikiaea plurijuga*	7	0.38	0	0.0	12	0.39	0	0.0	12	0.522	0	0.0	16	0.38	0	0.0	15	0.36	0	0.0
	Baphia massaiensis	18	0.44	3	0.04	20	0.53	11	0.24	20	0.58	13	0.42	14	0.35	10	0.36	0	0.0	0	0.0
	Bauhinia petersiana	23	0.60	8	0.11	19	0.56	13	0.40	20	0.59	15	0.52	9	0.12	2	0.22	0	0.0	0	0.0
	Combretum apiculatum	16	0.29	2	0.03	17	0.19	2	0.05	22	0.37	3	0.05	22	0.42	6	0.18	2	0.10	2	0.14
	Diplorhynchus condylocarpon	21	0.36	2	0.04	13	0.19	3	0.15	12	0.19	6	0.38	4	0.06	1	0.19	0	0.0	0	0.0
	Combretum collinum	15	0.20	7	0.52	19	0.30	4	0.14	20	0.38	4	0.10	10	0.14	2	0.08	0	0.0	0	0.0
	Ochna pulchra	18	0.29	0	0.0	17	0.22	0	0.0	14	0.24	0	0.0	7	0.08	3	0.14	3	0.02	0	0.0
Intermediate	*Burkea Africana*	12	0.21	1	0.04	10	0.13	1	0.03	2	0.15	1	0.11	7	0.09	4	0.51	7	0.16	5	0.63
	Commiphora mossambicensis	23	0.50	12	0.29	11	0.21	7	0.45	9	0.16	5	0.52	3	0.03	0	0.0	0	0.0	0	0.0
	Combretum fragrans	10	0.15	0	0.0	11	0.15	3	0.12	11	0.16	1	0.09	5	0.07	1	0.07	4	0.04	0	0.0
	Combretum zeyheri	9	0.09	0	0.0	8	0.08	8	0.13	11	0.14	4	0.29	2	0.02	1	0.25	0	0.0	0	0.0
	Grewia monticola	10	0.10	1	0.05	14	0.13	3	0.21	13	0.19	10	0.56	4	0.04	3	0.63	0	0.0	0	0.0

AVAILABILITY CATEGORY	SPECIES	SIZE CLASS																			
		0-0.5 m				0.5-1 m				1-2.5m				2.5-5 m				>5 m			
		n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bilty	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance
	Pseudolachnostylis mapreuneifolia	2	0.01	0	0.0	4	0.07	0	0.0	7	0.07	1	0.14	6	0.05	1	0.17	0	0.0	0	0.0
	Terminalia sericea	7	0.08	0	0.0	12	0.15	2	0.10	20	0.26	3	0.11	11	0.06	2	0.12	2	0.01	0	0.0
Uncommon	*Brachystegia boehmii*	5	0.12	3	0.23	5	0.07	3	0.05	5	0.10	3	0.37	4	0.05	0	0.0	3	0.43	3	0.72
	Colophospermum mopane	4	0.08	0	0.0	3	0.03	2	0.05	5	0.06	2	0.37	4	0.04	1	0.25	6	0.12	4	0.28
	Combretum elaeagnoides	3	0.07	0	0.0	0	0.0	0	0.0	4	0.13	3	0.30	4	0.08	1	0.08	2	0.01	0	0.0
	Combretum schumannii	0	0.0	0	0.0	1	0.01	0	0.0	1	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Dichrostachys cinera	4	0.06	1	0.13	5	0.05	1	0.25	6	0.10	2	0.25	4	0.07	3	0.50	0	0.0	0	0.0
	Guibourtia coleosperma	2	0.01	0	0.0	1	0.01	0	0.0	2	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Hippocratea buchananii	5	0.09	1	0.06	0	0.0	0	0.0	2	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Lonchocarpus nelsii	2	0.01	0	0.0	6	0.05	0	0.0	7	0.09	1	0.14	3	0.04	0	0.0	1	0.01	0	0.0
	Pterocarpus angolensis	2	0.01	2	1.0	0	0.0	0	0.0	8	0.07	2	0.31	0	0.0	0	0.0	0	0.0	0	0.0
	Psydrax livida	3	0.04	1	0.11	0	0.0	0	0.0	4	0.03	0	0.0	1	0.01	0	0.0	0	0.0	0	0.0
	Ximenia americana	2	0.01	0	0.0	2	0.01	1	0.50	1	0.01	0	0.0	1	0.01	0	0.0	0	0.0	0	0.0

AVAILABILITY CATEGORY	SPECIES	SIZE CLASS																			
		0-0.5 m				0.5-1 m				1-2.5m				2.5-5 m				>5 m			
		n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bilty	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance
Rare	*Clerodendrum glabrum*	0	0.0	0	0.0	1	0.01	1	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Commiphora africana	2	0.01	1	0.50	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Commiphora pyracanthoides	0	0.0	0	0.0	2	0.02	1	0.50	2	0.03	1	0.33	0	0.0	0	0.0	0	0.0	0	0.0
	Euclea divinorum	2	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Ximenia caffra	3	0.03	0	0.0	1	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Mean			**0.13**		**0.12**		**0.15**		**0.19**		**0.18**		**0.22**		**0.11**		**0.18**		**0.13**		**0.18**

Appendix Table 2.3b Acceptance by height class of woody species encountered by elephant during in the sandveld woodland during the cool-dry season in Chobe National Park, northern Botswana.

AVAILABILITY CATEGORY	SPECIES	HEIGHT CLASS																		
		0-0.5 m				0.5-1 m				1-2.5 m				2.5-5 m				>5 m			
		n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	N	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance
Common	*Baikiaea plurijuga*	18	0.21	0	0.0	17	0.23	0	0.0	18	0.37	0	0.0	21	0.39	0	0.0	23	0.53	0	0.0
	Baphia massaiensis	26	0.50	3	0.07	28	0.59	6	0.09	27	0.62	7	0.10	16	0.24	3	0.16	0	0.0	0	0.0
	Bauhinia petersiana	31	0.78	15	0.29	29	0.68	19	0.37	26	0.56	19	0.43	9	0.09	2	0.17	0	0.0	0	0.0
	Combretum apiculatum	16	0.18	0	0.00	17	0.22	1	0.03	22	0.35	1	0.01	21	0.34	4	0.10	0	0.0	0	0.0
	Diplorhynchus condylocarpon	26	0.62	20	0.42	29	0.68	25	0.56	23	0.51	17	0.40	6	0.04	1	0.17	0	0.0	0	0.0
	Combretum collinum	21	0.20	0	0.0	22	0.27	1	0.02	23	0.36	1	0.02	18	0.24	2	0.10	0	0.0	0	0.0
	Ochna pulchra	30	0.53	0	0.0	27	0.41	0	0.0	24	0.45	0	0.0	10	0.14	0	0.0	0	0.0	0	0.0
Intermediate	*Burkea africana*	29	0.71	0	0.0	24	0.39	0	0.0	22	0.33	2	0.03	12	0.10	0	0.08	0	0.0	0	0.0
	Commiphora mossambicensis	20	0.28	3	0.08	6	0.08	2	0.25	6	0.05	0	0.00	1	0.01	3	0.0	0	0.0	0	0.0
	Combretum fragrans	21	0.29	0	0.0	23	0.31	5	0.17	27	0.43	10	0.27	15	0.16	2	0.12	2	0.03	0	0.0
	Combretum zeyheri	17	0.25	2	0.25	20	0.31	3	0.09	26	0.29	5	0.14	8	0.06		0.29	0	0.0	0	0.0
	Grewia monticola	11	0.08	0	0.0	10	0.12	4	0.19	16	0.24	11	0.50	3	0.04	2	0.39	0	0.0	0	0.0
	Pseudolachnostylis mapreuneifolia	13	0.09	0	0.0	19	0.22	1	0.05	24	0.28	3	0.07	14	0.09	2	0.14	0	0.0	0	0.0
	Terminalia sericea	9	0.10	1	0.11	14	0.15	2	0.06	21	0.21	4	0.17	14	0.17	3	0.13	0	0.0	0	0.0

AVAILABILITY CATEGORY	SPECIES	HEIGHT CLASS																		
		0-0.5 m				0.5-1 m				1-2.5 m				2.5-5 m				>5 m		
		n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	N	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance
Uncommon	*Acacia fleckii*	3	0.05	1	0.17	1	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Brachystegia boehmii	2	0.02	0	0.0	3	0.02	0	0.0	2	0.02	1	0.11	0	0.0	0	0.0	0	0.0	0	0.0
	Combretum celastroides	2	0.02	0	0.0	2	0.01	0	0.0	3	0.02	1	0.17	3	0.04	1	0.33	0	0.0	0	0.0
	Combretum elaeagnoides	4	0.06	0	0.0	1	0.08	1	0.25	3	0.08	3	0.63	6	0.12	3	0.29	0	0.0	0	0.0
	Combretum schumannii	2	0.02	1	0.17	2	0.02	1	0.17	2	0.02	2	0.67	1	0.01	0	0.0	0	0.0	0	0.0
	Dialium engleranum	5	0.05	0	0.0	0	0.0	0	0.0	8	0.08	1	0.06	1	0.01	0	0.0	0	0.0	0	0.0
	Dichrostachys cinera	4	0.05	0	0.0	3	0.04	0	0.0	4	0.02	0	0.0	2	0.01	1	0.50	0	0.0	0	0.0
	Fiesodielsia obovata	4	0.05	0	0.0	5	0.04	0	0.0	7	0.06	1	0.05	5	0.6	2	0.30	0	0.0	0	0.0
	Guibourtia coleosperma	3	0.02	0	0.0	2	0.01	0	0.0	3	0.02	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Pterocarpus angolensis	9	0.07	0	0.0	1	0.08	1	0.13	8	0.09	4	0.34	0	0.0	0	0.0	0	0.0	0	0.0
	Psydrax livida	7	0.09	2	0.17	4	0.06	1	0.25	4	0.02	1	0.25	0	0.0	0	0.0	0	0.0	0	0.0
	Strychnos pangens	7	0.11	0	0.0	2	0.01	0	0.0	2	0.01	1	0.50	0	0.0	0	0.0	0	0.0	0	0.0
	Vitex payos	5	0.04	0	0.0	7	0.05	0	0.0	11	0.02	1	0.09	0	0.0	0	0.0	0	0.0	0	0.0
	Ximenia americana	3	0.02	2	0.67	0	0.0	0	0.0	3	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

AVAILABILITY CATEGORY	SPECIES	HEIGHT CLASS																		
		0-0.5 m				0.5-1 m				1-2.5 m				2.5-5 m				>5 m		
		n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	N	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance
Rare	*Amblygonocarpus andongensis*	5	0.05	0	0.0	3	0.02	0	0.0	3	0.02	1	0.03	0	0.0	0	0.0	0	0.0	0	0.0
	Commiphora mollis	2	0.01	0	0.0	0	0.0	0	0.0	3	0.02	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Commiphora africana	1	0.03	0	0.0	1	0.01	0	0.0	1	0.01	1	1.0	0	0.0	0	0.0	0	0.0	0	0.0
	Kirkia acuminata	2	0.01	1	0.50	1	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Peltophorum africanum	0	0.0	0	0.0	2	0.03	0	0.0	0	0.0	0	0.0	1	0.03	1	1.0	2	0.03	0	0.0
	Securidaca longipedunculata	1	0.01	0	0.0	1	0.01	1	1.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Strychnos coculoides	9	0.08	2	0.15	3	0.02	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Tricalysia cacondensia	2	0.01	1	0.50	1	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Mean			**0.16**		**0.10**		**0.16**		**0.11**		**0.19**		**0.20**		**0.15**		**0.16**		**0.28**		**0.0**

Appendix Table 2.3c Acceptance by height class of woody species encountered by elephant in the sandveld woodland during the hot-dry season in Chobe National Park, northern Botswana.

AVAILABILITY CATEGORY	SPECIES	HEIGHT CLASS																			
		0-0.5 m				0.5-1 m				1-2.5 m				2.5-5 m				>5 m			
		n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance
Common	*Baikiaea plurijuga*	21	0.15	0	0.0	27	0.17	0	0.0	39	0.37	0	0.0	42	0.36	0	0.0	47	0.56	0	0.0
	Baphia massaiensis	4	0.02	4	1.0	53	0.46	18	0.18	52	0.73	48	0.68	45	0.41	35	0.56	1	0.03	1	0.33
	Bauhinia petersiana	5	0.02	5	1.0	53	0.54	18	0.14	54	0.66	33	0.28	27	0.20	10	0.26	12	0.06	0	0.0
	Combretum apiculatum	17	0.09	2	0.09	29	0.14	4	0.08	47	0.37	15	0.16	0	0.0	0	0.0	0	0.0	0	0.0
	Diplorhynchus condylocarpon	32	0.21	7	0.09	24	0.22	8	0.22	24	0.19	13	0.29	0	0.0	0	0.0	0	0.0	0	0.0
	Combretum collinum	29	0.14	1	0.02	39	0.23	8	0.12	52	0.41	38	0.51	30	0.17	18	0.51	0	0.0	0	0.0
	Ochna pulchra	34	0.36	0	0.0	35	0.43	0	0.0	42	0.64	0	0.0	7	0.07	0	0.0	8	0.06	0	0.0
Intermediate	*Burkea africana*	21	0.12	1	0.02	20	0.11	5	0.16	28	0.21	12	0.26	13	0.05	3	0.23	17	0.14	0	0.0
	Commiphora mossambicensis	34	0.22	8	0.14	26	0.18	7	0.17	23	0.14	25	0.20	14	0.07	1	0.07	0	0.0	0	0.0
	Combretum fragrans	24	0.14	4	0.11	31	0.19	14	0.32	34	0.30	26	0.57	16	0.10	12	0.52	0	0.0	0	0.0
	Combretum zeyheri	9	0.04	0	0.0	27	0.14	11	0.29	34	0.28	25	0.56	12	0.08	9	0.68	0	0.0	0	0.0
	Erythrophleum	19	0.21	0	0.0	10	0.05	0	0.0	34	0.30	0	0.0	9	0.04	2	0.22	14	0.06	0	0.0

AVAILABILITY CATEGORY	SPECIES	HEIGHT CLASS																			
		0-0.5 m				0.5-1 m				1-2.5 m				2.5-5 m				>5 m			
		n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance
	africanum																				
	Grewia monticola	12	0.06	5	0.42	22	0.08	3	0.14	0	0.0	0	0.0	12	0.07	11	0.78	0	0.0	0	0.0
	Pseudolachnostylis mapreuneifolia	5	0.02	0	0.0	16	0.06	1	0.06	29	0.19	8	0.16	0	0.0	0	0.0	5	0.02	0	0.0
Uncommon	*Terminalia sericea*	15	0.06	0	0.0	31	0.17	7	0.16	40	0.38	18	0.23	36	0.31	16	0.28	20	0.11	5	0.13
	Acacia fleckii	0	0.0	0	0.0	2	0.01	0	0.0	6	0.03	1	0.08	5	0.03	1	0.10	6	0.03	2	0.22
	Combretum celastroides	0	0.0	0	0.0	3	0.01	1	0.33	3	0.04	2	0.50	5	0.04	1	0.07	0	0.0	0	0.0
	Combretum elaeagnoides	3	0.01	0	0.0	9	0.07	4	0.29	10	0.09	7	0.51	10	0.11	5	0.24	5	0.03	2	0.33
	Combretum schumannii	3	0.03	0	0.0	3	0.03	3	0.44	6	0.07	3	0.38	0	0.0	0	0.0	0	0.0	0	0.0
	Amblygonocarpus andongensis	3	0.01	0	0.0	0	0.0	0	0.0	3	0.02	1	0.17	0	0.0	0	0.0	0	0.0	0	0.0
	Dialium engleranum	2	0.01	1	0.25	2	0.01	1	0.50	3	0.02	0	0.0	5	0.04	2	0.18	0	0.0	0	0.0
	Dichrostachys cinera	6	0.02	1	0.17	7	0.03	2	0.22	5	0.04	2	0.18	4	0.03	1	0.06	2	0.01	1	0.50
	Diospyros batocana	3	0.02	0	0.0	0	0.0	0	0.0	2	0.01	2	1.0	0	0.0	0	0.0	0	0.0	0	0.0
	Grewia flava	0	0.0	0	0.0	3	0.02	1	0.17	5	0.05	3	0.23	2	0.01	0	0.0	0	0.0	0	0.0

AVAILABILITY CATEGORY	SPECIES	HEIGHT CLASS																			
		0-0.5 m				0.5-1 m				1-2.5 m				2.5-5 m				>5 m			
		n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance	n	Availa-bility	n	Accep-tance
	Guibourtia coleosperma	4	0.01	2	0.50	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Hippocratea buchananii	2	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Lonchocarpus nelsii	0	0.0	0	0.0	2	0.01	0	0.0	2	0.01	0	0.0	3	0.03	0	0.0	0	0.0	0	0.0
	Markamia acuminata	10	0.05	0	0.0	13	0.06	0	0.0	18	0.11	0	0.0	16	0.10	1	0.03	5	0.02	0	0.0
	Pterocarpus angolensis	5	0.02	1	0.20	10	0.04	2	0.20	11	0.04	3	0.27	8	0.03	1	0.13	0	0.0	0	0.0
	Psydrax livida	2	0.01	0	0.0	3	0.01	0	0.0	5	0.02	2	0.27	0	0.0	0	0.0	0	0.0	0	0.0
	Vitex payos	3	0.02	0	0.0	18	0.08	0	0.0	31	0.19	7	0.10	9	0.03	2	0.22	0	0.0	0	0.0
	Ximenia americana	7	0.02	0	0.0	0	0.0	0	0.0	15	0.06	9	0.53	2	0.01	0	0.0	0	0.0	0	0.0
Rare	*Adansonia digitata*	3	0.01	0	0.0	0	0.0	0	0.0	3	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Baissea wulfhorstii	3	0.03	2	0.75	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Commiphora pyracanthoides	0	0.0	0	0.0	0	0.0	0	0.0	4	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Kirkia acuminata	0	0.0	0	0.0	4	0.01	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Pteleopsis myrtifolia	2	0.01	0	0.0	5	0.02	1	0.20	7	0.06	0	0.0	6	0.05	2	0.22	0	0.0	0	0.0
Mean			**0.07**		**0.15**		**0.12**		**0.14**		**0.18**		**0.28**		**0.10**		**0.18**		**0.12**		**0.14**

CHAPTER 3

COMPOSITION AND SEASONAL VARIATION OF WOODY PLANT DIET OF ELEPHANT

3.1 Introduction

The African elephant *(Loxodonta africana,* Blumenbach 1797*)* has been classified as both a browser and grazer, or mixed feeder (Owen-Smith, 1982, 1988, 1992) utilizing a wide range of species and altering their food habits in relation to season (Bax and Sheldrick, 1963; Field and Ross, 1976; Barnes, R.F.W, 1979, 1982; Kabigumila, 1993). *Grazing* refers to the utilization of grass and other graminoid plants, while *browsing* refers to the utilization of dicotyledonous plants, both woody and herbaceous (Owen-Smith, 1992).

The browse : grass ratio in elephant diet seems to be a function of availability but where both were readily available, a higher proportion of grass was consumed in the wet season while woody plant parts formed a higher percentage of the food intake in the dry season. Due to a higher abundance of grass than woody vegetation, grass supplied much of the dietary bulk for elephant throughout the year in the national parks of Uganda particularly Murchison Falls (Buss, 1961; Laws and Parker, 1968; Wing and Buss, 1970), Queen Elizabeth (Field, 1971) and Kidepo Valley (Field and Ross, 1976). In the wooded savannas of east and southern Africa, grass provided the bulk of elephant diet in the wet season, while in the dry season woody vegetation parts composed much of the diet (Williamson, 1975; Guy, 1976; Barnes, R.F.W, 1982). The diet of the forest elephant (*L. a. cyclotis,* Matschie 1900) inhabiting forests with limited availability of grass in west and central Africa is primarily composed of browse and fruits (Short, 1981; White et al., 1993).

The food of herbivores has tended to be categorized in terms of plant species and this may be misleading as young and old shoots on the same plant may differ more widely in their nutrient contents than similarly aged leaves from different species (Owen-Smith, 1982, 1992). Within the savanna woodland, the woody vegetation component

of elephant diet consisted mainly of leaves during the wet season while woody materials dominated during the dry season when bark, roots and fruits were also included in the diet (Barnes, R.F.W., 1982; Williamson, 1975; Field and Ross, 1976; Guy, 1976; Jachmann and Bell, 1985).

Factors influencing consumption of woody plant parts by herbivores has been a subject of debate. The nutritive value of vegetation components was found to vary with growth stage, season, soil type and plant species (Owen-Smith, 1982; Owen-Smith and Cooper, 1988). At critical times of the year such as the dry season, herbivore species may be energy-limited (Bryant et al, 1980; Owen-Smith and Cooper, 1989), or protein limited (Bell, 1971; Sinclair, 1975).

Requirements for specific minerals such as calcium and magnesium were believed to influence the selective utilization of woody vegetation components by elephant (Bax and Sheldrick, 1963; Williamson, 1975; Dougall and Sheldrick, 1964; Jachmann and Bell, 1985). But Jachmann (1987) was of the opinion that woody vegetation selection by elephant was related to the avoidance of secondary metabolites as represented by condensed tannins. Tannins are secondary compounds which may reduce the digestibility of plant parts consumed (Cates and Rhoades, 1977 cited by Owen-Smith, 1982; Robbins et al., 1987).

In the wet season, elephants prefer grass to browse despite the generally higher crude protein content in dicotyledonous foliage than in grass (Dougall et al., 1964; Field, 1971). This may be due to the fact that grass has generally low levels of tannins and toxic substances (Owen-Smith, 1982). However, grasses rapidly become fibrous thereby diluting the nutrients present (Dougall et al., 1964; Bell, 1971). Browse was considered to be a dry season food reserve (Bell, 1985) as woody vegetation components maintain a relatively higher and seasonally constant crude protein content (Owen-Smith, 1982; Barnes, D.L., 1982).

3.1.1 Objectives

The objective of the study was to determine the seasonal dietary importance of (i) different woody plant species (ii) size classes and (iii) plant parts to the diet of elephant and (iv) how these aspects varied seasonally.

3.1.2 Research questions

The specific questions to be addressed in this study were:

(a) What was the diet composition obtained by the elephants in terms of plant parts? This question relates to the relative dependence of elephants on foliage, structural tissues (stems and bark), underground parts and reproductive parts (fruits). This may bear on elephant being labelled as folivores, woody stem browsers, rhizophages or frugivores or some mix thereof in comparison to other species termed browsers.

(b) What was the dietary importance of different woody species? This question concerns how broad or narrow elephant diet is in terms of the species composition of the vegetation consumed (specialist/ generalist in floristic composition).

(c) What was the dietary importance of different size classes in terms of plant parts? This question relates to the accessibility or suitability of woody plants of different size classes utilized by elephant and dependence of elephants upon particular vegetation layers.

3.1.3 Hypothesis

The proportions of different woody plant parts utilised by elephant from woody species and size classes do not differ among seasons.

3.2 Study Area

A full description of the study area was given in Chapter 2.

3.3 Observation and data recording methods

Data collection commenced in August, 1992 and ended in July, 1993, and included the seasons: wet (November-April), cool-dry (May-July) and hot-dry (August-October).

This involved computerized data recording of using plant-based and animal-based methods, as fully described in Chapter 2. The recorded feeding actions of elephant on a plant species included feeding actions such as branch breaking, uprooting, debarking, pushing over, leaf stripping, digging for roots or snapping of stems and twigs. For each feeding action, a record was made for the consumption of each of the following plant parts if it ocurred (a) leaves (b) stems (c) shoots (d) bark of stems (e) roots (f) bark of roots (g) fruits and (h) any other plant part or growth form such as flowers, forbs, creepers and fallen leaves. Plant species were categorized by height classes defined to span 0-0.5 m, 0.5-1 m, 1.0-2.5 m, 2.5-5 m and > 5 m.

The term leaves refers to leaves that are individually plucked or stripped off the woody plants and consumed. Shoots refers to a mixture of leaves and terminal twigs or supporting stems and leaves that are broken off and eaten together. Stems refer to twigs and supporting stems that have no leaves or may have been stripped of leaves before being consumed. Roots refer to the subterranean portion of a woody plant. Bark refers to tissues external to the cambium in a stem or root that can be peeled off and consumed. Flowers refer to all forms of inflorescence that are fed on. Fruits refer to pods, seeds, soft fruits such as berries or drupes.

3.4 Data analysis

Systat statistical package (Wilkinson et al., 1992) was used for statistical data analysis. A significance level test of 95% (α=0.05) was preselected and used constantly throughout the various statistical analyses.

3.4.1 Calculations of dietary importance of plant species, part and size class.

The dietary importance of a plant species to the diet of elephant was a function of plant species acceptance, availability and plant parts utilized on a feeding site. Hence, acceptances and availabilities of woody species were used as weighting factors on records of plant parts utilized to determine dietary importance of different woody species.

The term acceptance reflects the likelihood of an animal commencing feeding on a species when that species is nearby (Owen-Smith, 1979; Owen-Smith and Cooper, 1987). Woody species availabilities and acceptances by elephant were calculated as described in Chapter 2 of this thesis.

The relationship of the relative dietary importance of a woody species to acceptance, availability and frequency of plant parts utilized per site can be described as follows:

$$WDC = PF*AC*AV$$

where *WDC* = weighted dietary importance per site

AC = acceptance frequency per site

AV=proportional availability per site

PF = plant part records

The relative dietary importance of each woody species was calculated by dividing the weighted dietary importance for each species by the total weighted dietary importance for all species. The relative plant part dietary importance of plant species and size classes were similarly calculated.

3.4.2 Analysis of variance

Within and between season differences in woody species or plant part dietary importance of commonly accepted woody species were determined by a one way analysis of variance of site acceptance frequencies (Wilkinson et al., 1992). Differences in plant part dietary importance between and within seasons were determined by pairwise comparisons or contrast i.e. using coefficients of linear combination of means (Steel and Torrie, 1980; Wilkinson et al., 1992).

3.4.3 Chi-square test

The chi-square goodness of fit test (Zar, 1996; Box et al., 1978) was used to determine differences in the frequencies of woody plant parts utilized from different height classes in different seasons as indicated in Appendix Table 3.2.

3.5 Results

3.5.1 Seasonal dietary importance by woody species

Within each season an average of 55% of the woody plant component of elephant diet was provided by one to two woody species, while each of the remaining species contributed <15% each (Figure 3.1a-c, Appendix Table 3.1). Woody species which were seasonally important were *Baphia massaiensis* (wet and hot-dry seasons), *Bauhinia petersiana* (wet and cool-dry season) and *Diplorhynchus condylocarpon* (cool-dry season). None of the woody species had a consistent dietary importance over all the seasons.

About 60% of woody species diet of elephant in the wet season was provided by *B. massaiensis* and *B. petersiana* (Appendix Table 3.1). *B. petersiana* and *D. condylocarpon* provided about 70% of the cool-dry season woody species diet of elephant compared to all the other species. All other woody species contributed less than 10% each towards the woody species diet of elephant.

The most important woody species during the hot-dry season was *B. massaiensis* with a dietary importance of about 35%. The woody species elephant diet was widened in the hot-dry season by including *B. petersiana*, *Combretum collinum, C. fragrans* and *Combretum zeyheri*, *Grewia monticola,* contributing about 7-10% each.

There were no significant seasonal differences in the dietary importance for *B. massaiensis* between the wet and hot-dry seasons (ANOVA, $F_{(1,100)}=2.81$, $P=0.10$). However, the seasonal dietary importance of *B. massaiensis* was greater during the hot-dry season than the cool-dry season (ANOVA, $F_{(1,100)}=23.85$, $P<0.001$) and greater during the wet season than in the cool-dry season (ANOVA, $F_{(1,100)}=5.56$, $P=0.02$). Similarly, there were no significant seasonal differences in dietary importance of *B. petersiana* between the wet and cool-dry seasons (ANOVA, $F_{(1,112)}=0.014$, $P=0.907$). However, the dietary importance of *B. petersiana* was greater in the wet season than in the hot-dry season (ANOVA, $F_{(1,112)}=17.9$, $P<0.001$) and greater during the cool-dry season than in the hot-dry season (ANOVA, $F_{(1,112)}=23.96$, $P<0.001$).

3.6 Dietary importance by woody plant parts

3.6.1 Plant part dietary importance during the wet season

The most important plant parts during the wet season were leaves and shoots and their relative dietary importance to the total woody plant part diet were about 45% and 25% respectively (Fig. 3.2a, Table 3.1). Most of the leaves were taken from *B. massaiensis* and *B. petersiana* and the two species contributed about 80% of the leaf diet component (Appendix Table 3.1). The bulk of shoots were provided by *B. petersiana* (48%) and to a lesser extent by *B. africana, C. mossambicensis* and *Pseudolachnostylis maprouneifolia,* which all contributed in total of about 30%.

3.6.2 Plant part dietary importance during the cool-dry season

About 40% of the woody plant part was composed of stems followed by leaves (25%) and shoots (24%) (Fig. 3.2b, Table 3.1). Much of the stem diet component was provided by *D. condylocarpon* (68%) (Appendix Table 3.1). Most of the leaves were taken from *B. petersiana* (78%) with limited contribution from *B. massaiensis* (14%). *B. petersiana* provided about 77% of the shoots while *B. massaiensis* contributed about 17%.

3.6.3 Plant part dietary importance during the hot-dry season

The hot-dry season woody plant part diet was composed mainly of stems (55%) as well as bark of stems (27%) and roots (13%) (Fig. 3.2c, Table 3.1). About 40% of the stems and 46% of bark of stems were taken from *B. massaiensis. C. collinum, C. fragrans* and *C. zeyheri* contributed 10-12% of the stems; *G. monticola, T. sericea* and *C. zeyheri* each provided about 9-14% of the bark of stem (Appendix Table 3.1). A wide variety of woody species were utilized for roots during the hot-dry season. About 80% of the root diet component was provided by *B. petersiana, C. fragrans, C. zeyheri, Combretum mossambicensis, G. monticola* and *T. sericea* and the dietary importance of each species ranged from 8% to 28%.

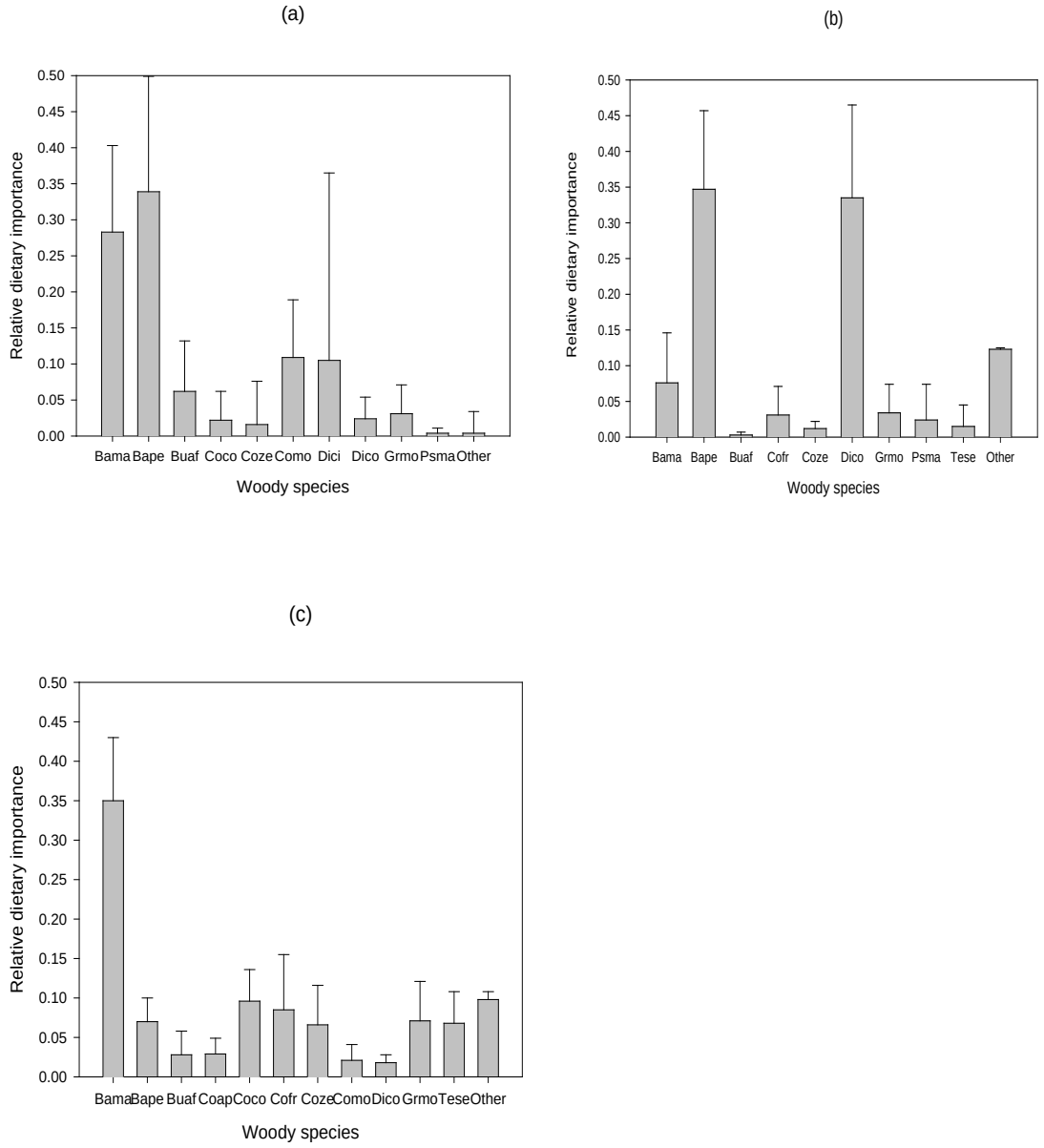

Figure 3.1. Relative woody species dietary importance to elephant during (a) wet season (b) cool-dry season and (c) hot-dry season in northern Botswana. Woody species acronyms used are: Bama=*Baphia massaisensis*, Bape=*Bauhinia petersiana*, Buaf=*Burkea africana*, Coap=*Combretum apiculatum*, Coco=*Combretum collinum*, Cofr=*Combretum fragrans*, Como=*Commiphora mossambicensis*, Coze=*Combretum zeyheri*, Dico=*Dichrostachys cinera*, Grmo=*Grewia monticola*, Psma=*Pseudolachnostylis maprouneifolia*, Tese=*Terminalia sericea*, Other=all other species combined.

3.6.4 Between season differences in plant part dietary importance

As indicated above, the commonly utilized woody plant parts, depending on season, were stems, leaves, shoots, bark of stems and roots. There was a significant difference in the amount of stems utilized among the three seasons (ANOVA, $F_{(2,118)}=47.77$, $P<0.001$). The least amount of stems was utilized during the wet season compared to the cool-dry and hot dry-seasons.

Roots and bark of stems were important during the hot dry-season only, and no comparison between seasons could be done due to inadequate sample sizes during the other seasons. The seasonal utilization of leaves showed a significant difference among seasons ($F_{(2,118)}=72.6$, $P<0.001$), but no significant difference between the wet and cool-dry seasons ($P=0.702$) as indicated by the pairwise comparison using the Bonferroni adjustment.

3.6.5 Dietary importance by height classes

The woody plant part diet of elephant was predominantly taken from the height class 1-2.5 m over all the seasons (Fig. 3.3 a-c, Appendix Table 3.2). The height class interval ≥ 5m contributed little over all the seasons. The dietary importance of the size class ≤1 m was greater during the wet and cool-dry seasons compared to the hot dry seasons. Fig. 3.4 shows the woody species dietary importance by height class. During the wet season, most of the plant parts with the exception of roots were taken from the height class 1-2.5 m (Fig. 3.4a, Appendix Table 3.2) and most of the roots were taken from height classes≤1 m.

During the cool-dry season, the favoured height class for leaves, stems and shoots included all size classes up to 5 m while roots while bark of stem was utilized mostly from the height class 1-2.5 m (Fig. 3.4b, Appendix Table 3.2). Utilization of fruits was recorded for B. petersiana and these were taken from the height class 1-2.5 m. For the hot-dry season, most of the plant parts were selected from the height class 1-2.5 m (Fig 3.4c, Appendix Table 3.2) with the exception of bark of root which was taken from size classes >1m and leaves from size class 0.5-1 m.

Table 3.1 Seasonal importance of woody plant parts to elephants diet. The number of sites sampled are wet season *n=27;* cool-dry season, *n=34;* hot dry-season, *n=60.* The ± refers to the 95% confidence limits.

PLANT PART	WET SEASON			COOL-DRY SEASON			HOT-DRY SEASON		
	Total plant part Records	Plant part records per site	Relative dietary importance	Total plant part Records	Plant part records per site	Relative dietary importance	Total plant part Records	Plant part records per site	Relative dietary importance
Stems	91	0.67	0.110±06	455	2.73	0.416±09	1154	3.88	0.548±05
Shoots	206	1.53	0.250±08	254	1.58	0.241±06	26	0.09	0.013±01
Leaves	378	2.8	0.458±11	274	1.61	0.245±06	19	0.07	0.010±01
Root	75	0.56	0.092±06	37	0.2	0.027±03	274	0.91	0.129±04
Bark of stem	62	0.46	0.075±05	27	0.18	0.070±08	576	1.93	0.273±05
Bark of root	12	0.09	0.011±01	0	0	0	61	0.2	0.028±03
Fruit	0	0	0	45	0.26	0.040±05	0	0	0

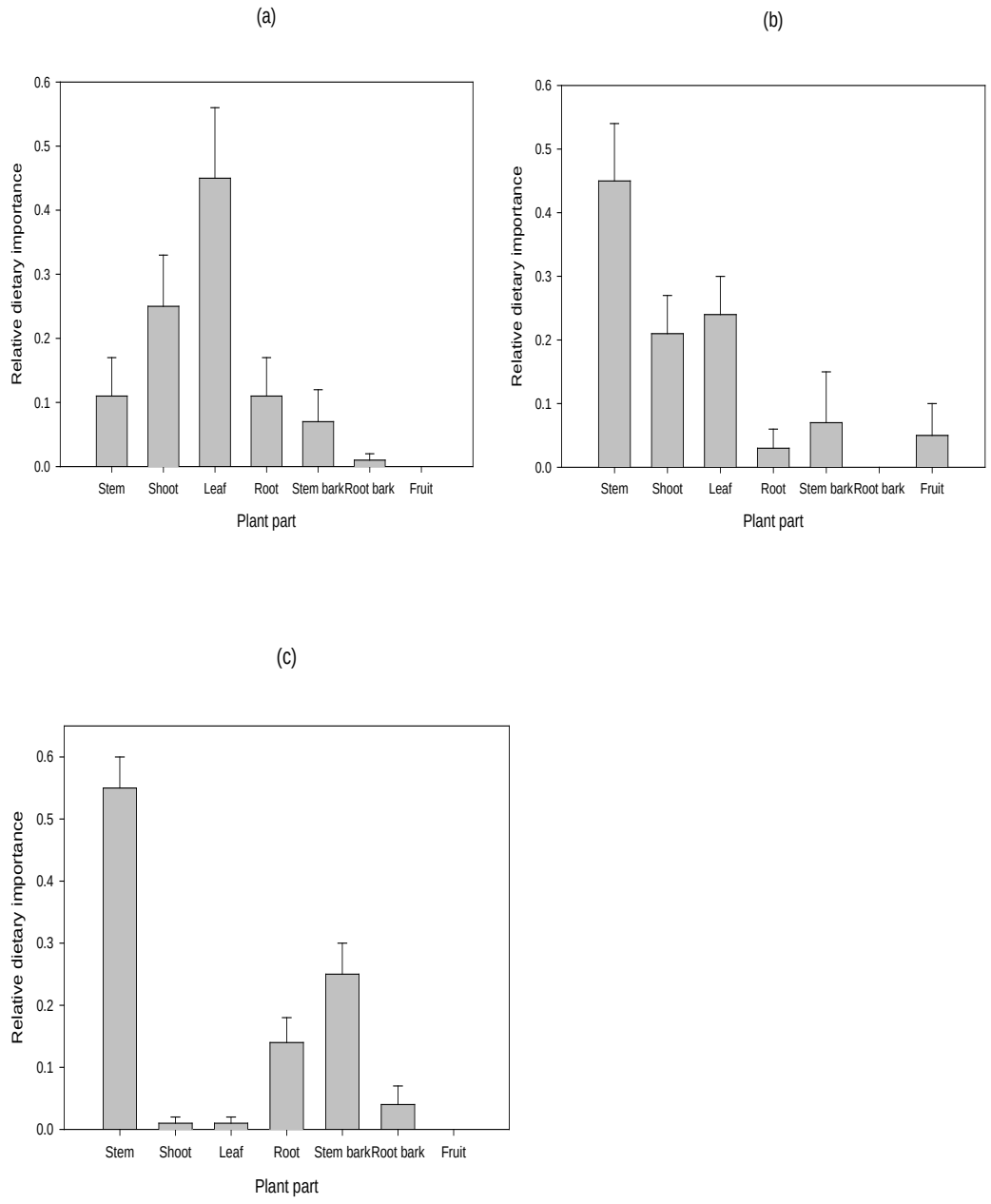

Figure 3.2 Seasonal variation of importance of woody species height class to elephant diet in Chobe National Park, northern Botswana during (a) wet season (b) cool-dry season and (c) hot dry season.

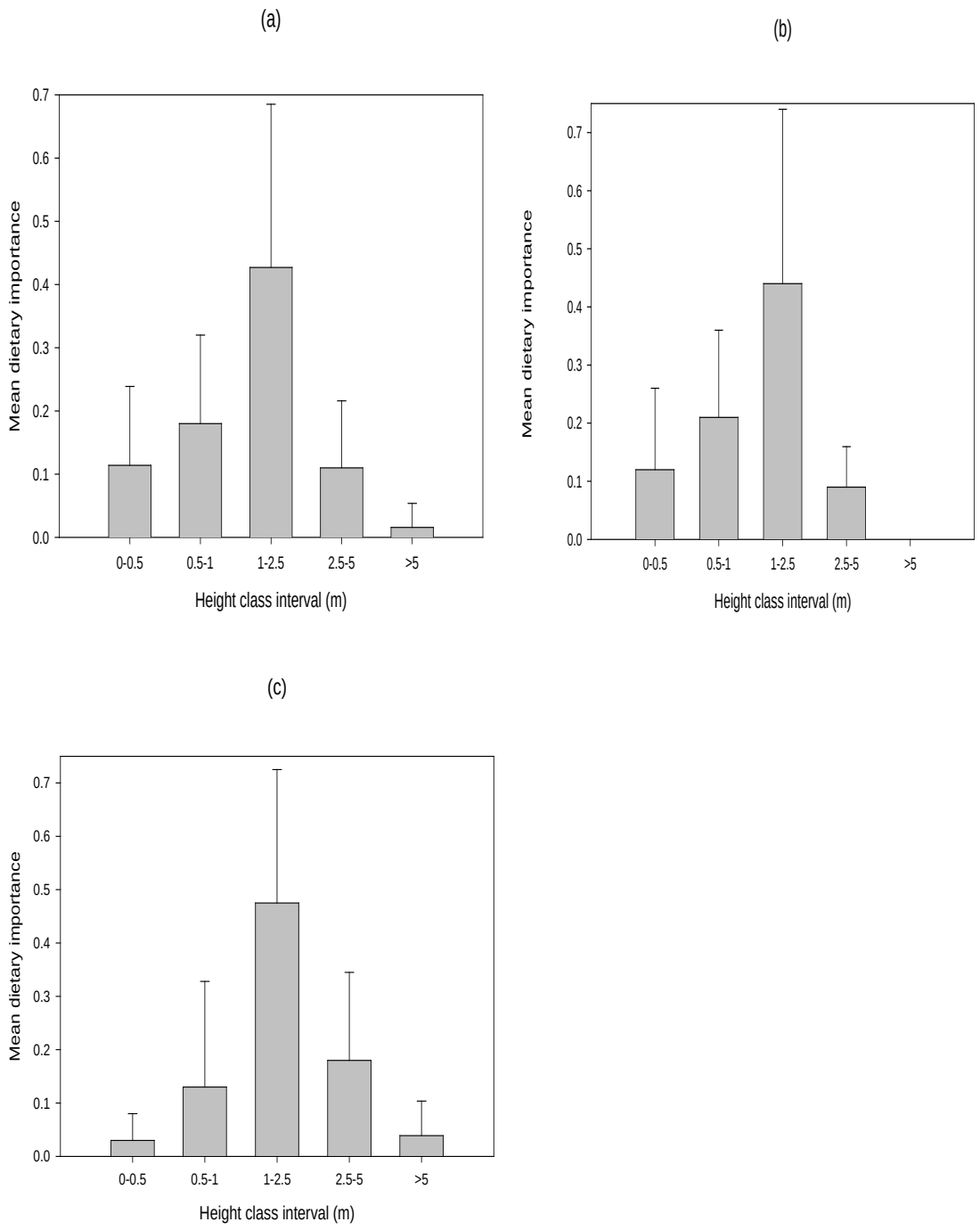

Figure 3.3 Overall woody species importance by height class to elephant diet in Chobe National Park, northern Botswana.

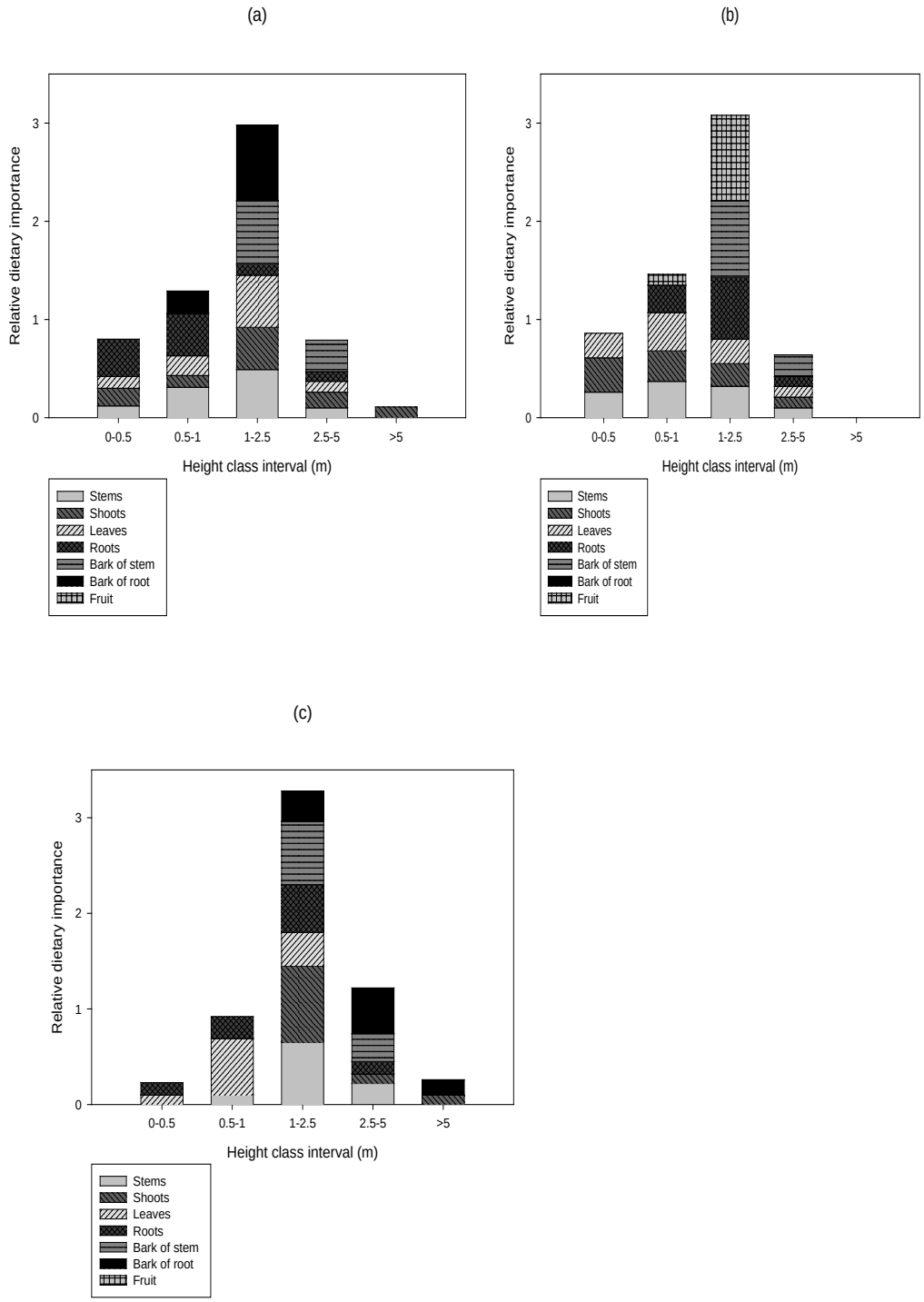

Figure 3.4 Dietary importance of plant parts by height class to elephant during (a) wet season (b) cool-dry season and (c) hot dry season in northern Botswana.

3.7 Discussion

Elephants utilized the following woody plant parts which varied in relative dietary importance to elephant the seasonal cycle: stems, shoots, leaves, root, bark of stem, bark of root and fruit. Elephant depended mainly on foliage (leaves and shoots) during the wet season, stems and foliage (cool-dry season) and structural tissues (stems and bark) during the hot-dry season. No woody species or plant part was consistently important over all the seasons.

The above observations confirmed earlier findings that, within the Africa savanna woodland, the woody vegetation component of elephant diet consisted mainly of leaves during the wet and cool-dry seasons, while structural tissue (stems and bark) including roots dominated elephant diet during the hot-dry season (Barnes, R.F.W., 1982; Williamson, 1975; Field and Ross, 1976; Guy, 1976; Jachmann and Bell, 1985). However, the contribution of this study in this respect was to quantify the relative proportions of these plant parts included in the elephant diet over the seasonal cycle within the study area. In addition, the elephant diet was quite narrow in terms of woody species included in the diet. Only one to two woody species dominated the diet with two of these species being included in the diet either jointly or alternately in any one season.

An interesting observation of elephant feeding habit was the manner in which some woody plant parts were either utilized or discarded. Notable was the observation that during the cool-dry season, elephant stripped off and discarded leaves of *D. condylocarpon* and utilised stems only. This habit was also observed to occur in *Combretum* species including *Combretum elaeagnoides, C. collinum, C. fragrans, and C. zeyheri*. However, determining the reasons for this observation was beyond the scope of this study, but could be related to the nutritive values of these plant parts (Owen-Smith, 1982, Robbins et. al., 1987).

Elephant generally utilized plant parts from the intermediate height categories (1-2.5 m), but were not narrowly selective for plant height classes with respect to specific plant parts. The utilization of plant parts from intermediate height classes has been a

common observation in related studies as observed in the same study area (Stokke and du Toit, 2000) and elsewhere (Guy, 1976, Jachmann and Bell, 1985).

The consumption by herbivores of specific woody plants parts was categorized by Owen-Smith and Danckwerts (1997) as folivory (consumption of leaves and supporting soft stems), granivory (consumption of seeds), frugivory (consumption of fruits), rhizophagy (consumption of roots), stem browsing (consumption of stems and bark). The results of this study suggest that elephant cannot be placed in any one herbivory category with respect to browsing on woody species. The results indicate that while elephant subsist on a narrow range of woody species either or a combination of folivory and stem browsing may dominate in any one season.

3.8 Conclusions

3.8.1 The results indicate that elephant subsisted on a narrow range of woody species whereby only one to two woody species dominated by being included in the diet either jointly or alternately in any one season.

3.8.2 With respect to browsing elephant showed a relative dependence on (a) leaves and supporting soft stems and/or (b) stems and bark for a given season.

3.8.3 Elephant utilized woody plant parts from a wide range of woody species but generally showed a dependence on the intermediate height classes.

Appendix Table 3.1 Seasonal woody plant species and plant part dietary importance to elephant in northern Botswana. The acceptance and availability frequencies were derived in Chapter 2 (Table 2.2).

PLANT SPECIES	RELATIVE WOODY SPECIES DIETARY IMPORTANCE							RELATIVE WEIGHTED PLANT PART DIETARY IMPORTANCE						
	Season	**Sites**	**Availability**	**Acceptance**	**Plant part records**	**Weighted site Records**	**Relative dietary importance**	**Stems**	**Shoots**	**Leaves**	**Root**	**Bark of stem**	**Bark of root**	**Fruit**
Baphia massaiensis	**Wet**	20	0.72	0.48	177	1.27	0.283±0.12	0.25	0.05	0.34	0.0	0.15	0.0	0.0
Bauhinia petersiana		24	0.62	0.54	211	1.52	0.339±0.16	0.15	0.48	0.46	0.16	0.0	0.0	0.0
Burkea Africana		19	0.21	0.29	34	0.28	0.062±0.07	0.08	0.09	0.03	0.0	0.0	0.0	0.0
Combretum collinum		24	0.20	0.15	25	0.10	0.022±0.04	0.04	0.03	0.0	0.0	0.04	0.0	0.0
Combretum zeyheri		18	0.09	0.20	13	0.07	0.016±0.06	0.06	0.0	0.0	0.03	0.12	0.0	0.0
Commiphora mossambicensis		23	0.56	0.37	77	0.49	0.109±0.08	0.19	0.15	0.09	0.69	0.0	0.0	0.0
Dichrostachys cinerea		8	0.06	0.36	32	0.47	0.105±0.26	0.03	0.04	0.0	0.0	0.15	0.0	0.0
Diplorhynchus condylocarpon		21	0.36	0.15	22	0.11	0.024±0.03	0.04	0.02	0.0	0.0	0.0	0.0	0.0
Grewia monticola		20	0.37	0.41	28	0.14	0.031±0.04	0.02	0.01	0.04	0.00	0.22	0.0	0.0
Pseudolachnostylis maprouneifolia		13	0.01	0.12	3	0.02	0.004±0.007	0.0	0.06	0.0	0.0	0.10	0.0	0.0
Other		**164**			**198**	**0.02**	**0.004±0.03**	**0.14**	**0.07**	**0.04**	**0.12**	**0.22**	**0.0**	**0.0**
Baphia massaiensis	**Cool-dry**	29	0.76	0.21	75	0.45	0.089±0.07	0.07	0.17	0.14	0.0	0.0	0.0	0.0
Bauhinia petersiana		34	0.86	0.59	409	1.95	0.384±0.11	0.04	0.77	0.78	0.69	0.0	0.0	0.80
Burkea Africana		30	0.69	0.03	6	0.01	0.002±0.004	0.0	0.0	0.0	0.0	0.16	0.0	0.0
Combretum fragrans		13	0.16	1	38	0.40	0.079±0.04	0.06	0.01	0.0	0.19	0.0	0.0	0.0
Combretum zeyheri		28	0.53	0.15	19	0.09	0.018±0.01	0.02	0.0	0.0	0.12	0.0	0.0	0.0
Diplorhynchus condylocarpon		30	0.9	0.71	299	1.81	0.356±0.13	0.68	0.03	0.0	0.0	0.0	0.0	0.0
Grewia monticola		23	0.34	0.39	48	0.19	0.037±0.04	0.0	0.0	0.0	0.0	0.43	0.0	0.0
Terminalia sericea		27	0.44	12	18	0.08	0.016±0.03	0.0	0.0	0.0	0.0	0.24	0.0	0.0
Other		**226**			**156**	**0.06**	**0.012±0.002**	**0.13**	**0.02**	**0.20**	**0.0**	**0.0**	**0.0**	**0.20**

PLANT SPECIES	RELATIVE WOODY SPECIES DIETARY IMPORTANCE							RELATIVE WEIGHTED PLANT PART DIETARY IMPORTANCE						
	Season	**Sites**	**Availability**	**Acceptance**	**Plant part records**	**Weighted site Records**	**Relative dietary importance**	**Stems**	**Shoots**	**Leaves**	**Root**	**Bark of stem**	**Bark of root**	**Fruit**
Baphia massaiensis	**Hot-dry**	55	0.85	0.66	623	1.94	0.378±0.08	0.40	0.31	0.17	0.0	0.46	0.0	0.0
Bauhinia petersiana		57	.0.82	0.34	156	0.32	0.062±0.03	0.04	0.0	0.08	0.19	0.0	0.18	0.0
Burkea Africana		39	0.39	0.19	55	0.13	0.025±0.03	0.02	0.06	0.0	0.01	0.04	0.0	0.0
Combretum apiculatum		51	0.59	0.25	88	0.15	0.029±0.02	0.05	0.01	0.08	0.04	0.0	0.0	0.0
Combretum collinum		57	0.61	0.43	149	0.25	0.049±0.04	0.12	0.03	0.0	0.04	0.02	0.0	0.0
Combretum fragrans		39	0.41	0.54	156	0.57	0.111±0.07	0.10	0.15	0.0	0.11	0.0	0.0	0.0
Combretum zeyheri		39	0.34	0.57	151	0.51	0.099±0.05	0.10	0.0	0.08	0.28	0.09	0.0	0.0
Commiphora mossambicensis		42	0.37	0.3	47	0.11	0.021±0.02	0.01	0.0	0.0	0.09	0.03	0.02	0.0
Diplorhynchus condylocarpon		40	0.41	0.23	56	0.13	0.025±0.01	0.04	0.0	0.25	0.01	0.0	0.03	0.0
Grewia monticola		34	0.35	0.61	144	0.55	0.0107±0.05	0.01	0.31	0.0	0.08	0.14	0.06	0.0
Terminalia sericea		48	0.53	0.39	148	0.39	0.076±0.04	0.01	0.0	0.0	0.08	0.11	0.68	0.0
Other		**318**			**265**	**0.08**	**0.016±0.01**	**0.11**	**0.13**	**0.33**	**0.07**	**0.11**	**0.03**	**0.0**

Appendix Table 3.2 Dietary importance of different plant species by height classes to elephant in northern Botswana. The number of sites sampled are wet season n=27; cool-dry season, n=34; hot dry-season, n=60.

PLANT PART	WET SEASON						COOL- DRY SEASON						HOT-DRY SEASON					
	Plant Part Records	Relative dietary importance by height class intervals					Plant Part Records	Relative dietary importance by height class intervals					Plant Part Records	Relative dietary importance by height class intervals				
		0-0.5 (m)	0.5-1 (m)	1-2.5 (m)	2.5-5 (m)	>5 (m)		0-0.5 (m)	0.5-1 (m)	1-2.5 (m)	2.5-5 (m)	>5 (m)		0-0.5 (m)	0.5-1 (m)	1-2.5 (m)	2.5-5 (m)	>5 (m)
Stems	91	0.12	0.31	0.49	0.1	0.0	455	0.26	0.37	0.32	0.1	0.0	1154	0.0	0.1	0.65	0.22	0.0
Shoots	206	0.18	0.12	0.43	0.16	0.11	254	0.35	0.31	0.23	0.11	0.0	26	0.0	0.0	0.8	0.1	0.1
Leaves	378	0.12	0.2	0.53	0.11	0.0	274	0.25	0.39	0.25	0.11	0.0	19	0.1	0.59	0.35	0.0	0.0
Roots	75	0.38	0.43	0.11	0.1	0.0	31	0.0	0.28	0.63	0.1	0.0	273	0.13	0.23	0.5	0.13	0.0
Bark of stem	62	0.0	0	0.65	0.32	0.0	27	0.0	0.0	0.78	0.22	0.0	576	0.0	0.0	0.66	0.29	0.0
Bark of root	12	0.0	0.23	0.77	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	61	0.0	0.0	0.32	0.48	0.16
Fruit	0	0.0	0.0	0.0	0.0	0.0	45	0.0	0.11	0.87	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
Mean	**118**	**0.11**	**0.18**	**0.43**	**0.12**	**0.02**	**155**	**0.12**	**0.21**	**0.44**	**0.09**	**0.0**		**0.03**	**0.13**	**0.47**	**0.18**	**0.04**

CHAPTER 4

SEASONAL VARIATION OF ELEPHANT IMPACTS ON WOODY VEGETATION

4.1 Introduction

The impact of elephant on woody vegetation and its consequences has been documented in the literature (Bax and Sheldrick, 1963; Lamprey et al., 1967; Croze, 1974a,b; Laws et al. 1975; Thompson, 1975; Guy, 1976; Barnes, R.F.W., 1979; Jachmann and Bell, 1985). But results of previous research have not been conclusive in providing guidance in the development of elephant management policies due to lack of adequate scientific facts. As used here, elephant *impacts* refer to types of feeding actions on different woody species and size classes. As described in Chapter 2, feeding actions may include digging and uprooting plants, tree felling, leaf stripping, bark stripping, branch breaking, plucking, chewing or any other manipulation of food items that may or may not be followed by consumption of plant parts.

The severity of impact of elephant on woody vegetation depends largely on the type of impact suffered by a plant species and its response to the impact. Elephant impacts which are considered severe and likely to kill a woody species include uprooting, tree felling and bark stripping. Susceptible genera have been found to be *Acacia*, *Adansonia* and *Commiphora* (Bell, 1985). Elephant impacts in woodlands dominated by *Adansonia* and *Commiphora* have been known to be major factors in the conversion of woodlands to grassland, with the conversion accelerated by fire in some cases in Murchison Falls National Park, Uganda (Buechner and Dawkins, 1961; Buss, 1961; Laws and Parker, 1968; Laws, 1970; Laws et al., 1970), Tsavo East National Park, Kenya (Bax and Sheldrick, 1963; Glover, 1963).

The probability of tree death following elephant impact has been found to be related to aridity, soil type, tree size, nutrient status and the woody species response to the damage. *Brachystegia, Julbernadia, Isoberlinia, Colophospermum*, some *Combretums, Terminalias*, and a range of other shrub species have a higher probability of coppicing (Bell, 1985). In well drained sandy soils of low nutrient status, the

response of woody species to elephant damage is shrub coppice regrowth as observed in the *Brachystegia* woodlands of Kasungu National Park, Malawi (Jachmann and Bell, 1985), in Vwaza Marsh Game Reserve, Malawi (McShane, 1989) and in the Kalahari sand woodland of Hwange National Park, Zimbabwe (Childes and Walker, 1987; Rushworth, 1975). In the Luangwa Valley, coppicing of *Colophospermum mopane* woodlands in response to elephant browsing occurred on clayey soils with an impervious B horizon and a nutrient rich A horizon (Lewis, 1991).

Despite the potential for coppicing following elephant impacts, elephant browsing may prevent recruitment of woody plants into larger size classes since the preferred feeding level was generally found to be in the range 1-2.5 m (Guy, 1976; Caughley, 1976; Jachmann and Bell, 1985; Dublin et al., 1990). Impacts on larger trees were observed to occur only when regenerating woody plants were not available (Laws et al., 1975).

The present study was designed to determine the types of impacts suffered by different woody species from elephant feeding activities in the elephant range of northern Botswana. Results of aerial surveys at the time this study was carried out indicated the elephant population size to be about 80 000 animals growing at an annual rate of about 5% (Craig, 1996; Gibson et al., 1998). The impacts associated with this expanding elephant population especially in the riverine concentration areas have been a source of much concern. The officially stated policy of the Botswana government (DNPW, 1991) was to hold the population steady at the 1990 level through culling of the annual increment but this was never implemented. In practice, the Botswana Government adopted a non-interference management policy for the elephant population since the ban on elephant hunting in 1983. The adoption of any other management policy appeared to have been made difficult due to lack of scientific facts on elephant/habitat interactions (Lindsay, 1990).

4.1.1 Objectives

The main objective of the study was to determine the seasonal variation and types of elephant impacts on woody plant species and size classes.

4.1.2 Research questions

The specific questions addressed by the study were:

(a) How did elephant impacts on woody species and height class vary over the seasonal cycle?

(b) Which species and size classes incurred severe impacts?

(c) Did the impacts differ between male and female elephant?

4.1.3 Hypotheses

4.1.3.1 ***Hypothesis 1:*** The impacts of on different woody species and size classes differ between seasons.

4.1.3.2 ***Hypothesis 2:*** The impacts on woody vegetation differ between bulls, cows and young elephant of both sexes.

4.2 Study area

The study area is located in the north-eastern corner of Botswana within Chobe National Park and Kasane Forest Reserve and Kasane Forest Reserve Extension and was fully described in Chapter 2.

4.3 Observation and data recording methods

This involved computerized data recording using the plant-based method described in Chapter 2. As already described in Chapter 2, the recorded impacts on each plant species in a patch included feeding actions such as branch breaking; uprooting and pushing over; digging for roots; snapping of trunks; bark damage; leaf stripping and snapping of stems and twigs. A woody plant stem was considered to be a trunk for mature growth forms of plants >2.5 m in height and of diameter ≥ 6 cm in diameter at the buttress swelling. Stems as used in text refers to small trees including immature growth forms such as saplings and coppice re-growth forms of diameter < 6 cm in diameter.

4.4 Data analysis

4.4.1 Calculation of impact and availability frequencies

An impact frequency was defined as a conditional probability of an impact type being inflicted when plants of a particular kind were encountered by an elephant. The conditional factors included (i) plant species (ii) plant height class and (iii) season. The probability of encountering a plant of a particular kind (availability) was calculated as the number of feeding patches in which the plant was available divided by the total

number of patches sampled per site. The probability of inflicting a particular kind of impact on a plant of a particular kind was calculated as the number of patches in which an impact type occurred divided by the number of patches in which the plant occurred per site. Mean availability and impact frequencies were calculated over all sites sampled. Impact type frequencies were recorded and analysed separately as distinct events for each species. Details of availability frequencies for the different woody species are provided in Chapter 2.

Sites were used as replicates in the calculations of confidence intervals for impact frequencies. As already explained in Chapter 2, feeding tracks or a group of elephants were located by searching, hence the sightings or feeding sites sampled were assumed to be independent in data analysis. Each group or individual elephant sighted or feeding tracks located had the same probability of being sighted at a particular day and time as for any other.

4.4.2 Seasonal variation of impacts

A general linear model of analysis of variance (Wilkinson et al., 1992) was used to distinguish the effects of seasons, plant species, height class and the interactions among them for each impact type for the commonly utilized woody species. The effects of seasons and height classes were analysed separately by species. Seasonal variations of impacts for the commonly utilized woody species were determined using a one way analysis of variance on impact frequencies. Differences between impacts or between an impact and a combination of impacts within and between species were determined using contrasts (a linear combination of means) (Wilkinson et al., 1992; Steel and Torie, 1980).

4.4.3 Determining differential bull and family group impacts

The analysis was limited by the difficulty of associating elephant impacts on woody plants with individual elephants by sex or age class as one plant could be fed upon by more than one animal if elephants were foraging in a group. It therefore became

necessary to compare differences in impacts in male and female elephants at the level of the two social groups, i.e. bull and family groups. A Student's t-test (using impact frequencies) was used to determine differences in impacts between the two social groups for different woody species. The hot-dry season data was used for the analysis due to larger sample sizes compared to other seasons.

4.5 Results

4.5.1 Factors influencing elephant impacts

The major factors which influenced the different types of elephant impacts on the commonly utilized woody vegetation appeared to be mostly season and height class and to a lesser extent woody species (Table 4.1). The influence of woody species as a factor was important for leaf stripping and digging for roots. The three factors (season, height class and plant species) appeared not to influence each other as no interaction was detected among them.

The following results are based on woody species favoured in one or more seasons where sufficient data was available. These woody species included *Baphia massaiensis, Bauhinia petersiana, Burkea africana, Combretum apiculatum, Combretum collinum, Combretum fragrans, Combretum zeyheri, Commiphora mossambicensis, Diplorhynchus condylocarpon, Grewia monticola, Pseudolachnostylis maprouneifolia* and *Terminalia sericea*.

Table 4.1 Significant effects of the influence of season, plant species and height class and the interaction of these factors on elephant impacts on different woody species**.**

IMPACT TYPE	SIGNIFICANT MAIN EFFECTS			INTERACTIONS
	Seasonal effects	**Species effects**	**Height effects**	
Branch breaking	$F_{(2,107)}$=6.19, P=0.001	*None*	$F_{(4,107)}$=7.57, P=0.001	*none*

Snap stem	$F_{(2,107)}$ =4.61, P<0.001	*None*	$F_{(4,107)}$=4.73, P=0.001	*none*
Dig for root	*None*	$F_{(7,106)}$=2.57, P=0.018	$F_{(2,106)}$=10.28, P<0.001	*none*
Leaf stripping	$F_{(2,106)}$ =10.34, P<0.001	$F_{(7,106)}$ =4.87, P<0.001	$F_{(4,106)}$=5.03, P=0.001	*none*
Uproot plant	$F_{(2,106)}$ =8.49, P<0.001	*None*	$F_{(4,106)}$=7.18, P<0.001	*none*
Snap trunk	$F_{(2,106)}$ =5.42,P =0.006	*None*	$F_{(4,106)}$=7.73, P<0.001	*none*

4.5.2 Seasonal variation of impacts

4.5.2.1 Wet season

The recorded impacts during the wet season were branch breaking, snapping of stems, digging for roots, leaf stripping, uprooting whole plant and snapping of trunks. Details of specific impacts by species are provided in Appendix Table 4.1 and Figure 4.1a, and these results show that the most common types of impacts during the wet season were snapping of stems and leaf stripping. Branch breaking, digging for roots, uprooting whole plant, and snapping of trunks occurred less frequently than leaf stripping (ANOVA, $F_{(1,35)}$=12.57, P=0.001) and also less frequently than snapping of stems (ANOVA, $F_{(1,35)}$=11.83, P=0.002).

Differences in leaf stripping for the commonly utilized woody species were significant (ANOVA, $F_{(7,161)}$=9.93, P<0.001). Significant differences were also observed among the species for snapping of stems (ANOVA, $F_{(7,173)}$=8.56, P<0.001. *B. massaiensis* , *B. petersiana* and *G. monticola* incurred significantly more leaf stripping than the other commonly utilized woody species (ANOVA, $F_{(1.161)}$=65.18, P<0.001), while B. petersiana and *G. monticola* incurred significantly more stem snapping than the other species (ANOVA, $F_{(1,173)}$=54.88, P<0.001). These results suggest that there was within season variation in the impacts of elephant between some tree species.

4.5.2.2 Cool-dry season

The cool-dry season types of elephant impacts on woody species were similar to those suffered by woody species during the wet season. The exception was that there were

no records for snapping of tree trunks. As for the wet season, leaf stripping and snapping of stems were the most common types of elephant impacts (Appendix Table 4.1, Figure 4.1b).

B. petersiana and *G. monticola* incurred significantly more leaf stripping than the other species (ANOVA, $F_{(1,204)}$=91.42, P<0.001). Also, *B. petersiana, C. fragrans* and *D. condylocarpon* incurred significantly more snapping of stems than the other species (ANOVA, $F_{(1,204)}$=187.24, P<0.001).

4.5.2.3 Hot-dry season

The recorded impacts in the hot-dry season were branch breaking, snapping of stems, digging for roots, uprooting of whole plants and snapping of trunks (Appendix Table 4.1, Figure 4.1c). Snapping of stems appeared to be the commonest type of impact and was significantly different from all other impacts (ANOVA, $F_{(1,35)}$=36.15, P<0.001. *B. massaiensis* incurred significantly more stem snapping than the other species (ANOVA, $F_{(1,361)}$=66.12, P<0.001). Also, *B. massaiensis* incurred more branch breaking than the other species (ANOVA, $F_{(1,332)}$=36.63, P<0.001).

The impacts classified as severe tended to occur more frequently during the hot dry season than the other seasons. These impacts included digging for roots, uprooting of whole plant and snapping of tree trunks. *B. petersiana, C. fragrans, T. sericea* incurred significantly more digging for roots than the other species (ANOVA, $F_{(1,362)}$=31.94, P<0.001.

4.5.3 Seasonal impacts by height classes

Details of seasonal impacts suffered by the different size classes of woody species are presented in Appendix Table 4.2 and Figures 4.2-6. The wet season impacts were centred on the size class 1-2.5 m followed by the size class 2.5-5 m (Figure 4.2 a). The cool-dry impacts were centred on the height class interval 1-2.5 m followed by the interval 0.5-1 m (Figure 4.2 c). For the wet and cool-dry seasons, the interval 0-0.5 m was lightly utilized with the interval >5 m hardly utilised. The hot-dry season impacts

were centred on the size class intervals 1-2.5 m and 2.5-5 m followed by both the size classes 0-0.5 and 0.5-5 m, but with light impacts on the size class >5 m (Figure 4.2c).

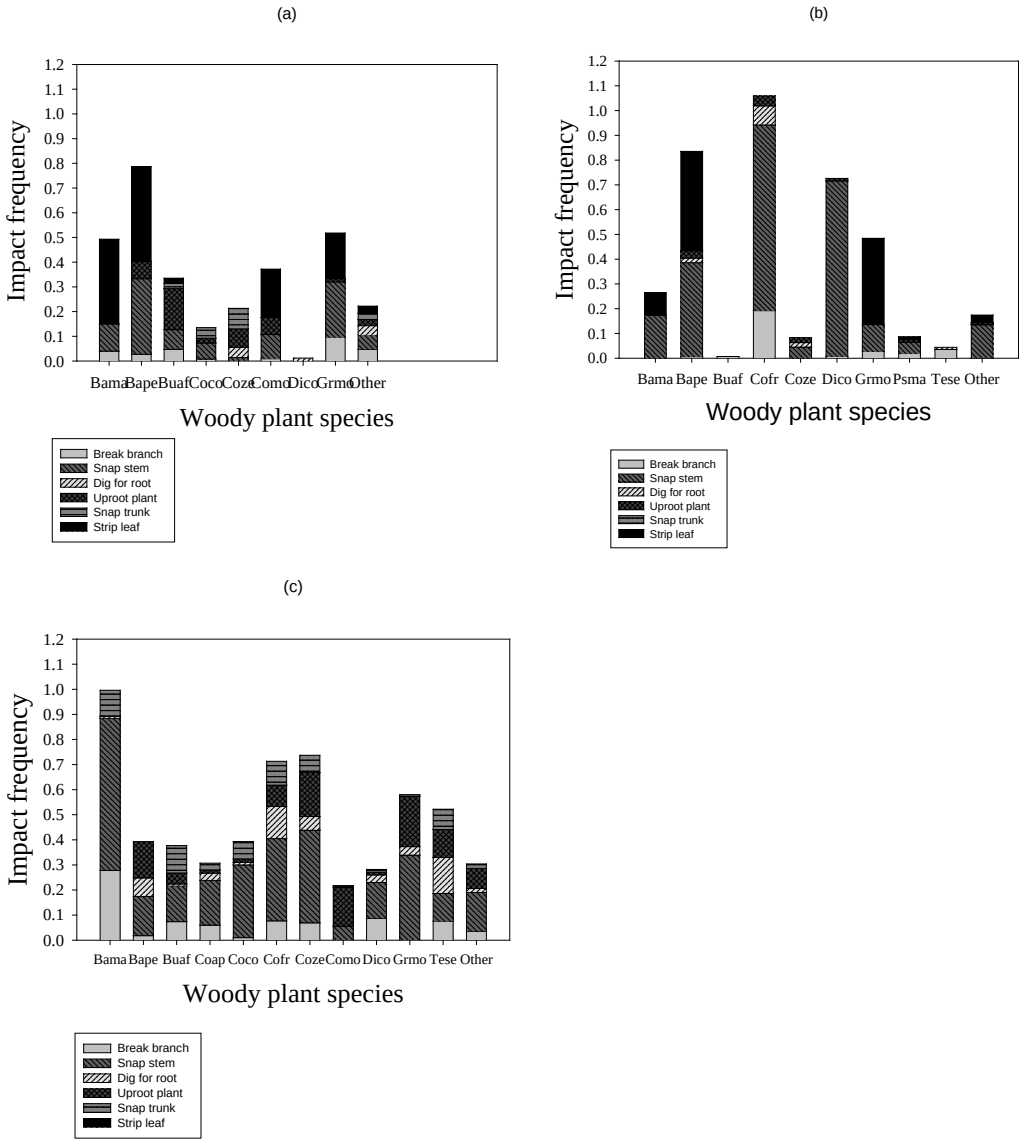

Figure 4.1 Impact types and frequencies on commonly utilized and other woody species by elephant during (a) wet season (b) cool-dry season and (c) hot-dry season in northern Botswana. Woody species acronyms used are: Bama=*Baphia massaisensis*, Bape=*Bauhinia petersiana*, Buaf=*Burkea africana*, Coap=*Combretum apiculatum*, Coco=Combretum collinum, Cofr=*Combretum fragrans*, Como=*Commiphora mossambicensis*, Coze=*Combretum zeyheri*, Grmo=*Grewia monticola*, Psma=*Psedolachnostylis maprouneifolia*, Tese=*Terminalia sericea*, Other=all other species combined.

4.5.3.1 Commonly utilised woody species suffering severe impacts

As defined in the introduction a woody plant is assumed to have suffered severe impact from elephant if feeding action involved uprooting, digging for root and snapping of

trunks. Occurrences of severe impacts were recorded only during the wet and mostly during the hot-dry seasons (Appendix Table 4.1, Figure 4.1). During the wet season, uprooting was recorded for *B. Africana, C. collinum, B. petersiana, C. zeyheri, C. zeyheri, C. mossambicensis,* and *G. monticola.* Digging for roots included *C. zeyheri,* and *D. condylocarpon,* while snapping of trunks occurred on *B. africana, C. collinum* and *C. zeyheri.* However, the severe impacts that occurred during the wet season (Appendix Table 4.1) were of smaller sample sizes to be sufficiently analysed according to the different height classes as presented in (Figure 4.2a-c).

The most severe impacts recorded by height class during the hot-dry season were digging and uprooting of plants and to a lesser extent snapping of trunks (Figure 4.2c and Appendix Table 4.2). Since digging for roots was likely to result in uprooting of a particular plant, data for uprooting and digging was pooled together in order to achieve sufficient sample sizes for different height class impact analysis.

Woody species suffering severe impacts of digging for root and uprooting during the hot-dry season included *B. petersiana, C. fragrans, C. zeyheri, C. mossambicensis, G. monticola and T. sericea (*Appendix Table 4.2, Figure 4.3). The height class impacts presented in Figure 4.3 suggest that impacts differed by species and height classes. For instance, the height class 0-0.5 m was neglected for *B. petersiana, C. zeyheri* and *T. sericrea* while this same height class was heavily utilised for *C. mossambicensis* and *G. monticola.*

The other type of severe impact recorded during the hot-dry season was snapping of trunks and target species were mostly *C. collinum, C. zeyheri, T. sericea* and to a lesser extent *B. massaiensis, B. petersiana* and *C. fragrans*. The target height class for snapping of trunks was the interval 2.5-5 m (Appendix Table 4.2).

4.5.3.2 Uncommon and rare woody species suffering severe impacts

Other than the common woody species described above, there were very few uncommon and rare woody species that seasonally suffered severe elephant impacts.

Table 4.2 shows the uncommon and mostly rare species with a high probability of severe impact *(digging and uprooting; and snapping of trunks)* on being encountered by elephant in the different seasons.

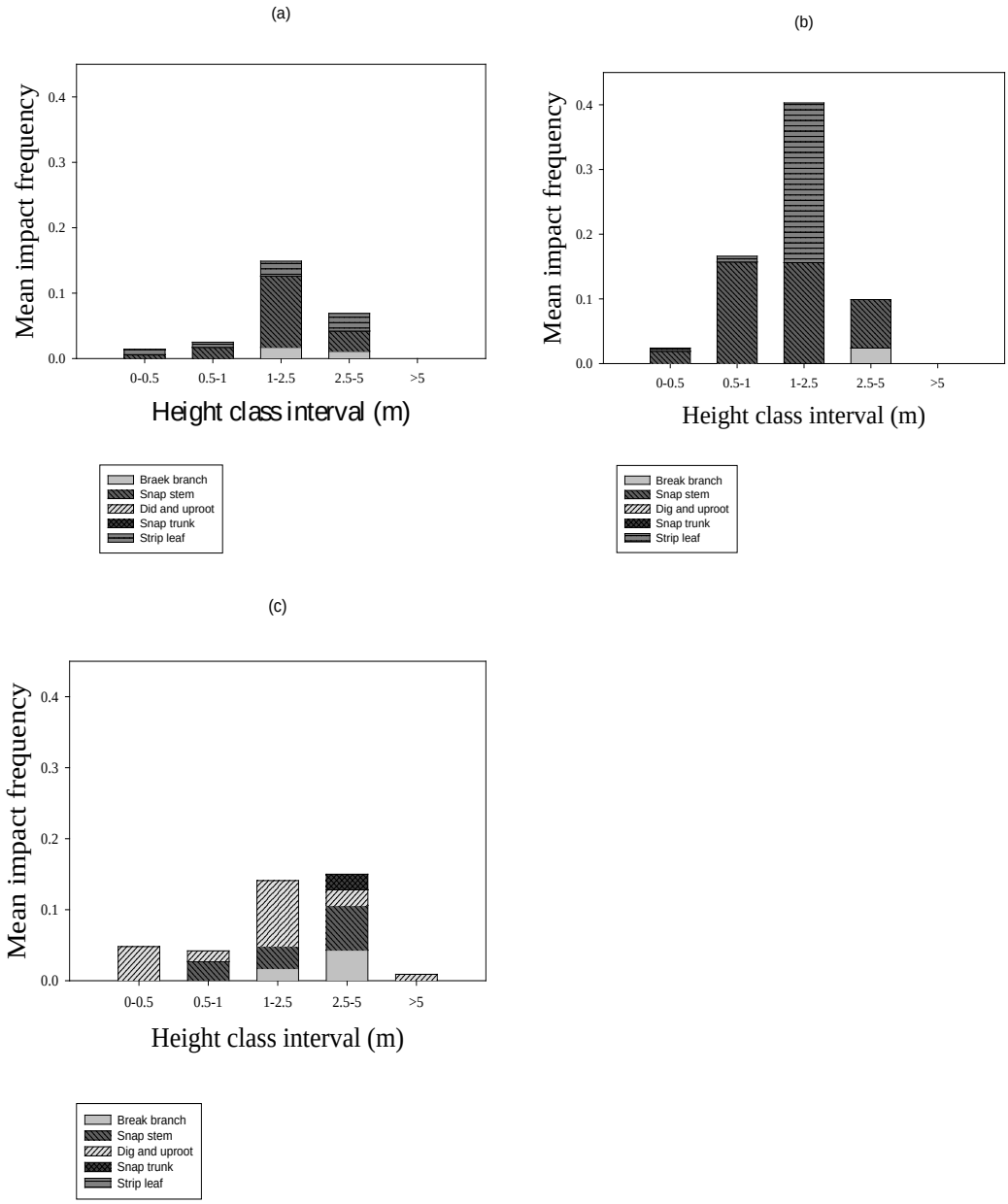

Figure 4.2. Mean impact types and frequencies on the different height classes of woody species utilized by elephant during (a) wet (b) cool-dry and hot-dry-season in northern Botswana.

Table 4.2. Digging and uprooting elephant impact and availability frequencies for some uncommon and rare woody species in the sandveld woodland of Chobe National; Park northern Botswana.

Season	Species	Sites	Availability frequency	Impact frequency	
				Dig and uproot	Snap trunk
Wet	*Brachystegia boehmii*	5	0.17	0.19	0.26
	Dicrostachys cinera	7	0.13		0.18
	Hippocratea buchananii	5	0.09	0.30	0.0
	Pterocarpus angolensis	12	0.08	0.13	0.0
	Ximenia americana	4	0.04	0.25	0.0
	Ximenia caffra	3	0.04	0.17	0.0
Cool-dry	*Brachystegia boehmii*	3	0.05	0.11	0.0
	Commiphora mollis	3	0.05	0.33	0.0
	Pterocarpus angolensis	14	0.16	0.06	0.0
Hot-dry	*Baissea wulfhorstii*	3	0.05	0.16	0.0
	Croton gratissimus	32	0.27	0.0	0.02
	Diospyros batocana	3	0.02	0.0	0.17
	Grewia flava	7	0.05	0.24	0.0
	Hippocratea buchananii	2	0.01	0.75	0.0
	Kirkia acuminata	8	0.03	0.25	0.0
	Pteleopsis myrtifolia	8	0.08	0.03	0.0
	Pterocarpus angolensis	25	0.13	0.18	0.04
	Ximenia Americana	21	0.07	0.14	0.10
	Ximenia caffra	4	0.02	0.20	0.0

4.5.3.3 Less severe elephant impacts by height class on commonly utilised woody species

Less severe impacts were defined as those not likely to kill a plant and in this study, such impacts were generally found to be snapping of stems and branch breaking and leaf stripping. Although the Less severe impacts may not kill a woody plant species, heavy elephant browsing on smaller size classes would negatively affect the recruitment dynamics of the affected plants including inhibiting recruitment into larger size classes. The results presented in Figures 4.4 – 4.6 indicate that there were within and between season variations in impacts by height class as illustrated in the following sections.

Wet and cool-dry seasons

With the exception of *C. mossambicensis,* leaf stripping impact tended to be focused on size classes 1-2.5 m when compared to snapping of stems which tended to be restricted to height class intervals 0.5-1m and 1-2.5 m for the same species (Figures 4.4). While the pattern of stem utilization by height class remained the same for the cool-dry season as for the wet season, there was a shift to size classes 1-2.5 m for leaf stripping. As already indicated in section 4.5.3.1, impacts recorded for the height class

>5 m was snapping of trunks for *B. africana*, *C. collinum* and *C. zeyheri* during the early wet season. Depending on woody species and the type of impact, the height class interval was either neglected, lightly utilized or heavily utilized (Figures 4.4-4.5a, b).

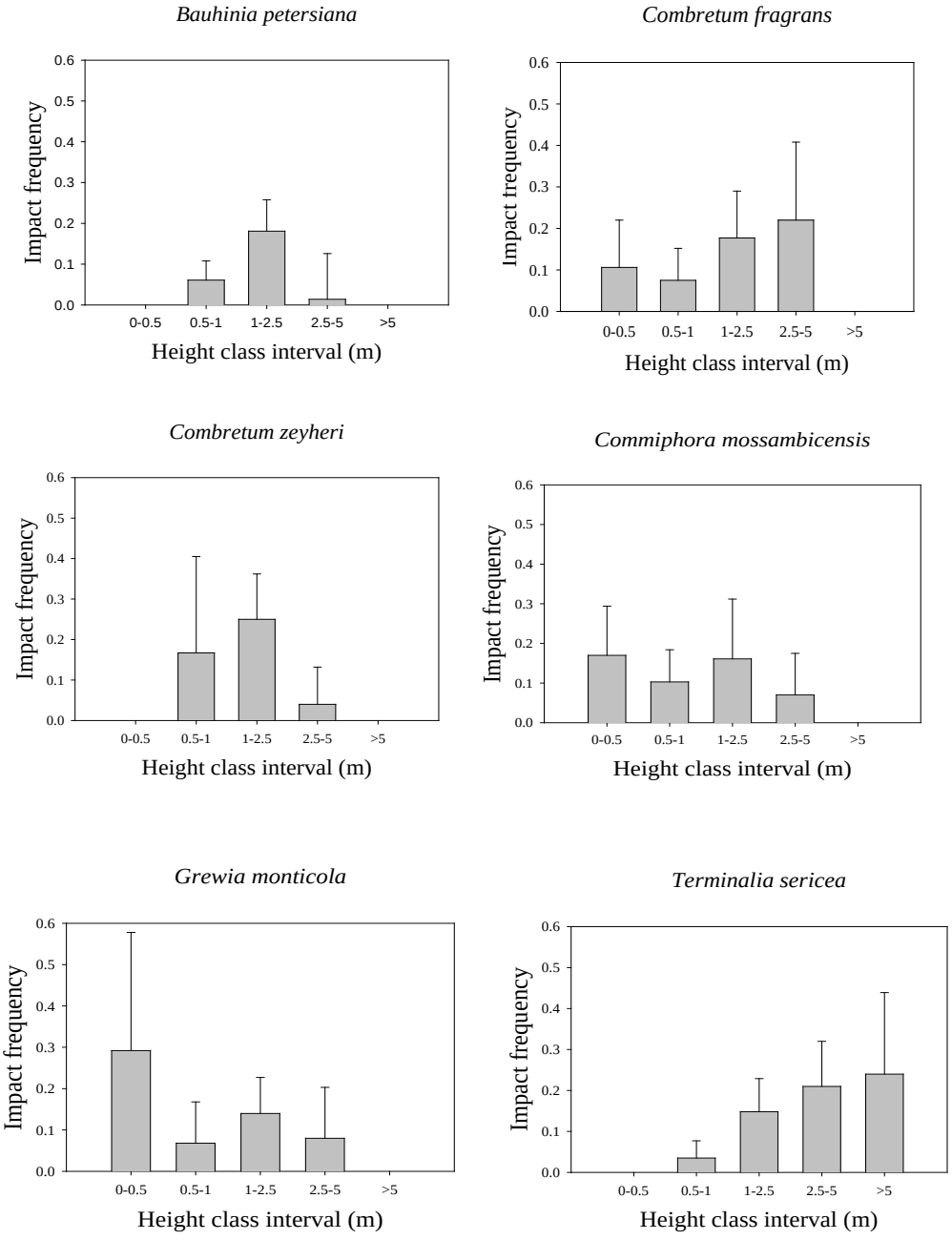

Figure 4.3. Woody species and size classes suffering digging and uprooting by elephant during the hot-dry season in northern Botswana.

(a) Snap stems (b) Leaf stripping

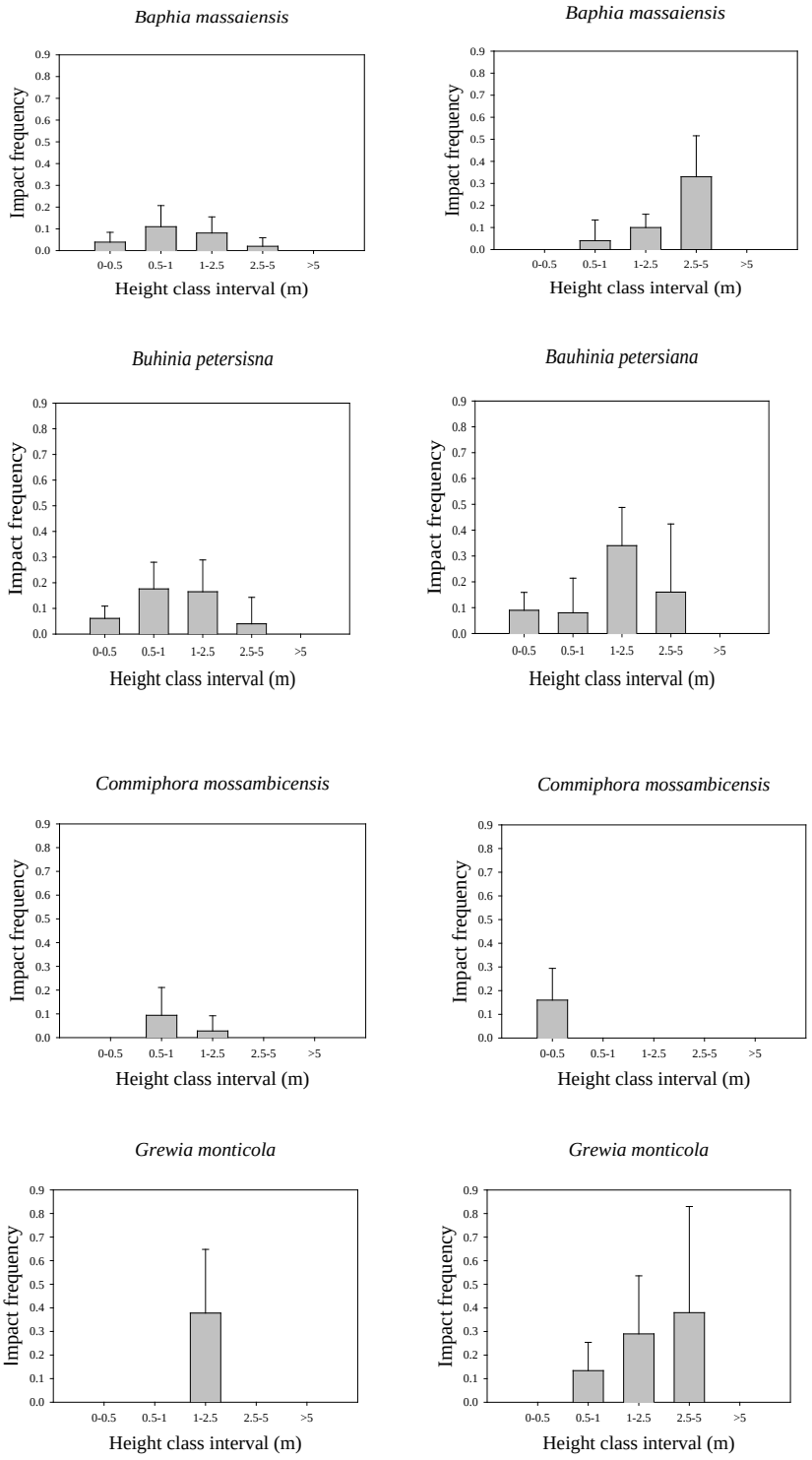

Figure 4.4 Wet season snapping of stems and leaf stripping elephant impacts for commonly utilised woody species in northern Botswana.

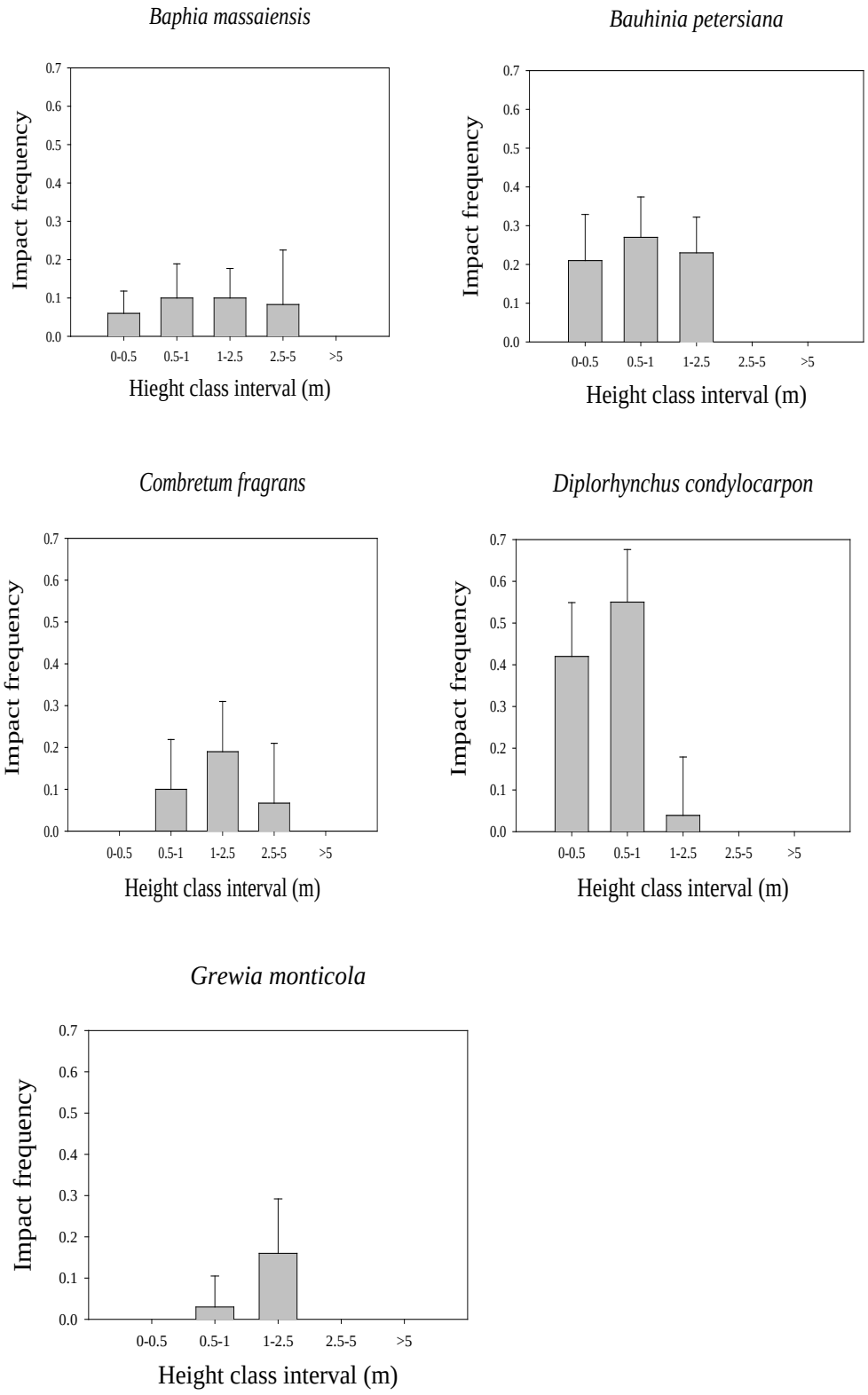

Figure 4.5a. Cool-dry season snapping of stems elephant impact for commonly utilised woody species in northern Botswana.

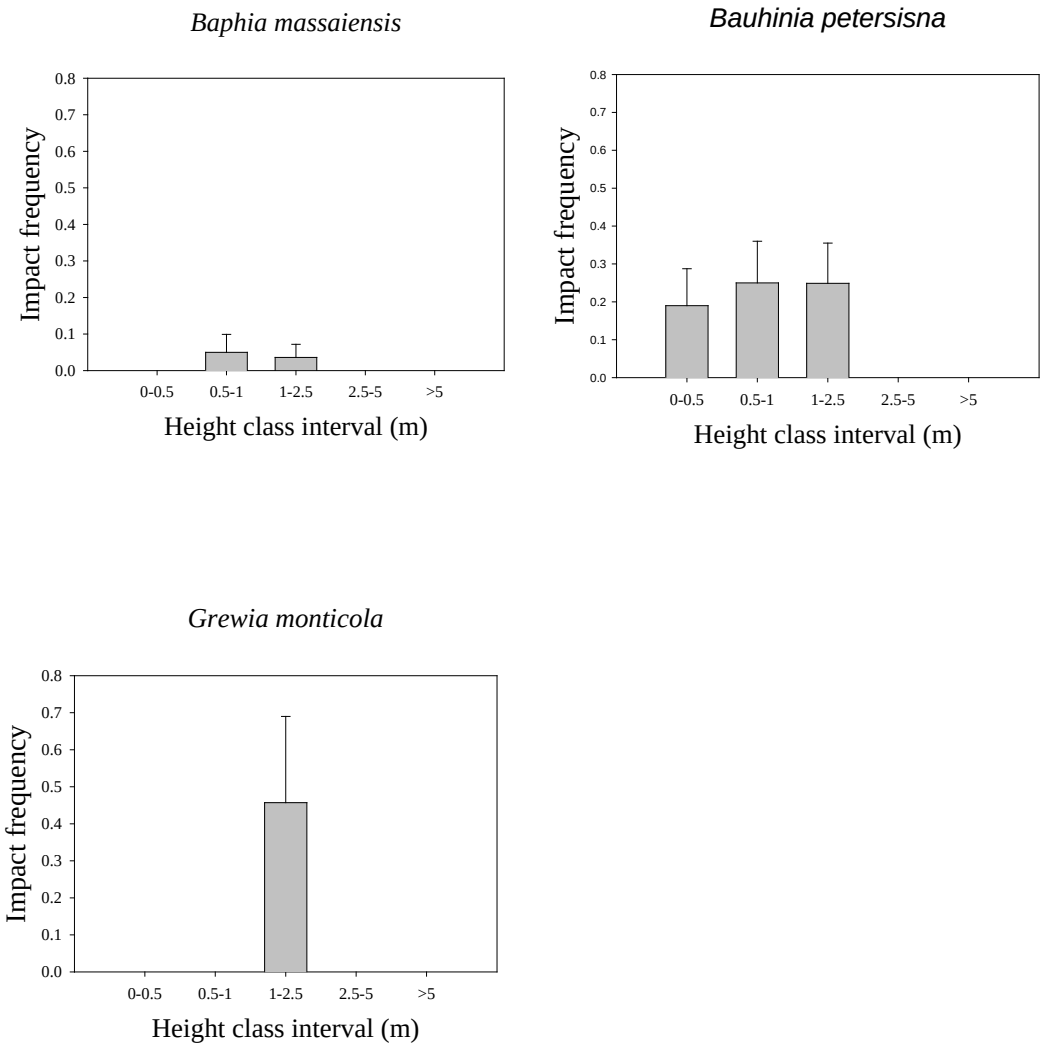

Figure 4.5b. Cool-dry season stripping of leaves elephant impact for commonly utilised woody species in northern Botswana.

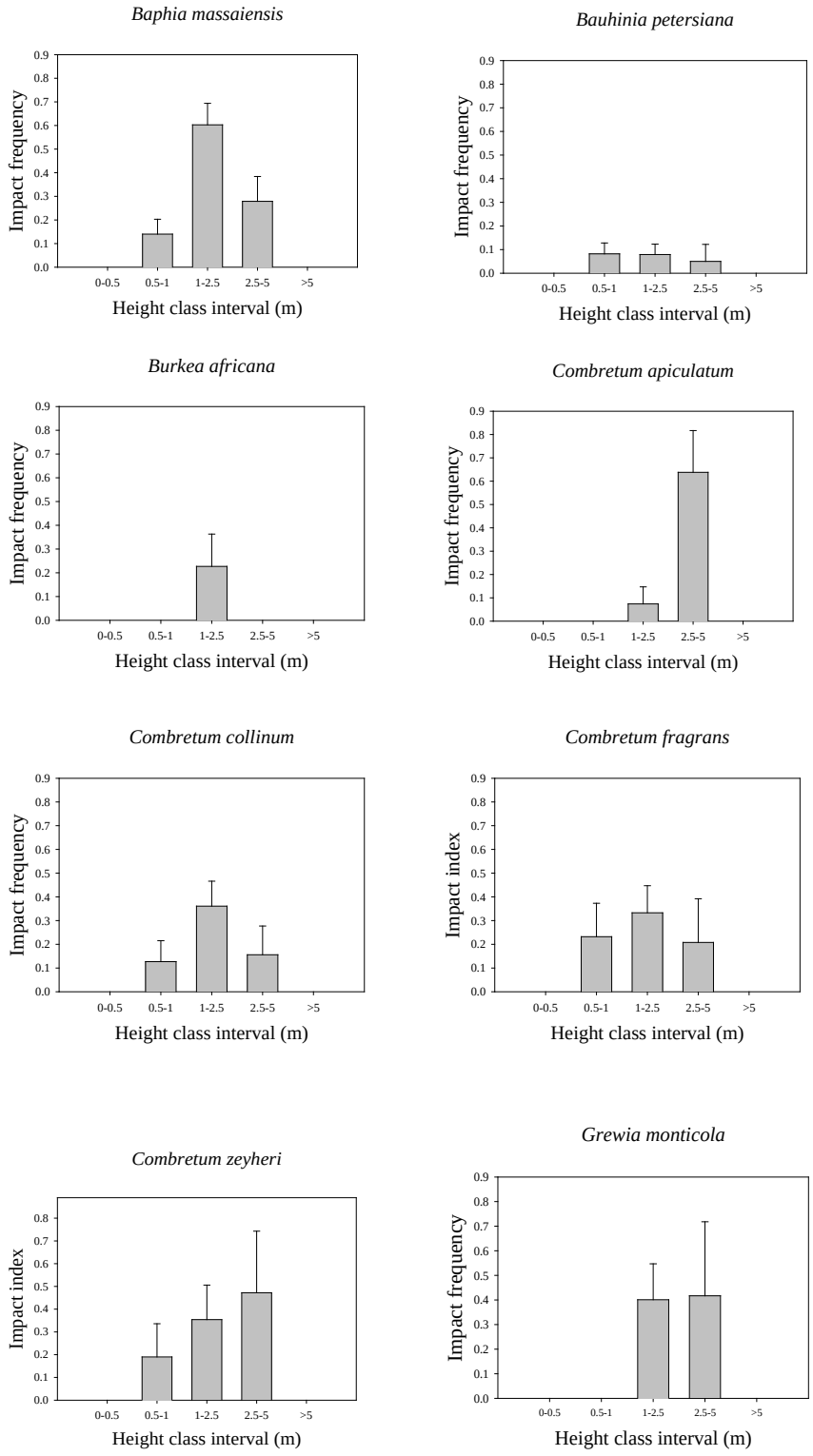

Figure 4.6 Hot-dry season snapping of stems elephant impact for commonly utilised woody species in northern Botswana.

Hot-dry season

Severe elephant impacts by height class during this season were presented in section 4.5.3.1 and Figure 4.3, and the less severe impact involving snapping of stems is presented in Figure 4.6. Unlike in the wet and cool-dry seasons, snapping of stems shifted to larger size classes, i.e 0.5-1 m especially for *B. massaiensis, B. petersiana,* and *Grewia monticola.*

For all other commonly utilised species, the snapping of stems was between height class intervals 1-2.5 m and 2.5-5 m. However, there was variation in that for some species, only one height class suffered the snapping of stem impact, i.e 1-2.5 m for *B. africana* and 2.5-5 m for *C. apiculatum*. In general the same type of impact could vary for the same height classes of different woody species.

4.5.4 Differences in bull and family group impacts

The hot dry-season data analysis was based on 37 bull groups averaging 3 individuals and 23 female groups averaging 19 individuals. With a few exceptions, there were generally no significant differences in impact types of bull and family groups on woody vegetation. Any differences that occurred were plant specific and where such differences occurred, bulls tended to have a greater impact on woody species than cows. Family groups had greater impact than bulls only in snapping stems of *C. fragrans* (P=0.042, t=2.2, df=22). Bulls showed a greater impact than family groups in snapping stems of *D. condylocarpon* (P=0.005, t=3, df=36); snapping trunks of *B. massaiensis* (P=0.024, t=2.3, df=53); and uprooting of *T. sericea* (P=0.027, t=2.8, df=44).

Some marginally non significant differences included snapping stems of *C. zeyheri* (P=0.079, t=1.8, df=26; cow>bull); snapping stems of *T. sericea* (P=0.067, t=1.9; df=19, cow>bull); and uprooting *B. petersiana* (P=0.066, t=1.9, df=55, bull>cow).

4.6 Discussion

Factors influencing impacts

The study revealed that major factors associated with variation of impacts of elephant on woody vegetation were season, plant height classes and to a lesser extent plant species over the annual cycle. There was insufficient evidence to indicate that these factors interacted.

Seasonal effects

The effect of season was that specific impacts tended to occur during certain times of the year. In general, less severe impacts *(snapping of stems and leaf stripping)* occurred during the wet and cool-dry seasons, while both less severe and severe impacts *(digging, uprooting and snapping of trunks)* occurred during the hot-dry season. Previous studies also indicated that elephants inflicted severe impacts during the hot-dry to early wet seasons. However, these studies placed emphasis on impacts on canopy trees in localised areas (Lamprey et al., 1967; Child, 1968; Thompson, 1975; Field and Ross, 1976; Mwalyosi, 1987; Conybeare, 1991; Cumming et al., 1997). The results of this study indicated the seasonal effects with respect to impacts on in individual woody species and size classes as fully discussed in the following sections. Limited tree felling or bark removal was recorded during this study suggesting that such impacts may occur in time and space under specific conditions as will be discussed in Chapter 5.

Species effects

The effect of woody species was not as strong as the seasonal and height class effects except for digging, uprooting and leaf stripping impacts. Woody species susceptible to digging and uprooting included *B. petersiana, C. fragrans, C. zeyheri, C. mossambicensis, G. monticola* and *T. sericea.* As for leaf stripping, susceptible woody species were *B. massaiensis, B. petersiana, C. mossambicensis* and *G. monticola.* Digging and uprooting were restricted to the hot-dry season and leaf stripping impact to the wet and cool-dry season.

Height class effects

Height class appeared to be one of the major factors influencing selective impacts of elephant on woody species. The height classes within the intervals 1-2.5 m and 2.5-5 m generally appeared to receive most impacts over the seasonal cycle. In general, the height classes <1 m were lightly utilized with the height class >5 m being neglected. The height class effect was such that some impact types targeted different height classes for the same species within or between seasons. For instance, snapping of stems shifted from smaller size classes to larger size classes for *B. massaiensis, B. petersiana* and *G. monticola* during the hot-dry season when compared to the wet and cool-dry seasons. The height class 0-0.5 m was completely neglected for snapping of stems but was utilized when digging and uprooting plants for *C. fragrans, C. mossambicensis,* and *G. monticola* during the hot-dry season. In some instances, a particular kind of impact could be restricted to one or two height classes as for *C. mosambicensis*, and G. monticola during wet, cool-dry and hot dry seasons.

It has been reported in the literature that elephant have a feeding level preference of between 1 and 2 metres with the overall height of trees they feed upon being somewhat higher than the actual feeding level. This generalization was based on studies carried out in Kasungu, Malawi (Jachmann and Bell, 1985) and the Sengwa Area, Zimbabwe, Guy (1976). Results of this study suggest that such a generalization may not always hold as height specific impacts may be related to species, season and impact types.

Impact differences between bulls and cows

No clear differences could be detected for differences in impacts on woody species between bull and family groups. However, bulls tended to have a greater impact in inflicting severe impacts during the hot-dry season particularly in the snapping of trunks and uprooting of plants. Comparative impacts between bull and cow elephants for other studies also suggested that bull elephant had greater impacts than cows with respect to severe impacts such as debarking and tree felling (Croze, 1974b; Guy, 1976; Barnes, 1980, 1982).

Recent studies by Stokke (1999) and Stokke and du Toit (2000) within Chobe National Park found no evidence of feeding height stratification between family units and male groups. However, the results of these studies suggested that the preferred feeding level was about 2 m.

Implications for woodland dynamics

It was indicated by Owen-Smith (1988) that the elephant impacts may eliminate some sensitive woody species. Furthermore, selective herbivory and hence impacts on woody species may influence competitive interactions among plant species and forms, leading to changes in community composition and physiognomy (Owen-Smith and Danckwerts, 1997). In this respect, herbivory may shape plant morphology, growth patterns and resource allocation in interacting with other environmental factors.

Digging for roots and uprooting of woody species may result in elimination of sensitive woody species particularly the uncommon and rare species. Affected species in this category include *G. flava, P. angolensis, X. americana and X. caffra*. Other woody species including *B. petersiana, C. fragrans, C. zeyheri, C. mossambicensis, G. monticola* and *T. sericea* that are susceptible to digging and uprooting impacts may not be eliminated from the environment as they are commonly available in the elephant range. Also, the heavily impacted woody species have the ability to regrow profusely by coppicing after elephant impact. However, as the different types of impacts tended to be height specific, this may affect the physiognomy and recruitment dynamics of the affected woody species. In particular, digging for roots, uprooting and snapping of stems which affect the smaller size especially for *B. massaiensis, B. petersiana, C. fragrans, C. mossambicensis, D. condylocarpon* and *G. monticola* may inhibit the recruitment of these woody into larger size classes. The observation in this study that elephant may also inflict heavy impact on size classes < 1 m is contradicts the findings of Croze (1974b) and Leuthold (1977) that seedling under 1 m were infrequently utilised by elephant. As already pointed out, elephant impacts types on woody species tend to be height specific by woody species as well as season making it difficult to make a conclusive generalization.

The shrub species commonly utilized by elephant in the habitat have a potential to grow into larger size classes (Palgrave, 1983). The limited availability for size classes ≥5 m (see Chapter 2) could have been caused by heavy browsing on smaller size classes, thus preventing recruitment into larger size classes.

As suggested by Lindsay (1990), and as observed in this study elephant impacts without other external influences such as fire and droughts, may maintain woodlands at shrub or coppice level by restricting recruitment into larger size classes due to heavy browsing. But Dublin et. al., (1990) reported that elephant alone prevented woodland regeneration in the Serengeti-Mara by feeding on small seedlings because there were few woody species in larger height classes. Impacts of elephant on saplings was also recorded for *Acacia tortilis* in Lake Manyara National Park, Tanzania (Mwalyosi, 1987), but sufficient saplings survived and reached maturity. In Luangwa Valley, Zambia, heavy elephant browsing on smaller size classes of *Colophopermum mopane* precluded growth of this species beyond 2 m.

It should be noted that the findings under discussion above refer specifically to the sandveld savanna woodland at Chobe and that patterns may differ in other vegetation types where shrubs with profuse coppicing potential are less prevalent. *B. plurijuga* would probably dominate in much of the sandveld woodland both in the shrub and canopy layer if the favoured species declined through lack of regeneration.

4.7 Conclusions

4.7.1 The major factors influencing elephant impacts on woody vegetation were found to be seasons and height classes.

4.7.2 Elephant impact types tended to be species and size class specific and varied seasonally. Snapping of stems appeared to be the most dominant type of impact all year round while leaf stripping was important during the wet and cool-dry seasons with severe impacts such as snapping of trunks, digging and uprooting of woody plants occurring mostly during the hot-dry season.

4.7.3 In general, woody species commonly utilized by elephant and which suffered

both severe and less severe impacts were the most commonly available woody species in the habitat. The height specific impacts for common, uncommon and rare species may negatively affect the physiognomy and recruitment dynamics of the targeted woody species.

4.7.4 No clear distinction could be made with respect to differences in impacts between cow and bull herds on the commonly utilized shrub species. However, bulls appeared to have greater impact than cows with respect to severe impacts such as snapping of trunks, digging and uprooting plants.

Appendix Table 4.1 Seasonal elephant impact frequencies (with 95% confidence intervals) for the commonly utilized woody species in northern Botswana. 'Sites' refers to the number of sites in which a woody plant species was encountered by elephant and where a particular kind of impact may or may not have occurred.

PLANT SPECIES	SEASON	SITES	IMPACT TYPE					
			Break branch	Snap stem	Dig for root	Uproot	Snap trunk	Strip leaf
Baphia massaiensis	**Wet**	20	0.040±0.049	0.110±0.094	0.0	0.0	0.0	0.343±0.040
Bauhinia petersiana		24	0.027±0.031	0.306±0.155	0.0	0.069±0.093	0.0	0.385±0.034
Burkea Africana		19	0.047±0.061	0.080±0.116	0.0	0.166±0.017	0.021±0.030	0.021±0.010
Combretum collinum		24	0.008±0.017	0.065±0.064	0.0	0.019±0.027	0.043±0.042	0.0
Combretum zeyheri		18	0.0	0.014±029	0.042±0.088	0.074±0.121	0.083±0.128	0.0
Commiphora mossambicensis		23	0.009±0.018	0.099±0.080	0.0	0.068±0.075	0.0	0.196±0.031
Diplorhynchus condylocarpon		21	0.0	0.0	0.012±0.025	0.0	0.0	0.0
Grewia monticola		20	0.095±0.119	0.225±0. 342	0.0	0.013±0.026	0.0	0.185±0.031
Burkea Africana		30	0.007±0.014	0.00	0.0	0.0	0.0	0.0
Combretum fragrans		13	0.192±0.232	0.750±0.482	0.077±0.168	0.040±0.084	0.0	0.0
Combretum zeyheri		28	0.0	0.045±0.054	0.018±0.037	0.020±0.037	0.0	0.0
Diplorhynchus condylocarpon		30	0.007±0.014	0.709±0.135	0.0	0.010±0.014	0.0	0.0
Grewia monticola		23	0.029±0.060	0.107±0.087	0.0	0.0	0.0	0.348±0.177
Pseudolachnostylis maprouneifolia		27	0.019±0.038	0.046±0.078	0.0	0.010±0.019	0.0	0.012±0.025

PLANT SPECIES	SEASON	SITES	IMPACT TYPE					
			Break branch	**Snap stem**	**Dig for root**	**Uproot**	**Snap trunk**	**Strip leaf**
Terminalia sericea		27	0.035±0.051	0.0	0.009±0.019	0.0	0.0	0.0
Other		226	0.001±0.001	0.134±0.014	0.002±0.002	0.007±0.005	0.0	0.030±0.007
Baphia massaiensis	**Hot-dry**	55	0.278±0.075	0.606±0.069	0.009±0.015	0.0	0.103±0.044	0.0
Bauhinia petersiana		57	0.018±0.013	0.156±0.046	0.074±0.034	0.144±0.044	0.0	0.0
Burkea Africana		39	0.074±0.054	0.141±0.081	0.009±0.017	0.044±0.044	0.109±0.029	0.0
Combretum apiculatum		51	0.060±0.035	0.178±0.072	0.029±0.026	0.013±0.015	0.027±0.024	0.0
Combretum collinum		57	0.0104±0.036	0.290±0.061	0.010±0.012	0.014±0.014	0.069±0.040	0.0
Combretum fragrans		39	0.077±0.067	0.328±0.116	0.128±0.072	0.085±0.072	0.095±0.056	0.0
Combretum zeyheri		39	0.069±0.053	0.369±0.129	0.055±0.059	0.175±0.085	0.067±0.046	0.0
Commiphora mossambicensis		42	0.0	0.056±0.045	0.0	0.154±0.090	0.008±0.016	0.0
Diplorhynchus condylocarpon		40	0.087±0.087	0.143±0.063	0.030±0.030	0.011±0.016	0.011±0.016	0.0
Grewia monticola		34	0.0	0.339±0.129	0.034±0.036	0.201±0.094	0.006±0.012	0.0
Terminalia sericea		48	0.076±0.052	0.110±0.062	0.144±0.063	0.111±0.059	0.081±0.043	0.0
Other		318	0.035±0.004	0.155±0.010	0.016±0.03	0.080±0.007	0.018±0.032	0.0

Appendix Table 4.2 Seasonal elephant impact frequencies by height class for the commonly utilized woody species in the sandveld of Chobe National Park, northern Botswana. For each woody species, the first row denotes number of sites in which a woody plant species was encountered and where particular kind of impact may or may not have occurred; the second row denotes the impact frequency and the third row denotes the 95% confidence intervals.

SEASON	WOODY SPECIES	IMPACT TYPE																			
		Break branch			Snap stem					Dig and uproot					Snap trunk		Strip leaf				
		1-2.5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5
Wet	*Baphia massaiensis*	20	14	0.0	18	20	27	14	0.0	18	20	27	14	0.0	14	0.0	18	20	27	14	0.0
		0.058	0.014	0.0	0.039	0.11	0.081	0.020	0.0	0.0.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.040	0.100	0.330	0.0
		0.085	0.031	0.0	0.045	0.097	0.074	0.039	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.094	0.060	0.186	0.0
	Bauhinia petersiana	20	9	0.0	23	19	24	9	0.0	23	29	24	9	0.0	9	0.0	23	19	24	9	0.0
		0.033	0.0	0.0	0.061	0.176	0.165	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09	0.080	0.340	0.160	0.0
		0.031	0.0	0.0	0.048	0.104	0.124	0.103	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.069	0.134	0.148	0.264	0.0
	Burkea Africana	13	7	7	12	11	11	7	7	12	11	11	7	7	7	7	12	11	11	7	7
		0.0	0.171	0.0	0.0	0.0	0.114	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.345	0.0	0.0	0.0	0.174	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Combretum collinum	21	12	9	15	18	20	10	9	15	18	20	10	9	10	9	15	18	20	10	9
		0.0	0.0	0.0	0.0	0.047	0.062	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.071	0.072	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Combretum zeyheri	12	1	0.0	9	8	11	2	0.0	9	8	11	2	0.0	2	0.0	9	8	11	2	0.0
		0.0	0.0	0.0	0.0	0.0	0.061	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.135	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Commiphora mossambicensis	11	3	0.0	24	11	9	3	0.0	24	11	9	3	0.0	3	0.0	24	11	9	3	0.0
		0.0	0.0	0.0	0.0	0.094	0.028	0.00	0.0	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.160	0.0	0.0	0.00	0.0
		0.0	0.0	0.0	0.0	0.117	0.064	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.134	0.0	0.0	0.0	0.0

SEASON	WOODY SPECIES	IMPACT TYPE																			
		Break branch			Snap stem					Dig and uproot					Snap trunk		Strip leaf				
		1-2.5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5
	Diplorhynchus condylocarpon	14	4	0.0	21	13	12	4	0.0	21	13	12	4	0.0	4	0.0	21	13	12	4	0.0
		0.0	0.0	0.0	0.036	0.038	0.063	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.054	0.084	0.099	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Grewia monticola	13	4	0.0	10	14	13	4	0.0	10	14	13	4	0.0	4	0.0	10	14	13	4	0.0
		0.096	0.0	0.0	0.0	0.0	0.378	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.134	0.290	0.380	0.0
		0.170	0.0	0.0	0.0	0.0	0.27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.120	0.246	0.452	0.0
	Other	131	61	33	103	104	113	48	33	108	104	113	48	33	48	33	103	104	113	48	33
		0.002	0.002	0.0	0.049	0.021	0.017	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.078	0.058	0.0	0.022	0.031	0.011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cool-dry	*Baphia massaiensis*	27	16	0.0	26	28	27	16	0.0	26	28	27	16	0.0	16	0.0	26	28	27	16	0.0
		0.0	0.060	0.0	0.060	0.100	0.100	0.083	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.050	0.036	0.0	0.0
		0.0	0.133	0.0	0.058	0.089	0.077	0.142	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.049	0.036	0.0	0.0
	Bauhinia petersiana	26	9	0.0	31	29	26	9	0.0	31	29	26	9	0.0	9	0.0	31	29	26	9	0.0
		0.0	0.0	0.0	0.210	0.270	0.230	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.190	0.250	0.249	0.0	0.0
		0.0	0.0	0.0	0.119	0.104	0.092	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0975	0.110	0.106	0.0	0.0
	Burkea Africana	22	12	0.0	29	24	22	12	0.0	29	24	22	12	0.0	12	0.0	29	24	22	12	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Combretum fragrans	27	15	2	21	23	27	15	2	21	23	27	15	2	15	2	21	23	27	15	2
		0.0	0.750	0.0	0.0	0.100	0.190	0.067	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.078	0.0	0.0	0.119	0.120	0.143	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SEASON	WOODY SPECIES	IMPACT TYPE																			
		Break branch			Snap stem					Dig and uproot					Snap trunk		Strip leaf				
		1-2.5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5
	Combretum zeyheri	26	8	0.0	17	20	26	8	0.0	17	20	26	8	0.0	8	0.0	17	20	26	8	0.0
		0.0	0.0	0.0	0.0	0.030	0.060	0.125	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.052	0.087	0.296	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diplorhynchus condylocarpon	23	6	0.0	26	29	23	6	0.0	26	29	23	6	0.0	6	0.0	26	29	23	6	0.0
		0.0	0.0	0.0	0.420	0.550	0.039	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.129	0.126	0.140	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Grewia monticola	16	3	0.0	11	10	16	3	0.0	11	10	16	3	0.0	3	0.0	11	10	16	3	0.0
		0.0	0.0	0.0	0.0	0.030	0.160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.457	0.0	0.0
		0.0	0.0	0.0	0.0	0.075	0.132	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.233	0.0	0.0
	Pseudolachnostylis maprouneifolia	24	14	0.0	13	19	24	14	0.0	13	19	24	14	0.0	14	0.0	13	19	24	14	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Terminalia sericea	21	14	0.0	9	14	21	14	0.0	9	14	21	14	0.0	14	0.0	9	14	21	14	0.0
		0.0	0.090	0.0	0.0	0.0	0.100	0.054	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.0	0.0	0.0
		0.0	0.134	0.0	0.0	0.0	0.137	0.116	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.073	0.0	0.0	0.0
	Other	118	64	2	140	102	116	64	2	140	102	116	64	2	64	2	140	102	116	64	2
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SEASON	WOODY SPECIES	IMPACT TYPE																			
		Break branch			Snap stem					Dig and uproot					Snap trunk		Strip leaf				
		1-2.5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5
Hot-dry	*Baphia massaiensis*	52	45	3	4	53	52	45	3	4	53	52	45	3	45	3	4	53	52	45	3
		0.222	0.627	0.0	0.0	0.140	0.603	0.279	0.0	0.0	0.009	0.011	0.0	0.0	0.095	0.0	0.0	0.0	0.0	0.0	0.0
		0.091	0.321	0.0	0.0	0.063	0.091	0.105	0.0	0.0	0.019	0.016	0.0	0.0	0.55	0.0	0.0	0.0	0.0	0.0	0.0
	Bauhinia petersiana	54	27	12	5	53	54	27	12	5	53	54	27	12	27	12	5	53	54	27	12
		0.008	0.094	0.0	0.0	0.082	0.079	0.050	0.0	0.0	0.061	0.181	0.014	0.0	0.063	0.0	0.0	0.0	0.0	0.0	0.0
		0.012	0.088	0.0	0.0	0.046	0.044	0.072	0.0	0.0	0.047	0.077	0.112	0.0	0.070	0.0	0.0	0.0	0.0	0.0	0.0
	Burkea Africana	28	13	18	21	20	28	13	18	21	20	28	13	18	13	18	21	20	28	13	18
		0.0	0.0	0.0	0.0	0.0	0.227	0.0	0.0	0.0	0.0	0.019	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.136	0.0	0.0	0.0	0.0	0.028	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Combretum apiculatum	47	24	18	17	29	47	24	18	17	29	47	24	18	24	18	17	29	47	24	18
		0.0	0.0	0.0	0.0	0.0	0.074	0.638	0.0	0.0	0.029	0.012	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.073	0.193	0.0	0.0	0.042	0.025	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Combretum collinum	52	30	0.0	29	39	52	30	0.0	29	39	52	30	0.0	30	0.0	29	39	52	30	0.0
		0.050	0.214	0.0	0.0	0.127	0.361	0.156	0.0	0.0	0.0	0.064	0.0	0.0	0.156	0.0	0.0	0.0	0.0	0.0	0.0
		0.045	0.137	0.0	0.0	0.088	0.105	0.121	0.0	0.0	0.0	0.057	0.0	0.0	0.111	0.0	0.0	0.0	0.0	0.0	0.0
	Combretum fragrans	34	16	0.0	24	31	34	16	0.0	24	31	34	16	0.0	16	0.0	24	31	34	16	0.0
		0.094	0.094	0.0	0.0	0.232	0.333	0.208	0.0	0.106	0.075	0.177	0.220	0.0	0.047	0.0	0.0	0.0	0.0	0.0	0.0
		0.092	0.145	0.0	0.0	0.141	0.114	0.184	0.0	0.114	0.077	0.113	0.188	0.0	0,072	0.0	0.0	0.0	0.0	0.0	0.0
	Combretum zeyheri	34	12	1	9	27	34	12	1	9	27	34	12	1	12	1	9	27	34	12	1
		0.031	0.264	0.0	0.0	0.190	0.354	0.472	0.0	0.0	0.167	0.250	0.040	0.0	0.299	0.0	0.0	0.0	0.0	0.0	0.0
		0.032	0.228	0.0	0.0	0.146	0.152	0.271	0.0	0.0	0.238	0.112	0.092	0.0	0.247	0.0	0.0	0.0	0.0	0.0	0.0

SEASON	WOODY SPECIES	IMPACT TYPE																			
		Break branch			Snap stem					Dig and uproot					Snap trunk		Strip leaf				
		1-2.5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5	2.5-5	>5	0-0.5	0.5-1	1-2.5	2.5-5	>5
	Commiphora mossambicensis	23	14	0.0	34	26	23	14	0.0	34	26	23	14	0.0	14	0.0	34	26	23	14	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.170	0.103	0.161	0.070	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.124	0.081	0.151	0.105	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Diplorhynchus condylocarpon	24	8	0.0	32	24	24	8	0.0	82	24	24	8	0.0	8	0.0	82	24	24	8	0.0
		0.099	0.0	0.0	0.0	0.194	0.208	0.250	0.0	0.023	0.0	0.036	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.085	0.0	0.0	0.0	0.148	0.121	0.387	0.0	0.035	0.0	0.042	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Grewia monticola	29	12	0.0	12	22	29	12	0.0	12	22	31	12	0.0	12	0.0	12	22	29	12	0.0
		0.141	0.264	0.0	0.0	0.0	0.401	0.417	0.0	0.292	0.068	0.140	0.080	0.0	0.069	0.0	0.0	0.0	0.0	0.0	0.0
		0.097	0.248	0.0	0.0	0.0	0.146	0.301	0.0	0.286	0.100	0.087	0.123	0.0	0.105	0.0	0.0	0.0	0.0	0.0	0.0
	Terminalia sericea	40	36	20	15	31	40	36	20	15	31	40	36	20	36	20	15	31	40	36	20
		0.039	0.174	0.0	0.0	0.097	0.088	0.033	0.0	0.0	0.035	0.148	0.210	0.240	0.136	0.240	0.0	0.0	0.0	0.0	0.0
		0.034	0.108	0.0	0.0	0.100	0.062	0.033	0.0	0.0	0.042	0.081	0.110	0.199	0.068	0.199	0.0	0.0	0.0	0.0	0.0
	Other	118	64	2	140	102	116	64	2	140	102	116	64	2	64	2	140	102	116	64	2
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

CHAPTER 5

CONDITIONS ASSOCIATED WITH SEVERE IMPACTS BY ELEPHANTS ON CANOPY TREES

5.0 Introduction

Woody vegetation associations in the high density elephant ranges in Southern Africa (northern Botswana; north and northwest Zimbabwe and Kruger National Park, South Africa) are dominated by the genera *Colophospermum, Brachystegia, Julbernardia, Baikiaea* and *Acacia* both in the shrub and canopy layers (Child, 1968; Childes, 1974; Rushworth, 1975; Williamson, 1975; Sommerlatte, 1976; Taylor, 1978; Brunt et al., 1986; Nyamapfene, 1991 quoted by Cunliffe, 1993; Mills et al., 1996). These species have a potential to regrow by coppicing following elephant impact. The severity of elephant impacts on woody vegetation depend largely on the plant species, the type of impact suffered by a plant species and its response to the impact. Severe elephant impacts include tree felling and bark stripping. As defined here, tree felling included snapping of tree trunks and uprooting.

Several factors have been linked to severe impacts on canopy trees by elephant. For instance elephants were reported to have severe impacts on canopy trees in localized zones particularly near permanent water sources as observed in the Chobe river front (Child, 1968; Sommerlatte, 1976; Moroka, 1984) or near artificial water sources as observed in Hwange National Park (Conybeare, 1991). Localized severe impacts on canopy trees may also occur if elephant movement is restricted by human disturbance (Lamprey et al., 1967; Thompson, 1975; Field and Ross, 1976; Mwalyosi, 1987) or movement restricted by physical barriers such as game fences and escarpments (Thompson, 1975; Cumming et al., 1997).

Impacts on canopy trees have also been linked to phenological changes. For instance, tree debarking was documented during the late dry season or start of rains when

nutrients were being translocated to the new foliage and flowering parts (Guy, 1976; Barnes, R.F.W., 1982). The impact of elephant on canopy trees was also found to be related to the age/sex of elephant. Studies by Croze (1974b), Guy (1976) and Barnes, R.F.W. (1980, 1982) indicated that bull elephants had a higher impact on vegetation than females with respect to debarking and tree felling. Guy (1976) found that bulls were responsible for 80% of all the trees observed pushed over and uprooted as compared to 20% by adult females. But recent studies by Stokke (1999) and Stokke and du Toit (2000) within Chobe National Park found no evidence of feeding height stratification between family units and male groups.

In northern Botswana, elephant impacts involving bark peeling and felling of tees threatened the survival of sensitive woody species especially in the riverine areas which experienced high elephant densities during the hot-dry season as described in Chapter 1. When pans persist well into the dry season following a good rainy season, elephant remained widely dispersed throughout the year (Calef, 1991a, b; Gibson et al., 1998), thus reducing pressure on the riverine areas.

This study confirmed that elephant generally have a feeding level preference of 1-2.5 m (see chapters 2-4) as was also reported by Guy (1976), Caughley (1976) and Jachmann and Bell (1985). However, the current study fortuitously identified important conditions likely to be associated with localised severe and thus episodic elephant impacts on canopy trees in the elephant range of northern Botswana. These episodic conditions included fire, frost and drought and the associated severe elephant impacts appeared to occur within a restricted time period if these conditions prevailed.

5.1 Objectives

5.1.1 To identify conditions that were associated with localized severe elephant impacts on canopy trees in different woodland types.

5.1.2 To assess and document levels of impacts of different types suffered by canopy trees under the different conditions.

5.2 Research questions

The specific questions to be addressed in this study were:

(a) Which localities did severe impacts occur?

(b) What conditions were associated with severe impacts?

(c) What were the levels of elephant impact types suffered by canopy trees under different conditions?

5.3 Study areas

Three localities where severe elephant impacts on canopy trees occurred were fortuitously identified in the elephant range of northern Botswana during routine data collection on elephant feeding activities. The three localities included Kasane Forest Reserve Extension, Kazuma Forest Reserve and Linyanti river front as detailed below.

5.3.1 Kasane Forest Extension

The study area was located at approximately 25°6´E and 18°9´S (Fig. 5.1) on the border of Chobe NP and lies between the southern edge of the *Baikiaea plurijuga* woodland. The woodland associations of this area had not been well documented. However, the common woody species existing in both the canopy and shrub layers were identified during the study period. The area has a mosaic of woodland types dominated by *Colophospermum mopane, Burkea africana* and *Brachystegia boehmii* in the tree layer. Woody species found in the shrub layer included *C. mopane, B. africana, B. boehmii, Diplorhynchus condylocarpon, Bauhinia petersiana, Combretum zeyheri, Combretum apiculatum* and *Combretum collinum*.

The study area had experienced an extensive wild fire which burned much of the north eastern part of Chobe National Park including the Kasane Forest Extension. A system of firebreaks saved a portion of the park from burning (Fig. 5.1). The dominant tree species which extended across the burned and unburnt localities was *B. africana*.

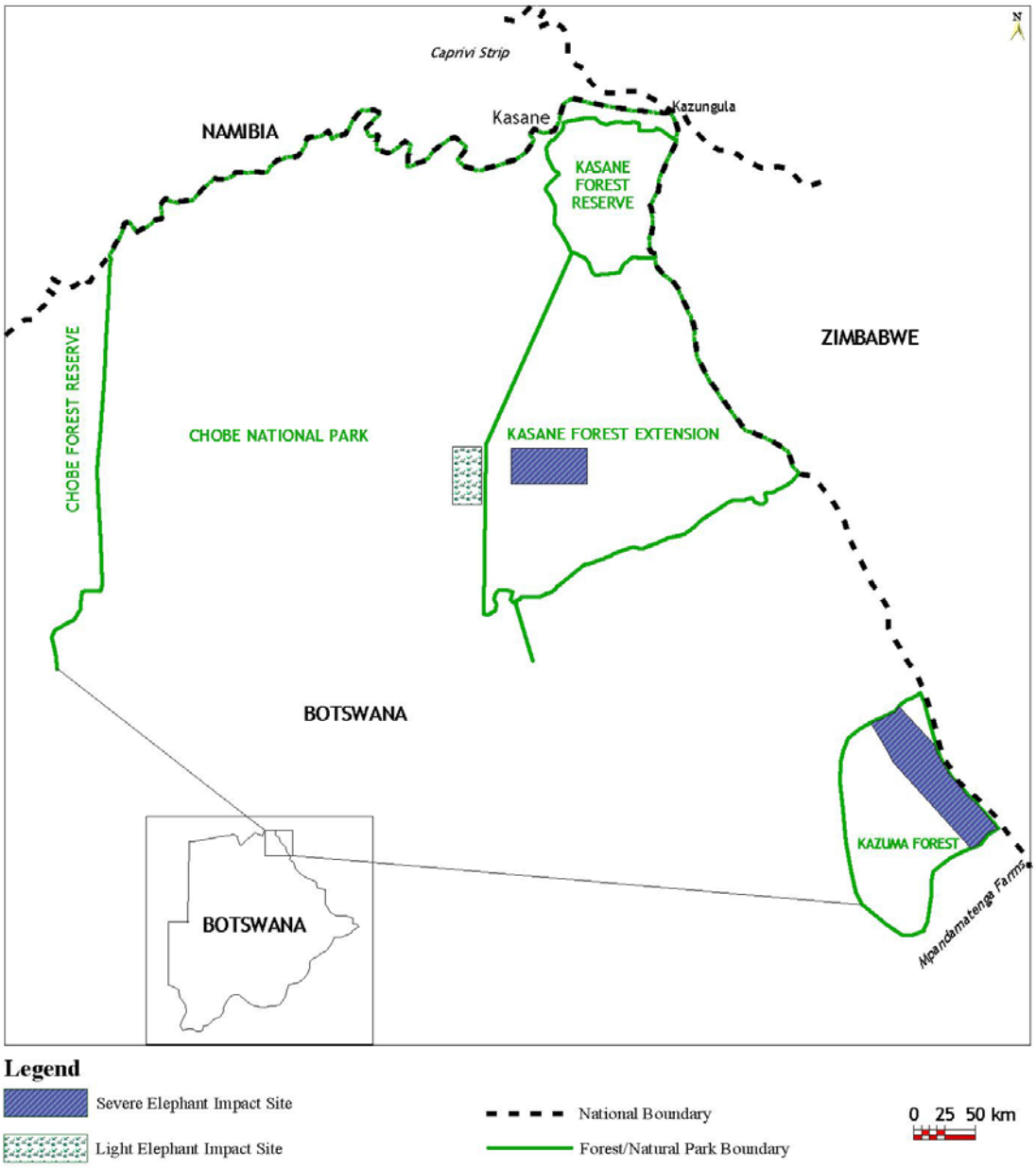

Figure 5.1. Map of northern Botswana showing sites where severe fire and frost induced elephant impacts on canopy trees were recorded in Kazuma Forest Reserve (1992) and Kasane Forest Extension (1994).

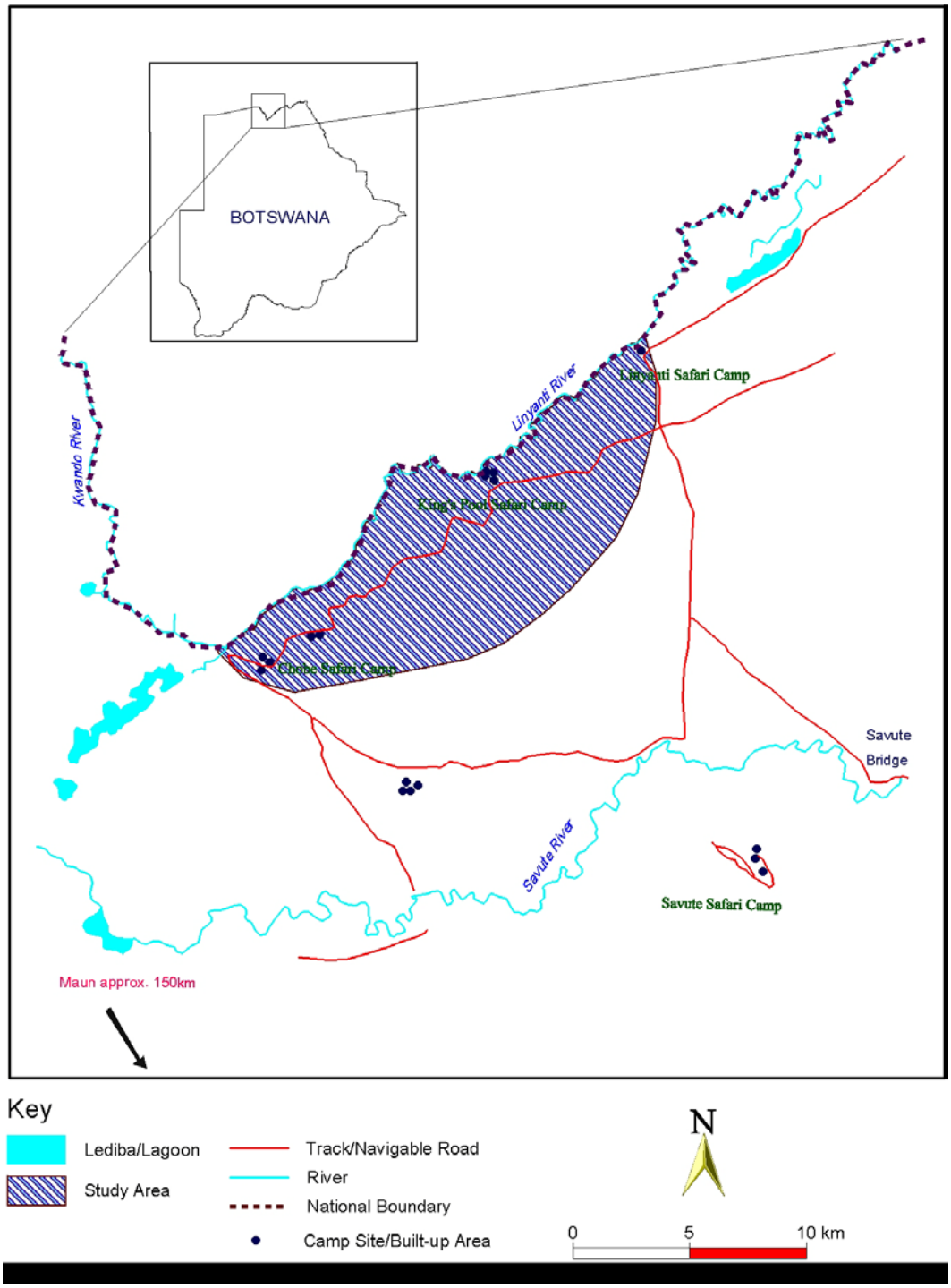

Figure. 5.2 Map of northern Botswana showing the Linyanti river front area where severe elephant impacts on canopy trees were recorded during the cool-dry and hot-dry seasons of 1993.

Mature *B. africana* trees in the study area were severely impacted by elephant through felling, observed in the second week of November, 1992. The impact on the canopy trees occurred very close to water pans which had filled up following showers of rain which fell at the end of October, 1992. Impacts on the mature trees were attributed to localized 'food restriction' as fire had burned the shrub layer normally utilized by elephants.

5.3.2 Kazuma Forest Reserve

The Kazuma Forest Reserve study area was located at 25°31´E and 18°25´S (Fig.5.1). The area is bounded by the Pandamatenga Farms in the south and in the east by the Kazuma Depression (flood plain) which extends into the Kazuma Pan National Park in Zimbabwe. The northern and western sides are bounded by communal grazing areas.

Common woody species existing in both canopy and shrub layers were identified during the study period. The canopy layer was dominated by *B. africana, Terminalia sericea* and *B. boehmii*. Other tree species found in the canopy layers included *Amblygonocarpus andongesis, Brachystegia spiciformis, Colophospermum mopane, Combretum imberbe, Erythrophleum africanum, Peltophorum africanum* and *Pseudolachnostylis maprouneifolia.*

The shrub layer was composed of a variety of woody species including those commonly utilised by elephant such as *C. mopane, B. boehmii, B. africana, T. sericea, B. petersiana, C. apiculatum, C. zeyheri, D. cinerea, D. condylocarpon, Grewia monticola and Vitex payos.*

Elephant impacts on canopy trees involving felling and uprooting of trunks occurred in the *Burkea/Brachystegia/Terminalia* woodland of the Kazuma Forest Reserve during the cool and hot-dry seasons of 1994. Elephant were expected to include in their diet woody species occurring in the shrub layer, but this appeared not to be the case. On closer examination of the vegetation, it was noticed that the above ground parts of woody species in the shrub layer had been killed by frost.

The temperature conditions which prevailed at Kasane Airport were used to indicate trends of temperature conditions for the Kazuma Forest Reserve study area, located 73 km away. Extreme temperatures as low as 2°C (June) and 1°C (July) were recorded in 1994. The observed severe elephant impacts on canopy trees could therefore have been associated with shrub layer 'food restriction' due to frost impact. No severe impacts on canopy trees were observed on this locality in the previous two years of the study period.

5.3.3 The Linyanti river front

This study area was located between 18°23´, 18°28´ S and 23°35´, 23°47´ E on the Linyanti river front (Fig. 5.2). The study area stretched for about 30 km westwards along the river from the Linyanti Safari Camp and for about 10 km southwards from the Linyanti river. The Linyanti river front woodland can broadly be categorized as the *riparian and C. mopane* woodlands. The species composition of the woodlands was described by Sommerlatte (1976), Coulson (1992) and Wackernagel (1993).

The riparian woodland occurs within a belt of about 500 m from the river. The tree layer was dominated by *Acacia erioloba, Acacia nigrescens, Terminalia prunioides* and *C. imberbe*. The most abundant species in the shrub layer included *Dichrostachys cinerea, C. mossambicense, A. erioloba, A. nigrescens, Acacia tortilis, Berchemia discolor, Diospyros mespliformis* and *Terminalia prunioides.*

The canopy layer within the woodland fringing the riparian area was dominated by *C. mopane*. Within the mopane woodland, the commonly available woody species in the shrub layer included *C. mopane, D. cinerea* and *C. mossambicense*.

Canopy trees of the Linyanti river front woodland were severely impacted from the end of June to late October, 1993. According to a resident safari operator in the area, no similar impacts had occurred in the previous year.

Early movement of elephant to the dry season concentration areas could have been triggered by below average rainfall which continued to be experienced as from the

1991/92 to 1992/93 rainy seasons in northern Botswana (Fig. 5.3). The only permanent sources of water in the elephant range of northern Botswana are the Chobe and Kwando/Linyanti river systems. The impacts were concentrated on *C. mopane* on the terrace woodland and on *A. erioloba, A. nigrescens, Acacia luederitzii, Berchemia discolor and T. prunioides* on the riparian woodland. However, the canopy trees in the riparian woodland, particularly the *Acacia spp*., were reported to have suffered severe elephant impacts in the past (Coulson, 1992; Wackernagel, 1993) as evidenced by the number of dead trees. Past elephant impacts could explain the absence of diameter size classes in the range 6-40 cm for *A. erioloba, A. nigrescens,* and *T. prunioides* (Fig. 5.7). No severe impacts on canopy trees were observed during same period in the year that followed i.e 1994.

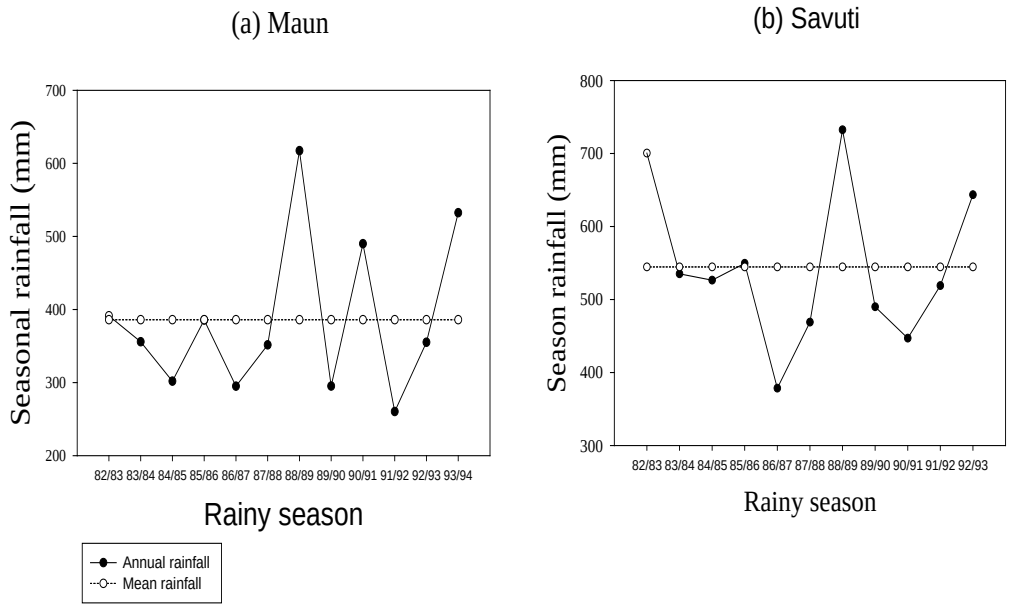

Figure 5.3 Annual and mean rainfall recorded at (a) Maun and (b) Savuti for the period 1982-1994. The rainfall data for Maun was provided by Botswana Meteorological Services, Gaborone and that for Savuti was provided by Mark Joos-Vandewalle, a researcher, who recorded the data from 1982 to 1993.

5.4 Methods

5.4.1 Sampling for impacts on Colophospermum mopane woodland, Linyanti river front

Sampling commenced at the beginning of August, 1993. Severe impact sites were identified by searching with a vehicle along hunting tracks. Each site was characterized by a large number of felled *C. mopane* trees concentrated on sites which ranged in size from 0.16 km^2 to 0.25 $km^{2.}$

For each site, the sampling was done within circular patches of 15 m radius systematically placed at 0 m, 100 m, 200 m 300 m and 400 m intervals along a strip transect. The next set of patches were defined in strip transects systematically placed at distances of 100 m apart. All trees in each patch were examined and the recorded data included impact types, plant parts utilized and diameter size classes.

Any woody plant of height >2.5 m with a main stem diameter ≥5 cm at breast height (DBH) measured at 1.3 m from the base was defined as a tree. Six diameter size classes were defined as 5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm and >50 cm.

Impacts on trees were considered to be severe if a feeding event involved snapping of trunks, uprooting and debarking of at least 50% or more of the circumference of a tree. Impacts such as leaf stripping and branch breaking were classified as minor or no impact. Only impacts which occurred during the cool-dry and hot-dry seasons of 1993 were assessed. Measurement of previous impacts on trees was attempted; however, classification by year of impact could not effectively be done. Quantities of trees felled in the past may not have been a true reflection of elephant impacts as some trees could have been felled by winds or had died from other causes (Coulson, 1992) and also felled mopane trees usually burnt completely following a wild fire.

5.4.2 Impacts on the riparian woodland, Linyanti river front

The sampling method used in *C. mopane* woodland could not be applied in the riparian woodland due to the sparse distribution of canopy trees. The sampling was done in twenty strip transects measuring 400 m x 10 m, systematically placed at about one kilometre apart. The impact assessment on canopy trees was restricted to the species that were observed to suffer severe impacts such as *Acacia spp., B discolor* and *T. prunioides*. All trees in the transects were assessed in terms of impact type, plant parts utilized and diameter size class. As before, the diameter was measured at 1.3 m from the base of the tree. Assessment was concentrated on impacts which occurred during the cool-dry and hot-dry seasons of 1993.

The strip transects were started about 3 km from the Linyanti Camp and the sampling process progressed westwards. The transects were placed perpendicular to the river. The spacing distance of the transects was determined by a vehicle odometer.

5.4.3 Impacts on Burkea/Brachystegia/Mopane woodland, Kasane Forest Extension

The sampling procedure involved systematic placement of 22 strip transects of size 400 m x 10 m at about 200 m apart. The transects were perpendicular and crossed a track road which passed through the burned site. Another 10 transects were similarly placed on the unburned site in the park across the firebreak which formed the boundary between the forest area and the park.

As for previous sites, trees within the transect were assessed in terms of impact type, plant parts utilized and diameter size class. The diameter of trees was measured at 1.3 m from the base of the tree.

5.4.4 Impacts on Burkea/Terminalia/Brachystegia woodland, Kazuma Forest Reserve

The sampling procedure involved systematic placement of eleven strip transects of size 400 m x 10 m perpendicular to the Kasane/Nata Road and another five strip transects

placed perpendicular to the main fire break which extended eastwards from the main road to the Zimbabwean border. All trees within the strip transect were assessed in terms of impact type, plant parts utilized and diameter size class. As before, the diameter was measured at 1.3 m from the base of the tree.

5.4.5 Calculation of impact frequencies

Impact frequencies were calculated as the number of patches in which an impact type occurred divided by the number of patches in which a woody species of a particular size class was encountered within transects. Mean impact proportions for the different woody species and size classes were calculated over all transects sampled.

5.5.1 Impacts on canopy trees in the Kasane Forest Extension

Severe impact was concentrated on *B. africana* and to a lesser extent *B. boehmii* and *C. mopane.* Hence sufficient data for statistical analysis was available for *B. africana* only. Severe impact on *B. africana* involved pushing over and uprooting with trees in the diameter size class 11-20 cm suffering the highest impact proportions 0.401±0.164, n=23 on the burned patch (Fig. 5.4 and Appendix Table 5.1). Tree felling and uprooting on the burned site was greater than on the unburned site Mann-Whitney U = 71, P=0.002) for the same diameter size class.

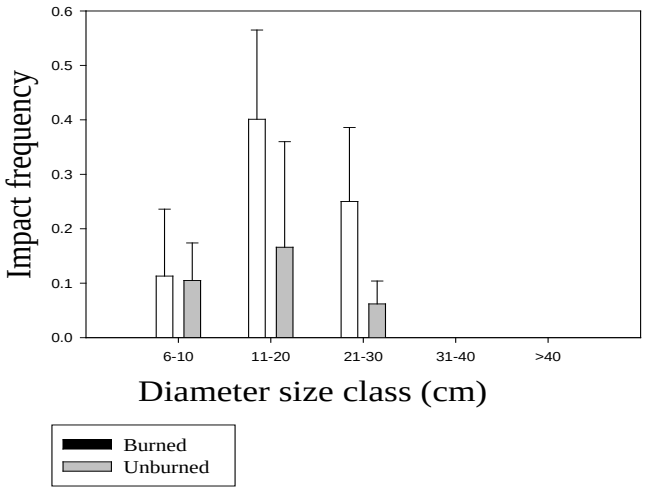

Figure 5.4 Severe elephant impact involving tree felling for *Burkea Africana* on burned and unburned areas in the Kasane Forest Extension, northern Botswana (1992).

5.5.2 Elephant impacts in the Kazuma Forest Reserve.

5.5.2.1 Impacts on canopy trees

Burkea africana

Most of the severe impact involving felling of trees was concentrated on the diameter size class 11-20 cm for snapping of trunks with an impact frequency 0.394±0.242, n=15 and diameter size class 21-30 cm for pushing over and uprooting with impact frequency of 0.622±0.187, n=15 (Fig. 5.5 and Appendix Table 5.1).

Terminalia sericea

The severe impacts suffered by this species were tree felling and the target diameter size classes were 11-20 cm for snapping of trunks with an impact frequency of 0.431±0.269, n=12 and felling and uprooting for the diameter size class 21-30 with an impact frequency of 0.356±0.270, n=11 (Figs. 5.5 and Appendix Table 5.1).

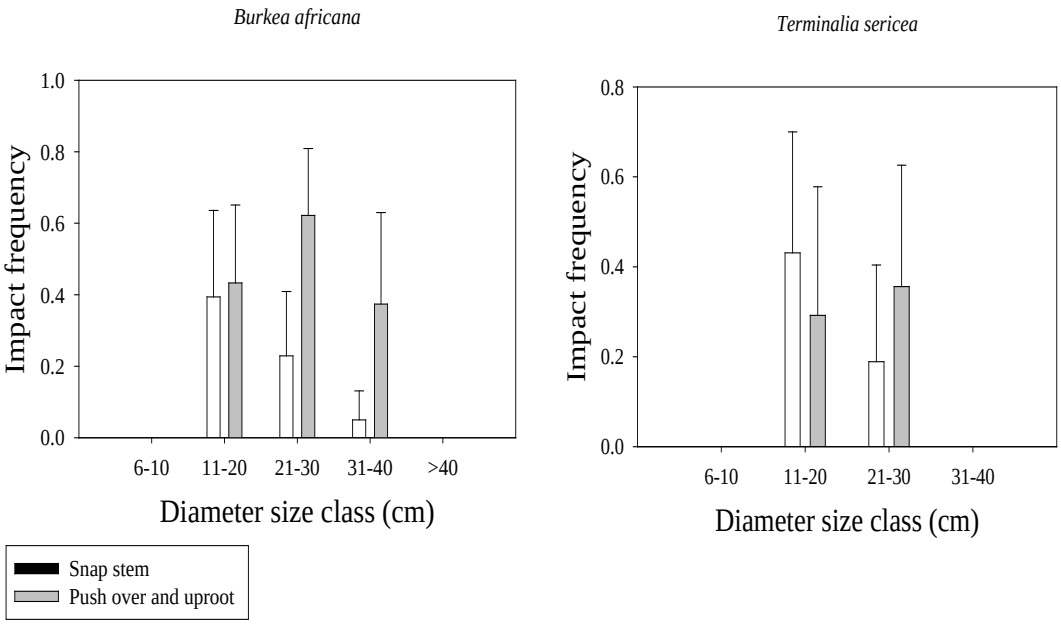

Figure 5.5 Severe elephant impacts involving tree felling on the different diameter size classes of *Burkea africana* and *Terminalia sericea* in Kazuma Forest Reserve northern Botswana in 1994.

5.5.3 Impacts on canopy trees in the Linyanti river front

5.5.3.1 Impacts on Colophospermum mopane trees

Felling of trees involving snapping of trunks, pushing over and uprooting were the most common types of severe impacts on *C. mopane* canopy trees. Snapping of trunks was concentrated on the diameter size class 11-20 cm with an impact frequency of 0.613±0.118, n=30 (Fig. 5.6 and Appendix Table 5.1). Uprooting and pushing over was concentrated on diameter size class 21-30 cm with an impact frequency of 0.217±0.018, n=32, while debarking was spread across all the diameter size classes ≥ 5 cm (Fig. 5.6 and Appendix Table 5.1).

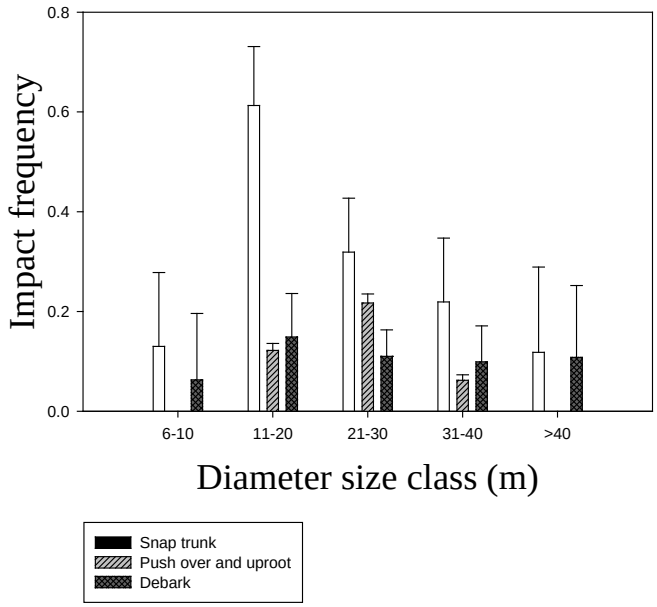

Figure 5.6 Severe elephant impacts involving felling and debarking on the different diameter size classes of *Colophospermum mopane* canopy trees in 1993 on the Linyanti river front, northern Botswana.

5.5.3.2 Impacts on the riparian woodland

Impacts on canopy trees were restricted to the commonly available tree species and size classes including *A. erioloba*, *A. nigrescens,* and *T. prunioides* (Fig. 5.7). As can be noted from Appendix Table 5.1 these species are currently characterised by absence of diameter size classes in the range 6 to 40 cm. For the available diameter size classes >40 debarking was the most common type of severe impact and with the following impact frequencies: *A. erioloba*, 0.660±0.154, n=14*; A. nigrescens*, 0.833±0.212, n=12*;* and *T. prunioides*, 0.688±0.385, n=20.

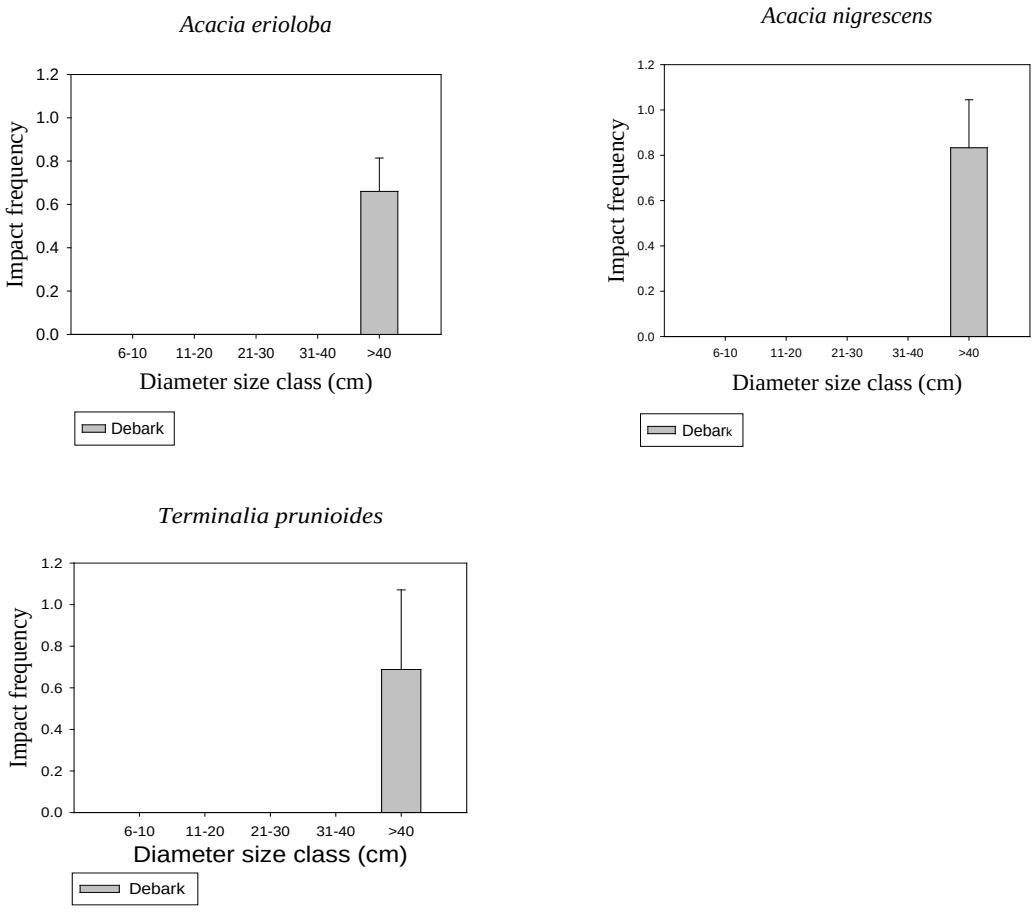

Figure 5.7 Severe elephant impact involving debarking on the different diameter size classes of *Acacia erioloba*, *Acacia nigrescens* and *Terminalia prunioides* in the riparian woodland of the Linyanti river front, northern Botswana in 1993.

5.6 Discussion

Fire and frost have the effect of killing the aboveground regrowth of the shrub layer on which elephant normally subsist as discussed in Chapter 2. Frost impact on the shrub layer in the Kazuma Forest Reserve appeared to have induced elephant impacts on some canopy trees spanning over the cool-dry and hot dry seasons of 1993.

Fire like frost has an impact on the shrub layer regrowth of woody species. The observation in the Kasane Forest Reserve Extension was that fire burned the shrub layer of the wet season concentration area. When elephant moved into the area, severe impact on the *B. africana* was recorded to be greater on the burned area than on the adjacent unburned area. The noted differences in impacts were attributed to the absence of the shrub layer on the burned site and availability of a mix of shrub species which were utilised by elephant on the unburned site. The fire event in the locality occurred once during the three year study period, and it was only following the fire event that impacts on canopy trees were noted.

The amount of water held in seasonal pans was reported to influence the spatial distribution of large mammals in relation to perennial water systems in northern Botswana as the dry season progressed (Joos-Vandewalle, 1988, Gibson et al., 1998). Below average rainfall experienced in the rainy seasons of 1991/92 and 1993/93 may have reduced the amount water held in seasonal pans. This could have induced elephants to move to the dry-season concentration area of the Linyanti earlier than expected thus increasing their length of stay in this locality. Elephant concentration in the Linyanti river front during the peak of the dry season was reported to range from 7 km^{-2} to 12 km^{-2} (Craig, 1990; Calef, 1991a, b; Gibson et al., 1998). The increased length of stay and high elephant density on the river front had the effect of shrub layer depletion and hence resulted in the observed elephant impacts on the on canopy trees.

The results of this study as presented above are limited in that there was no opportunity for replication, as the causal links of fire frost and drought occurred in as single events

each during the entire study period. Furthermore, there has been no specific report in the literature linking episodic events such as drought, frost and fire to elephant impacts on canopy trees. But as indicated in the introductory section of this chapter, impacts on canopy trees were also linked to phenological changes restriction of elephant movement due to physical barriers or human disturbance and proximity to water. However, three factors (drought, fire and frost) appear to have the effect of restricting the shrub layer food base on which elephant normally subsist, thus inducing impacts on canopy trees.

5.7 General conclusion

5.7.1 The findings of this study, although not replicated suggested a linkage of severe elephant impacts on canopy trees to the occurrence of drought, frost and fire events. As elephant normally subsist on the shrub layer, severe impacts on canopy trees may be induced by non availability of this food base as a result of localised over utilization in drought years and impacts of fire and frost.

Appendix Table 5.1 Diameter size class, availability and impact frequencies by elephant on the severe impact sites in northern Botswana. 'Site' refer to the number of transects in which a particular size class was encountered..

Species	Locality	Diameter Class (cm)	Sites	Availability	Snap Trunk	Uproot/ Push over	Debark
Colophospermum ***mopane***	Linyanti (Riparian fringe)	6-10	16	0.225±0.103	0.130±0.148	0.0	0.063±0.133
		11-20	30	0.731±0.100	0.613±0.118	0.122±0.014	0.149±0.087
		21-30	32	0.800±0.066	0.319±0.108	0.217±0.018	0.110±0.053
		31-40	23	0.369±0.112	0.219±0.128	0.062±0.011	0.099±0.072
		>40	17	0.231±0.109	0.118±0.171	0.0	0.108±0.144
Acacia erioloba	Linyanti (Riparian woodland)	6-10	0	0.0	0.0	0.0	0.0
		11-20	0	0.0	0.0	0.0	0.0
		21-30	0	0.0	0.0	0.0	0.0
		31-40	0	0.0	0.0	0.0	0.0
		>40	14	0.390±0.165	0.0	0.0	0.660±0.154
Acacia nigrescens	Linyanti (Riparian woodland)	6-10	0.0	0.0	0.0	0.0	0.0
		11-20	0.0	0.0	0.0	0.0	0.0
		21-30	0.0	0.0	0.0	0.0	0.0
		31-40	0.0	0.0	0.0	0.0	0.0
		>40	12	0.210±0.103	0.0	0.0	0.833±0.212
Terminalia prunioides	Linyanti (Riparian woodland)	6-10	0	0.0	0.0	0.0	0.0
		11-20	0	0.0	0.0	0.0	0.0
		21-30	0	0.0	0.0	0.0	0.0
		31-40	0	0.0	0.0	0.0	0.0
		>40	20	0.130±0.097	0.0	0.0	0.688±0.383
Burkea africana	Kazuma Forest Reserve	6-10	4	0.063±0.064	0.0	0.0	0.0
		11-20	15	0.425±0.140	0.394±0.242	0.433±0.218	0.0
		21-30	15	0.588±0.148	0.229±0.180	0.622±0.187	0.0
		31-40	14	0.350±0.138	0.050±0.081	0.374±0.256	0.0
		>40	5	0.100±0.110	0.0	0.0	0.0
Terminalia sericea	Kazuma Forest Reserve	6-10	0	0.0	0.0	0.0	0.0
		11-20	12	0.275±0.140	0.431±0.269	0.292±0.286	0.0
		21-30	11	0.275±0.145	0.189±0.215	0.356±0.270	0.0
		31-40	0.0	0.0	0.0	0.0	0.0
		>40	0.0	0.0	0.0	0.0	0.0
Burkea africana	Kasane Forest Extension (burned)	6-10	20	0.400±0.123	0.0	0.0	0.0
		11-20	23	0.569±0.135	0.0	0.113±0.123	0.0
		21-30	23	0.515±0.136	0.0	0.401±0.164	0.0
		31-40	16	0.131±0.051	0.0	0.250±0.136	0.0
		>40	0	0.0	0.0	0.0	0.0
Burkea Africana	Kasane Forest Extension (unburned)	6-10	14	0.467±0.193	0.0	0.069±0.105	0.0
		11-20	14	0.683±0.143	0.0	0.194±0.166	0.0
		21-30	14	0.650±0.087	0.0	0.042±0.062	0.0
		31-40	11	0.183±0.104	0.0	0.0	0.0
		>40	0	0.0	0.0	0.0	0.0

CHAPTER 6

A SIMPLE RULE-BASED FORAGING MODEL OF ELEPHANT IMPACTS ON WOODY VEGETATION

6.1 Introduction

Most models on elephant-vegetation interaction tended to be quantitative and were designed to predict long term vegetation trends under different fire regimes and herbivore browsing intensity (Norton-Griffiths, 1979; Barnes, R.F.W., 1983; Pellew, 1983). The field data to build such models was usually insufficient and hence supplemented by simulated data. Interpretation of quantitative models was often obscured by unanticipated sporadic natural events (Starfield and Bleloch, 1986). The quantitative modelling approach failed to incorporate fully the behavioural aspects of elephant impacts on vegetation induced by external forces such as fire, frost, and droughts. Knowledge of changes in foraging behaviour of elephant in response to external forces may assist wildlife managers to take appropriate management interventions.

Decisions in ecological management are often made on the basis of qualitative data and from an individual's accumulated experience (Starfield and Bleloch, 1983). According to Starfield (1990), qualitative, rule-based models (a) are useful in modelling systems that are driven by episodic natural events (b) are built on what one knows from experience and allows one to cope with insufficient data to construct more detailed models and (c) are easier to explain and understand and hence promote constructive discussion on conservation issues. The models may be updated in light of new data or better understanding of existing data.

A simple rule-based foraging model to predict elephant impacts on woody vegetation under different conditions in space and time is being developed in this chapter based on elephant feeding observations recorded over a 3 year period (1992-1994) in Chobe National Park, northern Botswana (Chapters 2-5). Specific factors which governed selective impacts were grouped into (a) factors associated with woody plants such as plant species, height class, plant parts and phenology (b) climatic factors such as frost

and drought (c) fire (d) factors associated with elephant such as bull or family group. These factors resulted in seasonal and spatial differences in elephant impacts on woody vegetation observed in the park over the study period. Other factors known to result in elephant impacts on canopy trees by concentrating elephant in defined localities such as game fences, escarpments, legal or illegal hunting were not considered as these were not important in the study area at the time.

It is hoped that this simple model which may be modified and expanded in light of new knowledge may be useful to park managers in adopting appropriate management decisions to deal with the elephant problem. This operation of the model by resource managers will be driven by a user friendly and interactive shell computer program as developed by Starfield and Bleloch, 1983, 1986). Some of the management decisions are suggested in Chapter 7.

6.2 Summary of feeding observations

6.2.1 Impacts on the shrub layer

In the absence of external events such as frost, fire and droughts elephants seasonally subsisted on different plant parts of favoured shrub species occurring in different woodland types as described in Chapters 2-5. For instance, the most favoured woody species in the Kalahari sandveld woodland were *Bauhinia petersiana* and *Baphia massaiensis* during the wet season; *B. petersiana* and *Diplorhynchus condylocarpon* during the cool-dry season while *B. massaiensis* and *Combretum spp.* were favoured during the hot-dry season. The preferred elephant feeding level for the shrub species was 1-2.5 m

6.2.2 Impacts on canopy trees

The common vegetation associations found in northern Botswana were (a) the riparian woodlands of the Chobe and Kwando/Linyanti river fronts dominated by *Acacia spp*; (b) the *Colophospermum mopane* woodland (c) the *Baikiaea plurijuga* woodland of the Kalahari sandveld and (d) the *Brachystegia boehmii/Burkea africana* woodland. Impacts on mature trees seemed to occur in time and space or episodically in

association with events such as severe drought, frost, and fire (Chapter 5). Impacts on canopy trees were considered to be severe if elephant feeding activities involved uprooting, tree felling and bark stripping. The variability and severity of elephant impacts on canopy trees due to frost, fire and drought appeared to be induced by the reduction in the availability of the shrub layer food base due to these factors or extended localised elephant impacts on the shrub layer.

6.2.2.1 Influence of drought

Drought related impacts were observed on the riparian and fringing *C. mopane* woodlands of the Linyanti river front (see Chapter 5). The amount and pattern of seasonal rainfall appeared to be crucial in influencing episodes of severe elephant impacts on canopy trees. Episodes of severe impacts on mature trees were likely to occur if the amount seasonal rainfall including the late wet season rainfall was far below average.

The amount of seasonal rainfall was found to influence the spatial distribution of elephant in northern Botswana (Calef, 1991a, b; Gibsdon et al. 1998). In good rainy years, elephant would be expected to concentrate on permanent water sources at the peak of the hot-dry season. Hence, drought conditions had the effect of lengthening the period of elephant concentration on perennial water systems. This would result in elephant having greater impacts on both the shrub and canopy tree layers of selected woody species near the permanent water sources.

The impacts on the canopy tree layer of the Linyanti river front woodlands was targeted at *Acacia erioloba, Acacia nigrescens, Berchemia discolor, Acacia luederitzii, C. mopane, Peltophorum africanum* and *Terminalia prunioides.*

6.2.2.2 Fire and frost induced impacts

Frost and fire affected the shrub layer similarly by killing the above ground parts of plants as described in Chapter 5), thus reducing the shrub layer food base on which elephant would normally subsist. This induced elephant impacts on canopy trees.

Frost induced elephant impacts were observed during the cool-dry and hot-dry seasons in the *Brachystegia/Burkea* woodland of the Kazuma Forest Reserve and the target trees were *B. africana*, *B. boehmii* and *T. sericea.* Fire induced elephant impacts were observed in the *Brachystegia/Burkea* woodland of the Kasane Forest Reserve Extension and the target trees were mainly *B. africana* and *B. boehmii.*

6.2.2.3 Impacts related to elephant

Bulls generally had a greater impact on mature trees than family groups. Severe impacts involving felling of mature trees appeared to be caused by bull groups. This observation stemmed from the fact that most of the mature trees that were available had diameters sizes ≥20 cm. Below this diameter size class, female groups were observed to make a significant contribution to felling of trees.

6.3 Driving Variables

The above summary of observations of elephant feeding observations on woody vegetation suggested the following important driving variables:

6.3.1 Elephants*:* elephant density was assumed to be that pertaining to the average hot-dry season concentration on the Chobe river front (5 km^{-2}) and the Linyanti river front (8 km^{-2}) (Melton, 1985; Work, 1986; Craig, 1990; Calef 1981a).

6.3.2 **Seasons**: three seasons of the year were defined as wet (November-April), cool-dry (May-July), hot-dry (August-October)

6.3.3 **R*ainfall***: seasonal rainfall was regarded to have three states: below average, average and above average.

6.3.4 Fire: was classified as no fire, hot fire (occurring during the peak of the dry season) or cool fire (occurring during the cool-dry season or after the first rains).

6.3.5 **F*rost*:** a frost event was rated as mild or severe

6.3.6 Plant species: this included the different size classes of tree species.

6.4 Elephant feeding knowledge base

6.4.1 Decisions

Context: This prototype expert system provides an insight into foraging behaviour and related elephant impacts on woody vegetation in different woodlands, tree species and size classes in space and time under different conditions.

Dec 1: Feed on preferred woody species during the wet season within a woodland type.

Dec 2: Feed on preferred woody species in a woodland type during the cool-dry season.

Dec 3: Feed on preferred wood species in a woodland type during the hot-dry season.

Dec 4: Feed mainly on woody species in the shrub layer.

Dec 5: Move to the river front starting in cool-dry season instead of at the peak of the hot-dry season.

Dec 6: Feed on tree layer with feeding actions involving felling of trees by bull elephant.

Dec 7: Feed on tree layer with feeding actions involving felling of trees by both bull and cow elephant.

Dec 8: Feed on palatable woody species in the shrub layer in the absence of canopy trees.

Dec 9: Feed on tree layer of available and preferred tree species as the above ground shrub regrowth would have been killed by fire.

Dec 10: Feed on tree layer of available and preferred tree species as the above ground shrub regrowth would have been killed by frost.

6.4.2 Questions

Question 1: Which season of the year is it?

***Why*:** Selective elephant impacts on different woody species and size classes occur at different times of the year.

Answer: **1** Wet season

2 Cool-dry season

3 Hot-dry season

***Question 2*:** What has been the amount of seasonal rainfall?

Why: Rainfall promotes regrowth of woody vegetation and spatial seasonal distribution of elephant.

Answer: **1** Below average

2 Average

3 Above average

Question *3*: What has been the amount of seasonal and late wet season rainfall?

Why: Amount of late wet season rainfall may determine period of movement of elephant from wet season range to dry season range i.e to the river front.

Answer: **1** Below average

2 Average

3 Above average

Question 4: Which woodland type is currently associated with elephant concentration?

Why: Woody vegetation close to water points is likely to suffer severe impacts.

Answer: **1** *Colophospermum mopane* woodland

2 Sandveld woodland e.g. *B. plurijuga*

3 *Brachystegia/Burkea* woodland

4 Riparian woodland

Question 5: Which source of water is associated with elephant concentration?

Why: Water may be available in permanent river systems or artificial water supplies.

Answer: **1** Perennial river systems

2 Water pans/boreholes

Question 6: What is the main physiognomy of susceptible woody species?

Why: Elephant impact on different susceptible woody species depend on size class and diameter.

Answer: **1** Shrub layer

2 Canopy trees ≥20 cm in diameter

3 Canopy trees ≤≤20 cm in diameter

Question 7: Did the area experience any fire during the year?

Why: Hot fires kill the shrub layer on which elephant normally subsist and a fire event may induce elephant impact on canopy trees.

Answer: **1** No fire or cool fire

2 Hot fire

Question 8: If the area experienced frost, how severe was the frost?

Why: Severe frost, like fire, kills the shrub layer on which elephant feed and this may induce impact on canopy trees.

Answer: **1** Nil or mild

2 Severe

6.4.3 Rules

The following are the rules required to reach a certain foraging decision under a given set of conditions. As used here, a rule is a combination of conditions and actions to be taken. The following rules have been constructed with the aid of the decision Table 6.1.

Rule 1

Why: Elephant subsist on a subset of woody species and size classes in the wet season. e.g. *B. massaiensis*, *B. petersiana* and *Commiphora mossambicensis* if the woodland type is *B. plurijuga* of the Kalahari sandveld.

IF [q1a1 AND q2a2 AND q4a2] THEN [dec 1].

Rule 2

Why: Elephant subsist on a subset of woody species and size classes in the cool-dry season e.g. *B. petersiana* and *D. Condylocarpon* if the woodland type is *B. plurijuga* of the Kalahari sandveld

IF [q1a2 AND q2a2 AND q4a2] THEN [dec 2].

Rule 3

Why: Elephant subsist on a subset of woody species and size classes in the hot-dry

season e.g. *B. massaiensis, Combretum spp, Grewia monticola* and *Terminali a sericea* if the woodland type is B plurijuga of the Kalahari sandveld.

IF [q1a3 AND q2a2 AND q4a2 AND q7a1] THEN [dec 3].

Rule 4

Why: Elephant concentration on the river front occurs during the peak of the hot-dry season in a good rainy year and impact on canopy trees is minimal.

IF [(q1a2 OR q1a3) AND q2a2 AND q3a2 AND q4a1 AND q5a1] THEN [dec4].

Rule 5

Why: Water availability in seasonal pans is reduced if both the total seasonal and late seasonal rainfall are below the normal averages.

IF [q2a1 AND q3a1] THEN [dec 5].

Rule 6

Why: Water availability in seasonal pans is reduced if late seasonal rainfall is below average regardless of whether or not the total seasonal rainfall is above average.

IF [q3a1] THEN [dec 5]

Rule 7

Why: Bulls and cows are both likely to have severe impacts on canopy trees with diameter sizes ≤ 20 cm.

IF [q2a1 OR q3a1] AND (q5a1 OR q5a2) AND q6a2 THEN [dec 6]

Rule 8

Why: Bulls are likely to have severe impacts on canopy trees with diameter sizes ≥ 20 cm.

IF [[q2a1 OR q3a1] AND q5a2 AND q6a3 THEN [dec 7].

Rule 9

Why: Elephant will feed on available shrub species as long as there are no canopy trees.

IF [q6a1 AND q7a1] THEN [dec 8].

Rule 10

Why: Elephant will feed on available canopy trees if the shrub layer is killed by fire.

IF [q1a3 AND q2a3 AND q7a2] THEN [dec 9].

Rule 10

Why: Elephant will feed on available canopy trees and frost resistant shrub species after the occurrence of a frost event.

IF [(q1a2 OR q1a3) AND q8a2 THEN [dec 10].

Table 6.1 Decision table of the rule-based foraging model. The table is filled up by appropriate answers and 'x' indicates that a particular question is irrelevant.

Decision	**Questions**							
	1	2	3	4	5	6	7	8
1	1	2	x	2	x	x	x	x
2	2	2	x	2	x	x	x	x
3	3	3	x	3	x	x	1	x
4	x	23	3	1	1	x	x	x
5	x	1	1	X	x	x	x	x
	x	x	1	X	x	x	x	x
6	x	1	x	X	12	3	x	x
	x	2	1	X	12	3	x	x
7	x	1	12	1	12	2	x	x
	x	2	1	1	12	3	x	x
8	x	X	x	X	X	1	1	x
9	3	2	x	3	2	2	2	x
10	23	X	x	X	X	x	x	2

6.5 Discussion

The prototype elephant rule-based foraging model was developed from field observations over a three year study period. The model was constructed using the knowledge base gained over the study period particularly the spatial differences in elephant impacts on woody vegetation in time and space induced by fire, frost, and amount of rain likely to be experienced in northern Botswana.

The prototype model is by no means complete as it did not incorporate all the factors likely to influence elephant impacts on woody vegetation which include the various aspects of human influences such as hunting and erection of physical barriers. The model may be updated in light of new research findings. For instance, rates of vegetation impacts by the different age/sex classes of elephant could not be fully assessed during the study period.

The model may be expanded and be linked to management strategies and hence assist park managers to take appropriate action to alleviate elephant impacts in localities of concern during critical periods by adopting one or a combination of management strategies described in Chapter 7. In particular, the model may be used by wildlife managers to deal with the elephant problem when certain conditions prevail i.e in (a) relating certain external conditions to the likely impacts on different vegetation types (b) deciding on an appropriate management option (c) locations of boreholes and artificial water provision to manipulate elephant movement patterns and (d) planning fire management strategies. Researchers may use the model to provide them with an overview of elephant foraging strategies when designing research projects. The model may also be used as a teaching aid in colleges on topics related to elephant vegetation-interaction.

6.6 Conclusion

6.6.1 Qualitative model development may be a long term process, and at each stage, the model may be updated to incorporate new experience and knowledge.

6.6.2 The model may be used by park managers as an aid in making quick decisions on elephant and other habitat management strategies.

CHAPTER 7

CONCLUSIONS

7.0 Overview

This chapter provides a critical synthesis of this study which was designed to determine factors governing selective impacts of elephant on woody vegetation in the sandveld elephant range of northern Botswana. The study objectives and hypotheses were outlined in the introductory chapter while the specific objectives and research questions associated with each component of the study are provided in the relevant chapters. In the broader interpretation of the conclusions as presented below, it should be recognised that the study findings are specific to the sandveld woodland of Chobe National Park, northern Botswana.

7.1 Synthesis and evaluation of factors

The range of factors considered in the study were plant species, plant size class, plant parts, availability of alternative food types, season, age/sex class of elephant, habitat types and episodic environmental conditions such as frost, fire and droughts. The following sections provide a synthesis and evaluation of these factors with respect to their influence on woody species acceptance by elephant; associated impacts suffered by the different size classes of woody species and implications on woodland dynamics.

7.1.1 Selection of plant species

The results of this study suggested that while elephant were selective in their feeding habits, they seasonally subsisted on a very narrow range of woody species to the extent that over 70% of the woody species diet component was obtained from two to four plant species. The selective feeding aspect involved the utilization of different plant parts from different size classes of the favoured woody species each season.

The results of this study suggested that selection of species was not necessarily due to woody plant species abundance indicating that there could be other factors influencing acceptability which were not addressed by this study. This finding differs from what has been reported in other studies that elephant utilized woody species in proportion to their relative abundance (Croze, 1974b; Anderson and Walker, 1974; Barnes, R.F.W., 1983; Jachmann and Bell, 1985).

Elephants generally neglected rare species. Of the 46 rare species encountered by elephant, only 4 of these were accepted by elephant. The accepted rare species included *Combretum hereroense, Euclea divinorum, Tricalysia cacondensia* and *Combretum glabrum*.

There was enough evidence from the study to suggest that acceptance of individual and commonly available woody species depended or was influenced by other woody species in a feeding patch. The negative implication of this scenario is the potential elimination or depression of such rare species if the feeding activities involved digging and uprooting as observed for *Grewia monticola*.

7.1.2 Size class selection

Plant size class appeared to be one of the most important factors which influenced acceptance of woody species by elephant. While the size class 1-2.5 m was the most favoured, the whole range of height classes of favoured woody species was also used by elephant. The range of favoured size classes included the elephant feeding level preference of about 1-2 m reported in previous studies by Guy (1976) and Jachmann and Bell (1985). That the size class 1-2.5 m was most favoured could not be explained in terms of depletion of the smaller size classes which for some species were equally abundant like any other size class.

While it has been reported that plant sizes 1<m were infrequently utilized (Croze, 1974b; Caughley, 1976; Leuthold, 1977; Pellew, 1983; Mwalyosi, 1990), this study showed that sizes classes ≤1m for some woody species were also favoured.

7.1.3 Influence of woody plant parts

The study confirmed that within the savanna woodlands woody plant part diet of elephant consisted mainly of leaves during the wet season while the woody material (stems, roots, and bark of stem) dominated from the cool-dry and through the hot-dry season (Williamson, 1975; Field and Ross, 1976; Guy, 1976 and Jachmann and Bell, 1985). It should be noted that although this study focused on woody species consumption, elephants also subsisted on grass. It was reported in the literature that

a higher proportion of grass is consumed in the wet season, while in the dry season, the woody plant parts form a higher percentage of the food intake (Buss, 1961, Bax and Sheldrick, 1963; Field, 1971; Laws et al. 1975; Williamson, 1975; Field and Ross, 1976; Guy, 1976; Barnes, 1982). But the browse-grass ratio in the diet was a function of tree density (Bell, 1985; Lindsay, 1986).

7.1.4 Age/sex differences in woody species acceptance by elephants

It was difficult to fully assess differences in acceptances at the level of individual age/sex classes of elephant due to the limited data collected. However, the study revealed that bull herds and cow herds did not differ in their acceptances of the commonly utilized woody species and size classes occurring in the shrub layer. Also, recent studies by Stokke (1999) and Stokke and du Toit (2000) within Chobe National Park found no evidence of feeding height stratification between family units and male groups. The only difference noted was that family units selected patches with a higher diversity of plant species than males.

The limited data collected on sex/age differences with respect to impacts on larger trees indicated that bull herds appeared to have a greater impact on the larger diameter size classes of trees than cow herds. All the trees felled were utilized for food and elephant revisited and fed upon the felled trees from time to time. This differs from observations elsewhere by Bax and Sheldrick (1963), Lamprey et al. (1967), Croze (1974a) and Guy (1976) that elephant may push over trees without attempts to feed on them.

7.1.5 Influence of episodic events

Impacts on canopy trees were reported to occur if elephant movement was restricted by human disturbance (Lamprey et al., 1967; Thompson, 1975; Field and Ross, 1976; Mwalyosi, 1987) or movement restricted by physical barriers such as game fences and escarpments (Thompson, 1975; Cumming et al., 1997).

This study fortuitously identified other conditions which may be viewed as episodic and likely to influence localised elephant impacts on canopy trees. These included drought, fire and frost. As discussed in Chapter 5, the three conditions restricted the availability of the shrub layer on which elephant normally subsisted. The impacts associated with these conditions tended to be localised and restricted to sensitive woodland associations. The wider and long term implication of such impacts is the depletions of canopy trees over time, thus resulting in localised reduction of sensitive woodlands to a shrub state. However, the limited study time frame did not provide

opportunities to replicate the occurrence of these episodic events and their spatial interactive effects with elephant on woody vegetation.

7.1.6 Implications of elephant impacts to woodland dynamics

A key finding of this study was that the common shrub species on which elephant preferred to feed on were able to regrow following elephant use as observed elsewhere (Jachmann and Bell, 1985; McShane, 1989). Hence the main food supplies are currently abundant and because of this, elephant population has continued to grow steadily at an annual rate of about 5 to 6% (Calef, 1991a; Craig, 1996; Gibson et al., 1998). The implication of this scenario is that either the elephant population will continue to grow much larger resulting in one or a combination of the following possibilities:

i) Adverse vegetation alteration thus limiting food supply and hence reduction in elephant population growth;

ii) A catastrophic mortality as observed in Tsavo, Kenya (Corfield, 1973; Parker, 1983);

iii) Elephant may potentially redistribute into neighbouring countries such as Zimbabwe, Namibia and Zambia if a coordinated protection and management system is put in place. This will reduce localised pressure on vegetation, thus reducing the likelihood of population crashes;

iv) Conversion of woodland to an open patch mosaic shrub state (Lindsay (1990) being maintained in this state mostly by elephant (Dublin et al., 1990; Western and Maitumo, 2004) and in interaction with other factors such as fire, frost and drought as discussed above.

The above possibilities suggest the need for some level of elephant management. Justification for reduction of elephant numbers has not been scientifically supported since there have been no noticeable change in elephant rate of increase or adverse effects on the numbers of other mammal species (Skarpe et al. 2004). However, Skarpe et al. concluded that justification for elephant management could only be based on social and economic needs.

Options for elephant management in northern Botswana were reviewed by Chafota and Owen-Smith (1996) who suggested adopting a combination of actions on ecological and socio-economic grounds to reduce or stablise elephant numbers, the effectiveness of which could be measured through a monitoring and evaluation programme.

The results of this study provided some evidence of localised severe elephant impacts, thus the distribution and extent of habitat transformation may need to be controlled and monitored to ensure that biological diversity is not sacrificed. It also means that the limits of permissible change in vegetation-herbivore changes must be scientifically defined and measured.

7.1.7 Rule-based qualitative modelling framework

The prototype rule-based qualitative foraging model was designed as a basis for the development of a full predictive management tool for elephant woodland interaction in different habitats and vegetation associations under different conditions in time and space. This pooled together important factors which were found to govern selective elephant impacts on woody vegetation into a decision making modelling framework. The utility of the model is focussed on aiding park managers to understand and predict impacts on woody vegetation resulting from the interaction of elephant and other factors.

It should be noted that the qualitative model development is a long term exercise built incrementally on the initial knowledge base, and at each stage, being updated to incorporate new experience and knowledge. This model development approach is a useful tool to build up and refine a knowledge base to be used in guiding research and management decisions.

7.2 Recommendations for future research

The study pointed to the following important research areas which if carried out will contribute to the knowledge of elephant-vegetation interactions as well as contributing to elephant management decisions.

7.2.1 Analysis of seasonal changes in chemical contents of woody plant parts.

Elephant were found to be seasonally selective in the utilization of woody plant species, size classes and plant parts. Also, the quantities and types of plant parts included in elephant diet varied seasonally. Hence, analysis of chemical contents with the objective of determining seasonal changes in the nutritional value of woody species plant parts as a factor governing acceptance by elephant is recommended.

7.2.2 Development of an integrated modelling framework for elephant-vegetation interaction.

Despite all the research advances to date on elephant-vegetation interactions, there are still uncertainties. In particular, permissible thresholds of elephant-vegetation interaction and related management options have not been clearly defined nor scientifically verified. As revealed by this study, contributory factors to the uncertainties include episodic events such as fire, frost and droughts. The integrated modelling framework could incorporate studies on elephant movements and distributions in different habitats; conditions associated with impact types in different vegetation associations and habitats; vegetation states associated with different elephant densities in time and space. Ideally the modelling framework would require short, medium and long term time frames including development of trends and a decision making tool-kits for resource mangers.

7.2.3 The effects of elephant disturbance on biodiversity.

Impacts on woody species by elephant may affect the physiognomic structure of woody vegetation and hence conditions in different habitats, thus inducing a likelihood of either a positive or a negative effect on a wide range of other living species. Results of the study by Skarpe et al. (2004) in Chobe National Park found little evidence of a reduction in the carrying capacities of other large herbivores which in fact have shown an increase in numbers concurrently with that of elephant. Despite all this, indicators of biodiversity change need to be defined and a comprehensive study carried out which takes into consideration other components of biodiversity including small mammals and birds. Such a study would also be useful in establishing the limit of acceptable vegetation change below which there would be an adverse effect on the biodiversity of sensitive species in different habitat types and elephant densities.

LITERATURE CITED

Addy, J. E. 1993. *Impact of elephant induced vegetation change on the Chobe bushbuck (Tragelaphus scriptus ornatus) along the Chobe River, northern Botswana.* M.Sc. thesis. University of the Witwatersrand.

Altmann, J. 1974. Observational study of behaviour sampling methods. *Behaviour* 49:227-267.

Anderson G.D and Walker, B.H. 1974. Vegetation composition and elephant damage in the Sengwa Wildlife Research Area, Rhodesia. *J. Sth. Afr. Wildl. Ass.* 4(1): 1-14.

Barnes, D.L. 1982. Management strategies for the utilization of southern African savanna. Pp. 627-656. *In*: Huntley, B.J. and Walker, B.H. (eds.), *Ecology of Tropical Savannas.* 669 pp.

Barnes R.F.W. 1979. *Elephant ecology in the Ruaha National Park, Tanzania*. Ph.D. thesis, University of Cambridge.

Barnes, R.F.W. 1980. The decline of baobab tree in Ruaha National Park, Tanzania. *Afr. J. Ecol.* 18: 243-52.

Barnes, R.F.W. 1982. Elephant feeding behaviour in Ruaha National Park, Tanzania. *Afr. J. Ecol.* 20: 123-36.

Barnes, R.F.W. 1983. The elephant problem in Ruaha National Park, Tanzania. *Biol. Cons*. 26:127-148.

Bax, N.P. and L.W. Sheldrick, D.L.W. 1963. Some preliminary observations on the food of elephants in the Tsavo Royal National Park (East) of Kenya. *E. Afr. Wildl. J.* 1: 40-35.

Bell, R.H.V. 1971. A grazing ecosystem in the Serengeti. *Sci. Am*. 225: 86-93.

Bell, R.H.V. 1983. Decision-making in wildlife management with reference to problems of overpopulation. Pp. 145-186. In: Owen-Smith, R.N. (ed.), Management of Large mammals in African Conservation Areas. Haum, Pretoria. 297 pp.

Bell, R.H.V. 1985. Elephants and woodland - a reply. *Pachyderm* 5: 17-18.

Box, G.E.P, Hunter, W.G. and Hunter, J. S. 1978. *Statistics for experimenters: An introduction to design, data analysis, and model building.* John Wiley & Sons. 653 pp.

Brunt, M.A., Clarke, V.J. and Greling, C. 1986. *Tsetse area development and land use planning in the Zambezi Valley, Zimbabwe*. FAO Consultant Report.

Bryant, F.C., Kothmann, M.M. and Merrill, L.B. 1980. Nutritive content of sheep, goat and white-tailed deer on excellent condition rangeland in Texas. *J. Range Manage.* 33: 410-414.

Buechner, H.K. and Dawkins, H.C. 1961. Vegetation change induced by elephants and fire in Murchison Falls National Park, Uganda. *Ecology* 42: 752-766.

Buss, I.O. 1961. Some observations of the food habits and behaviour of the African elephant. *J. Wildl. Manage.* 25: 131-148.

Calef, G. W. 1991a. Elephant numbers and distribution in Botswana and northwestern Zimbabwe. *Proceedings of workshop on Management of the Hwange Ecosystem*. Hwange Safari Lodge 9-13 July, 1991.

Calef, G. W. 1991b. *Seasonal migration of elephants in northern Botswana*. Dept. of Wildlife and National Parks, Botswana. 25 pp.

Cates, R.G. and Rhoades, D.F. 1977. Pattern in the production of anti-herbivore chemical defenses in plant communities. *Biochem. and Syst. Ecol.* 5: 185-194.

Caughley, G. 1976. The elephant problem - an alternative hypothesis. *E. Afr.Wildl. J.* 14:265-283.

Chafota, J. and N. Owen-Smith. 1996. Options for the management of elephant in northern Botswana. Pachyderm 22: 67-73.

Child, G. 1968. *An ecological survey of northeastern Botswana*. Report to the Government of Botswana. FAO Report No. TA 2563.

Childes, S.L. 1974. *The population dynamics of some woody species in the Kalahari sand vegetation of Hwange National Park.* M.Sc Dissertation, University of the Witwatersrand, Johannesburg. 194 pp.

Childes, S. L and Walker, B.H . 1987. Ecology and dynamics of the woody vegetation on Kalahari sands in Hwange National Park. *Vegetatio 72*: 111-128.

Conybeare, A.M. 1991. *Elephant occupancy and vegetation change in relation to artificial water points in a Kalahari sand area of Hwange National Park.* D. Phil. thesis, University of Zimbabwe. 210 pp.

Corfield, T. F. 1973. Elephant mortality in Tsavo National Park, Kenya. *E. Afr. Wildl. J.* 11: 339-68.

Coulson, I. M. 1992. *Linyanti/Kwando vegetation survey*. Kalahari Conservation Society. Gaborone, Botswana. 41 pp.

Craig, G.C. 1990. Present population and distribution of elephants in northern Botswana. Pp. 16-18. In: Hancock, P. (ed.), *The future of Botswana's elephants*. Gaborone, Botswana. 96 pp.

Craig, G.C. 1996. *Elesmap Project Final Technical Report*. CEC Project No. B7-5040. Namibia Nature Foundation. 41 pp.

Croze, H. 1974a. The Seronera bull problem I. The elephants. *E. Afr. Wildl. J.* 12: 1-27.

Croze, H. 1974b. The Seronera bull problem II. The trees. *E. Afr. Wildl. J.* 12:29-47.

Cumming, D.H.M. 1981. The management of elephant and other large mammals in Zimbabwe. Pp. 91-118. *In*: Jewel, P.A., Holt, S. and Hart, D. (eds.), *Problems in management of locally abundant wild mammals*. Academic Press, New York. 361 pp.

Cumming, D.H.M. 1983. The decision-making framework with regard to the culling of large mammals in Zimbabwe. Pp. 173-186. *In*: Owen-Smith, R.N. (ed.), *Management of large mammals in African conservation areas*. Haum, Pretoria. 297 pp.

Cumming, D.H.M., Fenton, M. B., Rautenbach, I.L., Taylor, R.D., Cumming, G.S., Cumming, M.S., Dunlop, J.M., Ford, A.G., Hovorka, M.D., Johnston, D.S., Kalcounis, M., Mahlangu, Z. and Portfors, C.V.R. 1997. Elephants, woodland and biodiversity in southern Africa. *Sth. Afr. J. Sci.* 93: 231-236.

Cunliffe, R.N. 1993. *Landuse in the southern lowveld of Zimbabwe*. Department of National Parks and Wildlife Management, Harare, Zimbabwe.

DNPW, 1991. *The conservation and management of elephant in northern Botswana.* Ministry of Commerce and Industry. 13 pp.

Dougall, H.P., V.M. Drysdale, and Glover, P.E. 1964. The chemical composition of Kenya browse and pasture herbage. *E. Afr. Wildl. J.* 2: 86-121.

Dougall, H.P. and Sheldrick, D.L.W. 1964. The chemical composition of a day's diet of an elephant. *E. Afr. Wildl. J.* 2:51-59.

Draper, N.R. and Smith, H. 1981. *Applied regression analysis*. 2nd Edition. John Wiley and Sons Inc. 709 pp.

Dublin, H.T., Sinclair, A.R.E., McGlade, J. 1990. Elephants, fire as causes of multiple stable states in the Serengeti-Mara woodlands. *J. Anim. Ecol*. 59: 1147-1164.

Field, C.R. 1971. Elephant ecology in the Queen Elizabeth National Park, Uganda. *E. Afr. Wildl. J*., 9: 99-123.

Field, C.R. and Ross, I.C. 1976. The savanna ecology of Kidepo Valley National Park. II. Feeding ecology of elephant and giraffe. *E. Afr. Wildl. J*. 14: 1-16.

Gibson, D. St. C, Craig, G.C and Masogo, R.M. 1998. Trends of elephant population in northern Botswana from aerial survey data. *Pachyderm* 25: 14-27.

Glover, J. 1963. The elephant problem at Tsavo. *E. Afr. Wildl. J*. 1:30-39.

Guy, P.R. 1976 The feeding behaviour of elephant (*Loxodonta africana*) in the Sengwa Area, Rhodesia. *Sth. Afr. J. Wildl. Res*. 6(1): 55-63.

Guy, P.R. 1981. Changes in the biomass and productivity of woodlands in the Sengwa Research Area, Zimbabwe. *J. Appl. Ecol*. 18: 507-19.

Hall-Martin, A. 1984. Conservation and management of elephants in the Kruger National Park, South Africa. Pp.104-115. *In:* Cumming, D.H.M. and Jackson, P. (eds), *The Status and Conservation of Africa's Elephants and Rhinos*. IUCN, Switzerland. 191 pp.

Hancock, P. 1990. *The future of Botswana's elephants*. Kalahari Cons. Society, Gaborone, Botswana. 96 pp.

Hanks, J. 1971. Reproduction of the elephant (*Loxodonta africana*) in the Luangwa Valley, Zambia. *J. Repr. Fert*. 30: 13-26.

Jachmann, H. 1987. Elephants and woodlands II. *Pachyderm* 8: 11-12.

Jachmann, H. and Bell, R.H.V. 1985. Utilization of *Brachystegia* woodlands of the Kasungu National Park, Malawi. *Afr. J. Ecol*. 23: 245-58.

Joos-Vandewalle, M. E. 1988. *Abundance and distribution of large herbivores in relation to environmental factors in Savuti, Chobe National Park, Botswana*. M.Sc. thesis, University of the Witwatersrand, Johannesburg.

Kabigumila, J. 1993. Feeding habits of elephants in Ngorongoro Crater, Tanzania. *Afr. J. Ecol*. 31: 156-164.

Lamprey, H.F., Glover, P.E., Turner, M. and Bell, R.H.V. 1967. Invasion of Serengeti National Park by elephants. *E. Afr. Wildl.* J. 5:151-166.

Laws, R.M. 1966. Age criteria for the African elephant, *Loxodonta africana*. *E. Afr. Wildl. J.* 4:1-36.

Laws, R.M. 1970. Elephants as agents of habitat and landscape change in East Africa. *Oikos* 21:1-15.

Laws, R.M. and Parker, I.S.C. 1968. Recent studies of elephant population in East Africa. *Symp. Zool. Soc. Lond.* 21:319-359.

Laws, R.M., Parker, I.S.C. and Johnstone, R.C.B. 1970. Elephants and habitats in North Bunyoro, Uganda. *E. Afr. Wildl.* J. 8: 163-180.

Laws, R.M., Parker, I.S.C., and Johnstone, R.C.B. 1975. *Elephants and their habitats. The Ecology of Elephants in North Bunyoro, Uganda*. Oxford, Clarendon Press. 376 pp.

Leuthold, W. 1977. Changes in tree populations of Tsavo East National Park, Kenya. *E. Afr. Wildl. J.* 15: 61-69.

Lewis, D.L. 1991. Observations of tree growth, woodland structure and elephant damage on *Colophospermum mopane* in Luangwa Valley, Zambia. *Afr. J. Ecol.* 29(3): 207-221.

Lindsay, K. 1986. Elephants and woodlands – what are the issues? Pachyderm 7: 16-17.

Lindsay, W.K. 1990. Elephant/habitat interactions. Pp. 19-23. *In*: Hancock, P. (ed.), *The Future of Botswana's Elephants.* Gaborone, Botswana. 96 pp.

McShane, T.O. 1989. Some preliminary results of the relationship between soils and tree response to elephant damage. *Pachyderm* 11: 21-31.

Melton, D.A. 1985. The status of elephant in northern Botswana. *Biol. Cons.* 31(4): 317-334.

Mills, M.G.L., Whyte, I.J., Viljoen, A.J., Zambatis, N. and Potgieter A.L.F. 1996. *Background information for the National Parks Boards review of the Kruger National Park=s elephant management policy*. Scientific Report 1/96. 38 pp.

Moroka, D.N. 1984. *Elephant - habitat relationships in northern Botswana*. Department of Wildlife and National Parks. Gaborone, Botswana. 46 pp.

Mwalyosi, R.B.B. 1987. Decline of *Acacia tortilis* in Lake Manyara National Park, Tanzania. *Afr. J. Ecol.* 25:51-53.

Mwalyosi, R.B.B. 1990. The dynamic ecology of *Acacia tortilis* woodland in Lake Manyara National Park, Tanzania. *J. Ecol*. 28: 189-199.

Norton-Griffiths, M. 1979. The influence of grazing, browsing and fire on the vegetation dynamics of the Serengeti. Pp. 310-352. *In:* Sinclair, A.R.E and Norton-Griffiths, M. (ed.), *Serengeti: Dynamics of an ecosystem*. Univ. of Chicago Press. 389 pp.

Nyamapfene, K. 1991. *Soils of Zimbabwe*. Nehanda Publishers, Harare. 179 pp.

Owen-Smith, N. 1974. The social system of the white rhinoceros. Pages 341-51. *In:* Geist, V and Walther, F. (eds.), *The Behaviour of Ungulates and its Relation to Management.* IUCN Publications New Series, Vol 1, No.24, Morges. 511 pp.

Owen-Smith, N. 1979. Assessing the foraging efficiency of a large herbivore, the kudu. *Sth. Afr. J. Wildl. Res*. 9(3/4): 102-110.

Owen-Smith, N. 1981. The white rhino overpopulation problem and a proposed solution. *Pp. 129-150. In:* Jewell, P.A, Holt, S and Hart, D. (eds.), *Problems in Management of locally Abundant Wild Animals*. Academic Press. New York. 361 pp.

Owen Smith, N. 1982. Factors influencing the consumption of plant products by large herbivores. Pp. 359-404. *In*: Huntley, B.J. and Walker, B.H. (eds.), *Ecology of Tropical Savannas.* 669 pp.

Owen-Smith, R.N. 1988. *Megaherbivores: The influence of very large body size on ecology*. Cambridge University Press. 363 pp.

Owen-Smith, N. 1992. Grazers and browsers:ecological and social contrasts among African ruminants. Pp. 175-181. *In:* Spitz, F., Janeau, G., Gonzalez, G., and Aulaguier, S. (eds.). *"Ongule!s/Ungulates 91"*. SFERM-IRCM, Toulouse, France.

Owen-Smith, N. and Cooper, S.M. 1987. Assessing food preferences of ungulates by acceptability frequencies. *J. Wildl. Manage.* 51 (2): 372-378.

Owen-Smith, N. and Cooper, S.M. 1988. Plant palatability assessment and its implications for plant herbivore relations. *J. Grassl. Soc. South Afr*. 5(2): 72-75.

Owen-Smith, N. and Cooper, S.M. 1989. Nutritional ecology of a browsing ruminant, the kudu *(Tragelaphus strepsiceros)*, through the seasonal cycle. *J. Zool. Lond*., 219: 29-43.

Owen-Smith, N. and Danckwerts, J. 1997. Herbivory. Pages 397B420, *In:* Cowling, R. and Richardson, D. (eds.). *Vegetation of southern Africa*. Cambridge University Press.

Palgrave, K.C. 1983. *Trees of Southern Africa*. Struik Publishers. 959 pp.

Parker, I.S.C. 1983. The Tsavo story : An ecological case history. Pp.37- 49. *In*: Owen-Smith, R.N. (ed.), *Management of Large mammals in African Conservation Areas*. Haum, Pretoria. 297 pp.

Pellew, R.A. 1983. The impact of elephant, giraffe and fire upon the *Acacia tortilis* woodlands of the Serengeti. *Afr. J. Ecol*. 21:41-74.

Prins, H.H.T. and van der Jeugd, H.P. 1993. Herbivore population crashes and woodland structure in East Africa. *J. Ecol*. 81: 305-314.

Robbins, C.T., Hanley, T.A, Hagerman, A.E, Hjeljord, O., Baker, D.L., Schwartz, C.C., and Mautz, W.W. 1987. Role of tannins in defending plants against ruminants: reduction in protein availability. *Ecology* 68: 98-107.

Rushworth, J.E. 1975. *The floristic, physiognomic and biomass structure of Kalahari sand shrub vegetation in relation to fire and frost in Wankie national Park, Rhodesia*. M.Sc. thesis. University of Rhodesia. 163 pp.

Said, M.Y., Chunge, R.N., Craig, G.C., Thouless, C.R., Barnes, R.F.W, Dublin, H.T. 1995. *African Elephant Database* 1995. IUCN, Gland, Switzerland. 225 pp.

Short, J. 1981. Diet and feeding behaviour of the forest elephant. *Mammalia* 45: 177-185.

Simpson, C.D. 1975. A detailed vegetation study on the Chobe River in the northeast Botswana. *Kirkia* 10(1): 185-227.

Simpson, C. D. 1978. Effects of elephant and other wildlife on vegetation along the Chobe River, Botswana. *Occasional Papers Museum Texas Tech University* 48:1-15.

Sinclair, A.R.E. 1975. The resource limitation of trophic levels in tropical grassland ecosystems. *J. Anim. Ecol*. 44: 497-520.

Skarpe, C., Aarrestad, P.A., Andreassen, H.P., Dhillion, S.S., Dimakatso, T., du Toit, J.T., Halley, D.J., Hytteborn, H., Makhabu, S., Mari, M., Marokane, W., Masunga, G., Modise, D., Moe, S.R., Mojaphoko, R., Mosugelo, D., Mptsumi, S., Neo-Mahupeleng, G., Ramotadima, M., Rutina, L., Sechele, L., Sejoe, T.B., Stokke, S., Swenson, J.E., Taolo, C., Vandewalle, M. and P. Wegge. 2004. The return of the giants: Ecological effects of an increasing elephant population. *Ambio*. 33 (6) 276-282.

Sokal, R.R. and Rohlf, F.J. 1981. *Biometry*. W.H. Freeman and Company, New York. 859 pp.

Sommerlatte, M.W. 1976. *A survey of elephant populations in north-eastern Botswana*. Dept. of Wildlife and National Parks and UNDP/FAO Project 72/020, Wildlife Management and Utilization in Botswana, Gaborone. 100 pp.

Starfield, A.M. and Bleloch, A.L. 1983. Expert systems: an approach to problems in ecological management that are difficult to quantify. *J. Env. Manage.* 16: 261-268.

Starfield, A.M. and Bleloch, A.L. 1986. *Building models in conservation and wildlife management.* Macmillan Publishing Company. 253pp.

Starfield, A.M. 1990. Qualitative rule-based modeling. *Bioscience* 40: 601-604.

Steel, R. G. D. and Torrie, J.H. 1980. *Principles and procedures of statistics: A Biometrical Approach.* McGraw-Hill. 633 p.

Stokke, S. 1999. Sex differences in feeding-patch choice in a megahebivore: elephants in Chobe National Park, Botswana. Can. J. Zool. 77: 1723-1732.

Stokke, S. and du Toit, J. 2000. Sex and size related differences in the dry season feeding patterns of elephants in Chobe National Park, Botswana. Ecogeography 23: 70-80

Taylor, R.D. 1978. *Regional planning for the Sebungwe: An outline description and evaluation of natural resources within the Sebungwe Region in relation to rural development.* Cyclo Report, Department of National Parks and Wildlife Management, Harare, Zimbabwe.

Thompson, P.J. 1975. The role of elephants, fire and other agents in the decline of a *Brachystegia boehmii* woodland. *J. Sth. Afr. Wildl. Manage. Ass*. 5: 11-18.

Unwin, D.M. and Martin, P. 1987. Recording behaviour using a portable microcomputer. *Behaviour* 101:87-100.

Viljoen, A.J. 1988. Long-term changes in the tree component of the vegetation in the Kruger National Park. In: Macdonald I.A.W and Crawford, R.J.M. (eds.), *Long Term Data Series Relating to Southern Africa's Renewable Natural Resources*. South African National Scientific Report No. 157.

Wackernagel, A. 1993. *Elephants and vegetation: severity, scale and patchiness of impacts along the Linyanti river, Chobe District, Botswana*. MSc. thesis. University of the Witwatersrand, Johannesburg. 74 pp.

Walker, B.H. 1989. Diversity and stability in ecosystem conservation. Pages 121-130. In: D. Western and M. Pearl (eds), *Conservation for the 21st Century*. Oxford Universiy Press.

Western, D. and D. Maitumo. 2004. Woodland loss and restoration in a savanna park: a 20-year experiment. *Afr. J. Ecol*., 42: 111-121.

Western, D., Moss, C. and Georgiadis, N. 1983. Age estimation and population age structure of elephants from footprint dimensions. *J. Wildl. Manage.* 47(4): 1192-1197.

White, L.J.T., Tutin, C.E.G. and Fernandez, M. 1993. Group composition and diet of the forest elephants, *Loxodonta africana cyclotis* Matschie 1900, in the Lope! Reserve, Gabon. *Afr. J. Ecol*. 31: 181-199.

Whiten, A. and Burton, R.A. 1988. Demise of the check sheet: using off-the-shelf miniature hand-held computers for remote fieldwork applications. *Trends in Ecol. Evol*. 3(6): 146-148.

Williamson, B.R. 1975. The condition and nutrition of the African elephant in Wankie National Park. *Arnoldia* (Rhod.) 7: 1-20.

Wilkinson, L., Hill, M., Welna, J.P. and Birkenbeuel, G.K. 1992. *Systat Statistics*. Systat, Inc, Evanston, Illinois. 750 pp.

Wing, L. D. and Buss, I.O. 1970. Elephant and Forests. *Wildl. Monogr*. No. 19: 92 pp.

Work, D.R. *1986. Summary report of aerial surveys conducted in 1983, 1984 and 1985.* Unpublished report, Resource Ecology Group, University of the Witwatersrand.

Work, D.R. and Owen-Smith, N. 1986. *Preliminary management recommendations for elephant in northern Botswana*. Unpublished report, University of the Witwatersrand. 14 pp.

Zar, H.J. 1996. *Biostatistical analysis*. Third Edition. Prentice Hall. 662 pp

APPENDIX 1

The following are subroutines of a Psion Organizer program used to capture elephant feeding activity data in the field as described in Chapter 2. The subroutines are functionally grouped into the main menu from which the plant-based, the animal-based or severe impacts data collections options may be selected. The different options are

labeled or grouped by name as follows:

Jumbo - main menu from which the options are selected.

Ju1 to Ju13 - subroutines dealing with the animal based data collection method.

Fo1 to Fo13 - subroutines dealing with the plant-based data collection method.

Severe1 to Severe5 - subroutines dealing with the severe impacts.

1. MAIN MENU

JUMBO:

```
REM FORAGING HABITS OBSERVATIONS OPTIONS
LOCAL M1%,A$(1)
GLOBAL HABTAT%,HABKEY%,M%,D%,Y%,HABTYPE%,GR%,HABCL%,IMKEY%
GLOBAL HR1,MIN1,SEC1,HR2,MIN2,SEC2,T%,END,ST,SWITCH%,REV%
GLOBAL GST%,GSIZE%,IMM%,COW%,BULL%,GRID$(8),ACT%,H%,SEX%,AGE%,COND%,BARK%
GLOBAL GF%,SP%,FACT%,PART%,PROP%,SPACEC%,SPACEB%,PUKEY%
GLOBAL CURR%,CUOD%,PATCH%,PNO%,REP%,RPT$(1)
GLOBAL JUKEY%,GRKEY%,AGR%,FEED%(30),MOVE%(30),OTHER%(30),FEEDP%(30),DIST%
HABKEY%=1
GR%=0
BARK%=0
M%=MONTH
D%=DAY
Y%=YEAR
PNO%=0
SWITCH%=0
OP1::
CLS
DO
BEEP 2,100
M1%=MENU("ANIMAL-BASED,PLANT-BASED,SEVERE-IMP,QUIT")
IF M1%=0 OR M1%=4
  BEEP 2,100
  STOP
ELSEIF M1%=1
  CLS
  BEEP 2,100
  PRINT "ANIMAL-BASED"
ELSEIF M1%=2
  CLS
  BEEP 2,100
  PRINT "PLANT-BASED"
ELSEIF M1%=3
  CLS
  BEEP 2,100
  PRINT "SEVERE IMPACT"
ENDIF
AT 1,3 :PRINT "ACCEPT (Y/N)"
INPUT A$
IF A$="Y"
  GOTO OP2::
ELSE
  GOTO OP1::
ENDIF
OP2::
IF M1%=1
  FO1:
  JU7:
ELSEIF M1%=2
  FO1:
  FO6:
```

```
ELSEIF M1%=3
  SEVERE1:
ENDIF
UNTIL 0
```

2. ANIMAL-BASED SUBROUTINES

2.1 Plant-based patch counter

This subroutine is being used as a patch counter during the animal-based data collection process.

```
JU1:
REM ANIMAL/PLANT BASED PATCH COUNTER
LOCAL A$(1)
P1::
CLS
BEEP 2,100
PRINT "ADD PATCH (Y/N)"
INPUT A$
IF A$="Y"
  PATCH%=PATCH%+1
ELSEIF A$="N"
  IF PATCH%=0
    PATCH%=PATCH%+1
  ENDIF
ELSE
  GOTO P1::
ENDIF
RETURN
```

2.2 Elephant group structure and general data.

The purpose of this subroutine is to capture the following information: the grid reference where elephant were located; elephant group structure defined as bull or cow herds; and elephant activities such as moving, resting or other.

```
JU2:
REM ANIMAL-BASED ELEPHANT GROUP STRUCTURE AND GENERAL DATA
LOCAL A%,DIST%
IF NOT EXIST ("B:GEN")
  CREATE "B:GEN",A,A1%,A2%,A3%,A4%,A5%,A6%,A7%,A8%,A9$,A10%,A11%,A12%
ELSE
  OPEN "B:GEN",A,A1%,A2%,A3%,A4%,A5%,A6%,A7%,A8%,A9$,A10%,A11%,A12%
ENDIF
IF GRKEY%=0
  GOTO AP::
ENDIF
BEEP 2,100
CLS
PRINT "GRID REF"
INPUT GRID$
D::
CLS
BEEP 2,100
PRINT "DIST. FROM WATER"
INPUT DIST%
IF DIST%<1 OR DIST%>4
  GOTO D::
ENDIF
CLS
GR1::
BEEP 2,100
PRINT "GROUP STRUCTURE"
PRINT "1 BULL HERD"
PRINT "2 COW HERD"
INPUT GST%
```

```
IF GST%=0 OR GST%>2 :GOTO GR1:: :ENDIF
CLS
BEEP 2,100
PRINT "GROUP SIZE"
INPUT GSIZE%
A::
CLS
BEEP 2,100
PRINT "ACTIVITY:"
PRINT "1 FEED  2 MOVE"
PRINT "3 REST  4 OTHER"
INPUT A%
IF A%<1 OR A%>4
  GOTO A::
ENDIF
AP::
CLS
A.A1%=GR% :A.A2%=M% :A.A3%=D% :A.A4%=Y%
A.A5%=GST% :A.A6%=GSIZE% :A.A7%=HABTYPE% :A.A8%=HABCL%
A.A9$=GRID$ :A.A10%=H% :A.A11%=A% :A.A12%=DIST%
USE A :APPEND
GRKEY%=1
CLOSE
RETURN
```

2.3 Elephant age/sex classification

This subroutine classified elephant into different sex groups as male (M), female (F) and unknown (U). The age groups were categorized as immature (IMM) and adults (AD).

JU3:

```
REM ANIMAL-BASED AGE/SEX CLASSIFICATION
GR%=GR%+1
H%=HOUR
CLS
F1::
BEEP 2,100
PRINT "SEX (1=M 2=F,3=U)"
INPUT SEX%
IF SEX%=0 OR SEX%>3
  CLS
  GOTO F1::
ENDIF
F2::
BEEP 2,100
CLS
PRINT "AGE CLASS"
PRINT "1=IMM 2=AD"
INPUT AGE%
IF AGE%<1 OR AGE%>3
  GOTO F2::
ENDIF
JUKEY%=1
RETURN
```

2.4 Elephant feeding activity options

This subroutine called other subroutines to handle activities and other data related to feeding, moving, woody species phenological changes, woody species regrowth after elephant impacts.

JU4:

```
REM ANIMAL-BASED FORAGING ACTIVITY OPTIONS
LOCAL A$(1),ACT%,J%,NFP%
GLOBAL AA1%,AA2%,AA3%
HB::
CLS
BEEP 2,100
```

```
PRINT "HABITAT CHANGE Y/N"
INPUT A$
IF A$="Y"
  HABKEY%=0
  FO1:
ELSEIF A$="N"
  GOTO CONT::
ELSE
  GOTO HB::
ENDIF
CONT::
  AA1%=0 :AA2%=0 :AA3%=0 :SPACEC%=0
CLS
DO
BEEP 2,100
ACT%=MENU("FEED,MOVE,OTHER,PHENO,REGROW,ASSESS,EXIT")
IF ACT%=0 OR ACT%=7
   CLS
   BEEP 2,100
   PRINT "EXIT ACTIVITY (Y/N)"
   INPUT A$
   IF A$="Y"
     RETURN
   ELSE
     GOTO CONT::
   ENDIF
ENDIF
IF ACT%=1
  IF JUKEY%=0
    JU3:
  ENDIF
  JU1:
  AA1%=AA1%+1
  FEEDP%(AA1%)=PATCH%
  JU6:
  FEED%(AA1%)=T%
ELSEIF ACT%=2
  AA2%=AA2%+1
  JU6:
  MOVE%(AA2%)=T%
ELSEIF ACT%=3
  AA3%=AA3%+1
  JU6:
  OTHER%(AA3%)=T%
ELSEIF ACT%=4
  JU11:
ELSEIF ACT%=5
  FO5:
ELSEIF ACT%=6
  IF AA1%<>0
     JU5:
     CLS
     BEEP 2,100
     PRINT "G FEED PATCHES"
     INPUT NFP%
     IF NFP%>0
       J%=1
       DO
         PATCH%=PATCH%+1
         FO12:
         J%=J%+1
       UNTIL J%>NFP%
     ENDIF
  ENDIF
  IF AA2%<>0
    CLS
    PRINT "SAVING DATA"
    JU8:
  ENDIF
  IF AA3%<>0
    CLS
    PRINT "SAVING DATA"
```

```
   JU9:
  ENDIF
  GR::
  CLS
  BEEP 2,100
  PRINT "NEW GROUP (Y/N)"
  INPUT A$
  IF A$="Y"
    JU2:
  ELSEIF A$="N"
    IF AGR%<>1
      AGR%=1
    ENDIF
    GRKEY%=0
    JU2:
  ELSE
    GOTO GR::
  ENDIF
  PATCH%=0
  JUKEY%=0
  RETURN
ENDIF
UNTIL 0
```

2.5 Feed actions on plant species and related data

This subroutine recorded data related to plant species, height class, plant part, feeding action and proportion of plant part removed by elephant.

```
JU5:
REM ANIMAL-BASED FEEDING ACTIVITIES
LOCAL I%,PCH%,REV%,S,A$(1),PUP%
GLOBAL G%
IF NOT EXIST ("B:FEED")
  CREATE "B:FEED",B,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%,B14%,B15%,B16$
ELSE
  OPEN "B:FEED",B,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%,B14%,B15%,B16$
ENDIF
IF SPACEB%=1
  S=SPACE
  PRINT S
  BEEP 2,100
  AT 1,3 :PRINT "ANY KEY TO CONT"
  GET
  SPACEB%=0
  CLOSE
  RETURN
ENDIF
CLS
PUKEY%=0
I%=1
PNO%=0
REP%=0
PCH%=FEEDP%(1)
IMKEY%=0
QT::
DO
PNO%=PNO%+1
IF FEEDP%(I%)>PCH%
  PUP%=PCH%
  PNO%=1
  REP%=0
  PCH%=FEEDP%(I%)
  PC1::
  CLS
  BEEP 2,100
  PRINT "PATCH ",PCH%," DONE"
  PRINT "CONT PAST USE (Y/N)"
  INPUT A$
  IF A$="Y"
    PATCH%=PUP%
```

```
    PUKEY%=1
    FO12:
    PUKEY%=0
   ELSEIF A$="N"
    GOTO PC2::
   ELSE
    GOTO PC1::
   ENDIF
ENDIF
PC2::
PUP%=FEEDP%(I%)
IF REP%=1
  CLS
  BEEP 2,100
  PRINT "REPLICATE Y/N"
  INPUT A$
  IF A$="N"
    GOTO SP::
  ELSE
    GOTO AP::
  ENDIF
ELSE
  REP%=1
ENDIF
SP::
BEEP 2,100
CLS
PRINT "PLANT SPECIES ";PNO%
PRINT "PATCH =",FEEDP%(I%)," ID =",GR%
INPUT SP%
IF SP%<1 OR SP%>200
  GOTO SP::
ENDIF
IF SP%=100
  G%=I%
  JU13:
  I%=I%+1
  PNO%=PNO%-1
  CONTINUE
  ENDIF
PP::
CLS
BEEP 2,100
PRINT "PLANT PART "
INPUT PART%
IF PART%<1 OR PART%>12
  GOTO PP::
ENDIF
IF PART%=6 OR PART%=11
  BARK%=PART%
ENDIF
GR::
CLS
BEEP 2,100
PRINT "HEIGHT CLASS"
  INPUT GF%
  IF GF%<1 OR GF%>5
  GOTO GR::
ENDIF
ACT1::
CLS
BEEP 2,100
PRINT "FEEDING ACTION"
  INPUT FACT%
IF FACT%<1 OR FACT%>16
   :GOTO ACT1::
ENDIF
PD1::
CLS
BEEP 2,100
PRINT "PAST IMPACT (Y/N/R)"
INPUT RPT$
```

```
IF RPT$="Y"
  GOTO PR::
ELSEIF RPT$="N"
  GOTO PR::
ELSEIF RPT$="R"
  GOTO PR::
ELSE
  GOTO PD1::
ENDIF
PR::
CLS
BEEP 2,100
PRINT "PROP. REMOVED"
  INPUT PROP%
  IF PROP%<1 OR PROP%>8
    GOTO PR::
  ENDIF
R::
CLS
BEEP 2,100
IF PROP%=8
  REV%=0
ELSE
  PRINT "REVERSAL"
  INPUT REV%
  IF REV%>GF%
    GOTO R::
  ENDIF
ENDIF
AP::
T%=FEED%(I%)
CLS
BEEP 2,100
PRINT "ACCEPT RECORD Y/N"
INPUT A$
IF A$="Y"
  B.B1%=GR% :B.B2%=M% :B.B3%=D% :B.B4%=Y% :B.B5%=REV%
  B.B6%=FEEDP%(I%) :B.B7%=H% :B.B8%=SEX% :B.B9%=AGE% :B.B10%=SP%
  B.B11%=GF% :B.B12%=FACT% :B.B13%=PART%
  B.B14%=T% :B.B15%=PROP% :B.B16$=RPT$
  USE B :APPEND
  IMKEY%=1
  PATCH%=FEEDP%(I%)
  FO12:
ELSE
  IF I%>1
    I%=I%-1
  ENDIF
  PNO%=PNO%-1
  REP%=0
  GOTO QT::
ENDIF
IF PART%=6 OR PART%=11
  JU12:
  BARK%=0
ENDIF
I%=I%+1
UNTIL I%>AA1%
LP1::
CLS
BEEP 2,100
PRINT "LAST PATCH PROCESSED"
AT 1,3 :PRINT "CONT PAST USE (Y/N)"
INPUT A$
IF A$="Y"
  PUKEY%=1
  PATCH%=PUP%
  FO12:
  PUKEY%=0
ELSEIF A$="N"
  GOTO LP2::
ELSE
```

```
  GOTO LP1::
ENDIF
LP2::
CLOSE
RETURN
```

2.6 Timing of feeding action on plant species

The following subroutine recorded the time taken for a specific feeding action on a plant species by elephant.

JU6:

```
REM ANIMAL-BASED FORAGING ACTIVITY TIMING
LOCAL STATE%
BEEP 2,100
HR1=HOUR
MIN1=MINUTE
SEC1=SECOND
ST=(MIN1+SEC1/60)/60+HR1
X::
CLS
PRINT "ACTIVITY TIME (0,E)"
INPUT STATE%
IF STATE%<>0
  BEEP 2,100
  GOTO X::
ENDIF
HR2=HOUR
MIN2=MINUTE
SEC2=SECOND
END=(MIN2+SEC2/60)/60+HR2
T%=INT((END-ST)*60*60)
CLS
RETURN
```

2.7 Animal-based main menu

This was the main menu of the animal-based observation method which also gave an option to switch to the plant-based observation method if need be.

JU7:

```
REM ANIMAL-BASED MAIN MENU
LOCAL M1%,Q$(1)
QT::
BEEP 2,100
CLS
DO
M1%=MENU("ACTIVITY,NFGR,P-BASED,BPACK,CPACK,QUIT")
IF M1%=0 OR M1%=6
   BEEP 2,100
   PRINT "QUIT (Y/N)"
   INPUT Q$
   IF Q$="Y"
     RETURN
   ELSE
     GOTO QT::
   ENDIF
ELSEIF M1%=1
  JU4:
ELSEIF M1%=2
  CLS
  BEEP 2,100
  PRINT "HABTAT CHANGE Y/N"
  INPUT Q$
  IF Q$="Y"
    HABKEY%=0
    FO1:
```

```
  ELSE
    GOTO CONT::
  ENDIF
  CONT::
  H%=HOUR
  JU2:
ELSEIF M1%=3
  IF SWITCH%=2
    RETURN
  ELSE
    SWITCH%=1
    HABKEY%=1
    FO1:
    FO6:
    HABKEY%=0
  ENDIF
ELSEIF M1%=4
  SPACEB%=1
  JU5:
ELSEIF M1%=5
  SPACEC%=1
  FO8:
ENDIF
UNTIL 0
```

2.8 Movement data during foraging

The subroutine recorded elephant movements from one plant to the other or between patches.

JU8:

```
REM ANIMAL-BASED MOVEMENT DATA
LOCAL I%
IF NOT EXIST ("B:MOVE")
  CREATE "B:MOVE",C,C1%,C2%,C3%,C4%,C5%,C6%,C7%,C8%,C9%,C10%
ELSE
  OPEN "B:MOVE",C,C1%,C2%,C3%,C4%,C5%,C6%,C7%,C8%,C9%,C10%
ENDIF
CLS
I%=1
DO
T%=MOVE%(I%)
C.C1%=GR% :C.C2%=M% :C.C3%=D% :C.C4%=Y% :C.C5%=HABTYPE% :C.C6%=HABCL%
C.C7%=H% :C.C8%=SEX% :C.C9%=AGE% :C.C10%=T%
USE C :APPEND
I%=I%+1
UNTIL I%>AA2%
CLOSE
RETURN
```

2.9 Time spent on other activities

The following subroutine recorded the time spent on activities other than feeding on a plant species by elephant such as standing or resting.

JU9:

```
REM ANIMAL-BASED "OTHER" ACTIVITY DATA
LOCAL I%
I%=1
DO
CLS
IF NOT EXIST ("C:OTHER")
  CREATE "C:OTHER",D,E1%,E2%,E3%,E4%,E5%,E6%,E7%,E8%,E9%,E10%
ELSE
  OPEN "C:OTHER",D,E1%,E2%,E3%,E4%,E5%,E6%,E7%,E8%,E9%,E10%
ENDIF
T%=OTHER%(I%)
D.E1%=GR% :D.E2%=M% :D.E3%=D% :D.E4%=Y% :D.E5%=HABTYPE% :D.E6%=HABCL%
D.E7%=H% :D.E8%=SEX% :D.E9%=AGE% :D.E10%=T%
```

```
USE D :APPEND
CLOSE
I%=I%+1
UNTIL I%>AA3%
RETURN
```

2.10 Amount of bark damage

The subroutine recorded the amount of bark damage as a proportion of the total circumference of the tree.

JU10:

```
REM ANIMAL-BASED BARK DAMAGE DATA
IF NOT EXIST ("C:BARK")
  CREATE "C:BARK",D,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%
ELSE
  OPEN "C:BARK",D,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%
ENDIF
CLS
BEEP 2,100
PRINT "CURRENT BARK DAMAGE"
INPUT CURR%
CLS
BEEP 2,100
PRINT "CURRENT+OLD DAMAGE"
INPUT CUOD%
CLS
D.B1%=GR% :D.B2%=M% :D.B3%=D% :D.B4%=Y% :D.B5%=HABTYPE% :D.B6%=FACT%
D.B7%=H% :D.B8%=SEX% :D.B9%=AGE% :D.B10%=SP% :D.B11%=GF% :D.B12%=CURR%
D.B13%=CUOD%
USE D :APPEND
CLOSE
RETURN
```

2.11 Woody plant phenological data

The phenological state of the woody plants such as buds, full leafless, blossoming, fruits, leafless were recorded in this subroutine.

JU11:

```
REM PLANT-BASED AND ANIMAL BASED GENERAL PHENOLOGICAL DATA
LOCAL LF%,FL%,FR%,PL%,A$(1)
IF NOT EXIST ("B:GENPHENO")
  CREATE "B:GENPHENO",A,B1%,B2%,B3%,B4%,B5%,B6%,B7%
ELSE
  OPEN "B:GENPHENO",A,B1%,B2%,B3%,B4%,B5%,B6%,B7%
ENDIF
LOOP::
DO
  CLS
  BEEP 2,100
  AT 1,1 :PRINT "GENERAL PHENOLOGY":
  AT 1,3 :PRINT "PLANT SPECIES(0,E)"
    INPUT PL%
    IF PL%=0 OR PL%>200
      CONTINUE
    ENDIF
CLS
P1::
CLS
BEEP 2,100
AT 1,1 :PRINT "GENERAL PHENOLOGY"
AT 1,3 :PRINT "PHENO LEAVES"
INPUT LF%
IF LF%<1 OR LF%>5
  BEEP 2,100 :GOTO P1::
ENDIF
P2::
CLS
BEEP 2,100
```

```
AT 1,1 :PRINT "GENERAL PHENOLOGY"
AT 1,3 :PRINT "PHENO FLOWERS"
INPUT FL%
IF FL%<1 OR FL%>4
  BEEP 2,100 :GOTO P2::
ENDIF
P3::
CLS
BEEP 2,100
AT 1,1 :PRINT "GENERAL PHENOLOGY"
AT 1,3 :PRINT "PHENO FRUIT"
INPUT FR%
IF FR%<1 OR FR%>4
  BEEP 2,100 :GOTO P3::
ENDIF
AP::
CLS
BEEP 2,100
PRINT "ACCEPT RECORD (Y/N)"
INPUT A$
IF A$="Y"
  A.B1%=M% :A.B2%=D% :A.B3%=Y% :A.B4%=PL% :A.B5%=LF% :A.B6%=FL% :A.B7%=FR%
  USE A :APPEND
ELSE
  GOTO LOOP::
ENDIF
UNTIL PL%=0
CLOSE
RETURN
```

2.12 Phenological state of debarked trees

The subroutine recorded the phenological state of trees which had bark of trees damaged by elephant.

JU12:

```
REM ANIMAL-BASED PHENOLOGICAL DATA OF BARK DAMAGED TREES
LOCAL LF%,FL%,FR%
IF NOT EXIST ("C:PHENO")
  CREATE "C:PHENO",D,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%
ELSE
  OPEN "C:PHENO",D,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%
ENDIF
CLS
P1::
CLS
BEEP 2,100
PRINT "PHENO LEAVES"
INPUT LF%
IF LF%=0 OR LF%>5
  BEEP 2,100 :GOTO P1::
ENDIF
P2::
CLS
BEEP 2,100
PRINT "PHENO FLOWERS"
INPUT FL%
IF FL%=0 OR FL%>4
  BEEP 2,100 :GOTO P2::
ENDIF
P3::
CLS
BEEP 2,100
PRINT "PHENO FRUIT"
INPUT FR%
IF FR%=0 OR FR%>4
  BEEP 2,100 :GOTO P3::
ENDIF
CLS
D.B1%=GR% :D.B2%=M% :D.B3%=D% :D.B4%=Y% :D.B5%=HABTYPE% :D.B6%=FACT%
D.B7%=SEX% :D.B8%=AGE% :D.B9%=SP% :D.B10%=GF% :D.B11%=LF% :D.B12%=FL%
```

```
D.B13%=FR%
USE D :APPEND
CLOSE
IF FACT%>=3 AND FACT%<=6
  JU10:
ENDIF
RETURN
```

2.13 Records of grass feeding

The subroutine the time a particular elephant spent feeding of grass**.**

```
JU13:
REM ANIMAL-BASED DATA ON GRASS FEEDING
CLS
IF NOT EXIST ("B:GRASS")
  CREATE "B:GRASS",D,G1%,G2%,G3%,G4%,G5%,G6%,G7%,G8%,G9%,G10%
ELSE
  OPEN "B:GRASS",D,G1%,G2%,G3%,G4%,G5%,G6%,G7%,G8%,G9%,G10%
ENDIF
T%=FEED%(G%)
D.G1%=GR% :D.G2%=M% :D.G3%=D% :D.G4%=Y% :D.G5%=HABTYPE% :D.G6%=HABCL%
D.G7%=H% :D.G8%=SEX% :D.G9%=AGE% :D.G10%=T%
USE D :APPEND
CLOSE
RETURN
```

3. PLANT-BASED SUBROUTINES

3.1 Habitat specification

This subroutine was used to specify the habitat types and the level of utilization for each habitat for both the plant-based and animal-based subroutines.

```
FO1:
REM PLANT/ANIMAL-BASED HABITAT SPECIFICATION AND VARIABLE DECLARATION
LOCAL P$(1)
PATCH%=0
JUKEY%=0
GRKEY%=1
HAB::
CLS
BEEP 2,100
PRINT "HABTAT"
INPUT HABTYPE%
IF HABTYPE%<1 OR HABTYPE%>40
  GOTO HAB::
ENDIF
UTL::
CLS
BEEP 2,100
PRINT "UTL. CLASS"
INPUT HABCL%
IF HABCL%<1 OR HABCL%>3
  GOTO UTL::
ENDIF
IF HABKEY%=0
   RETURN
ENDIF
RETURN
```

3.2 Plant-based group structure and general data.

The data captured by this subroutine is similar to that of animal-based described in section 2.2 above.

```
FO2:
```

```
REM PLANT-BASED ELEPHANT GROUP STRUCTURE AND GENERAL DATA
LOCAL A%
IF NOT EXIST ("B:FOGEN")
  CREATE "B:FOGEN",A,A1%,A2%,A3%,A4%,A5%,A6%,A7%,A8%,A9$,A10%,A11%,A12%
ELSE
  OPEN "B:FOGEN",A,A1%,A2%,A3%,A4%,A5%,A6%,A7%,A8%,A9$,A10%,A11%,A12%
ENDIF
GR%=GR%+1
BEEP 2,100
CLS
PRINT "GRID REF"
INPUT GRID$
D::
CLS
BEEP 2,100
PRINT "DIST. FROM WATER"
INPUT DIST%
IF DIST%<1 OR DIST%>4
  GOTO D::
ENDIF
CLS
GR1::
BEEP 2,100
PRINT "GROUP STRUCTURE"
PRINT "1 BULL HERD"
PRINT "2 COW HERD"
INPUT GST%
IF GST%<1 OR GST%>2 :GOTO GR1:: :ENDIF
CLS
BEEP 2,100
PRINT "GROUP SIZE"
INPUT GSIZE%
A::
CLS
BEEP 2,100
PRINT "ACTIVITY:"
PRINT "1 FEED  2 MOVE"
PRINT "3 REST  4 OTHER"
INPUT A%
IF A%<1 OR A%>4
  GOTO A::
ENDIF
FO10:
CLS
IF A%<>1
  H%=HOUR
ENDIF
A.A1%=GR% :A.A2%=M% :A.A3%=D% :A.A4%=Y%
A.A5%=GST% :A.A6%=GSIZE% :A.A7%=HABTYPE% :A.A8%=HABCL%
A.A9$=GRID$ :A.A10%=H% :A.A11%=A% :A.A12%=DIST%
USE A :APPEND
CLOSE
IF A%=1
  FO4:
ENDIF
RETURN
```

3.3 Plant-based age/sex classification

The data captured by this subroutine is similar to that of animal-based described in section 2.3 above.

FO3:

```
REM PLANT-BASED AGE/SEX CLASSIFICATION
CLS
F1::
BEEP 2,100
PRINT "SEX (1=M 2=F 3=U"
INPUT SEX%
IF SEX%<1 OR SEX%>3
```

```
  CLS
  GOTO F1::
ENDIF
F2::
BEEP 2,100
CLS
PRINT "AGE CLASS"
PRINT "1=IMM 2=AD 3=U"
INPUT AGE%
IF AGE%<1 OR AGE%>3
  GOTO F2::
ENDIF
RETURN
```

3.4 Plant-based feeding actions on plant species and related data

The information recorded by this subroutine is the same as that recorded for animal-based in section 2.5 above.

```
FO4:
REM PLANT-BASED FEEDING ACTIVITIES
LOCAL A$(1),M1%,P%,S,REVS%
IF NOT EXIST ("B:FOFEED")
  CREATE "B:FOFEED",B,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%,B14%,B15$
ELSE
  OPEN "B:FOFEED",B,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%,B14%,B15$
ENDIF
REP%=0
SPACEC%=0
IMKEY%=0
QT::
DO
BEEP 2,100
M1%=MENU("FEED,MAJOR,USE,BPACK,CPACK,REGROW,PHENO,EXIT")
IF M1%=0 OR M1%=8
  BEEP 2,100
  PRINT "EXIT Y/N"
  INPUT A$
  IF A$="Y"
    IF PATCH%=5
      FO11:
    ENDIF
    PATCH%=0
    PNO%=0
    CLOSE
    RETURN
  ELSE
    GOTO QT::
  ENDIF
ELSEIF M1%=1
  IF REP%=0
    REP%=1
    GOTO F1::
  ELSE
    CLS
    BEEP 2,100
    PRINT "REPLICATE Y/N/Q"
    INPUT A$
    IF A$="Y"
      GOTO AP::
    ELSEIF A$="N"
      GOTO F1::
    ELSE
      GOTO QT::
    ENDIF
  ENDIF
ELSEIF M1%=2
  GOTO F2::
F1::
FO3:
P1::
```

```
CLS
BEEP 2,100
IF PATCH%=5
  GOTO P2::
ENDIF
PRINT "ADD PATCH (Y/N)"
INPUT A$
IF A$="Y"
  PATCH%=PATCH%+1
  PNO%=0
  REP%=0
  GOTO P2::
ELSEIF A$="N"
  IF PATCH%=0
    PATCH%=PATCH%+1
  ENDIF
  GOTO P2::
ELSE
  GOTO P1::
ENDIF
F2::
IF M1%=2
  FO3:
  P%=PATCH%
  PATCH%=0
ENDIF
P2::
PNO%=PNO%+1
SPP::
BEEP 2,100
CLS
PRINT "PLANT SPECIES ";PNO%
PRINT "PATCH NO. ";PATCH%
INPUT SP%
IF SP%<1 OR SP%>200
  GOTO SPP::
ENDIF
IF SP%=100
  PNO%=PNO%-1
  FO7:
  CONTINUE
ENDIF
PP::
BEEP 2,100
CLS
PRINT "PLANT PART "
INPUT PART%
IF PART%<1 OR PART%>12
   BEEP 2,100
   GOTO PP::
ENDIF
IF PART%=6 OR PART%=11
  BARK%=PART%
ENDIF
GR::
CLS
BEEP 2,100
PRINT "HEIGHT CLASS"
  INPUT GF%
  IF GF%<1 OR GF%>5
  GOTO GR::
ENDIF
ACT1::
CLS
BEEP 2,100
PRINT "FEEDING ACTION"
  INPUT FACT%
IF FACT%<1 OR FACT%>16
   :GOTO ACT1::
ENDIF
PD1::
CLS
```

```
BEEP 2,100
PRINT "PAST IMPACT (Y/R/N)"
INPUT RPT$
IF RPT$="Y"
  GOTO PR::
ELSEIF RPT$="N"
  GOTO PR::
ELSEIF RPT$="R"
  GOTO PR::
ELSE
  GOTO PD1::
ENDIF
PR::
CLS
BEEP 2,100
PRINT "PROP. REMOVED"
  INPUT PROP%
  IF PROP%<1 OR PROP%>8
    GOTO PR::
  ENDIF
R::
CLS
BEEP 2,100
IF PROP%=8
  REV%=0
ELSE
  PRINT "REVERSAL"
  INPUT REVS%
  IF REVS%>GF%
    GOTO R::
  ENDIF
ENDIF
AP::
CLS
BEEP 2,100
PRINT "ACCEPT RECORD Y/N"
INPUT A$
IF A$="Y"
  CLS
  B.B1%=GR% :B.B2%=M% :B.B3%=D% :B.B4%=Y% :B.B5%=REVS%
  B.B6%=PATCH% :B.B7%=H% :B.B8%=SEX% :B.B9%=AGE% :B.B10%=SP%
  B.B11%=GF% :B.B12%=FACT% :B.B13%=PART%
  B.B14%=PROP% :B.B15$=RPT$
  USE B :APPEND
  IMKEY%=1
  FO12:
ELSE
  REP%=0
  PNO%=PNO%-1
  GOTO QT::
ENDIF
IF PART%=6 OR PART%=11
  FO8:
  BARK%=0
ENDIF
IF M1%=2
  PATCH%=P%
ENDIF
ELSEIF M1%=3
  JU1:
  FO12:
ELSEIF M1%=4
  S=SPACE
  PRINT S
  BEEP 2,100
  AT 1,3 :PRINT "ANY KEY TO CONT"
  GET
ELSEIF M1%=5
  SPACEC%=1
  FO8:
ELSEIF M1%=6
  FO5:
```

```
ELSEIF M1%=7
JU11:
ENDIF
UNTIL 0
```

3.5 Plant-based regrowth data

This subroutine recorded the woody species regrowth data after elephant and fire impacts.

```
FO5:
REM PLANT REGROWTH AFTER ELEPHANT DAMAGE
LOCAL OLDHT%,NEWHT%,JUREV%,FIREV%,RESP%,JUIMP%,FIIMP%,A$(1)
IF NOT EXIST ("C:REGROW")
  CREATE "C:REGROW",C,D1%,D2%,D3%,D4%,D5%,D6%,D7%,D8%,D9%,D10%,D11%,D12%,D13%
ELSE
  OPEN "C:REGROW",C,D1%,D2%,D3%,D4%,D5%,D6%,D7%,D8%,D9%,D10%,D11%,D12%,D13%
ENDIF
REP%=0
P2::
DO
IF REP%=0
  REP%=1
  GOTO R1::
ELSE
  CLS
  BEEP 2,100
  PRINT "REPLICATE (Y/N)"
  INPUT A$
  IF A$="Y"
    GOTO AP::
  ELSEIF A$="N"
    GOTO R1::
  ELSE
    GOTO P2::
  ENDIF
ENDIF
R1::
CLS
BEEP 2,100
AT 1,1 :PRINT "PLANT REGROWTH"
AT 1,3 :PRINT "PLANT SPECIES (0,E)"
  INPUT SP%
  IF SP%=0
    CONTINUE
  ENDIF
OLD::
CLS
BEEP 2,100
PRINT "OLD HEIGHT CLASS"
  INPUT OLDHT%
  IF OLDHT%>6
    GOTO OLD::
  ENDIF
F::
CLS
BEEP 2,100
PRINT "FEEDING ACTION"
INPUT FACT%
IF FACT% <1 OR FACT% >18
  GOTO F::
ENDIF
IF FACT%=17 OR FACT%=18
  JUIMP%=0
  JUREV%=OLDHT%
  GOTO FIMP::
ENDIF
JUIM::
CLS
BEEP 2,100
```

```
CLS
PRINT "JU IMPACT"
INPUT JUIMP%
IF JUIMP%<1 OR JUIMP%>9
  GOTO JUIM::
ENDIF
JUREV::
CLS
BEEP 2,100
PRINT "JU REVERSAL"
INPUT JUREV%
IF JUREV%>OLDHT%
   GOTO JUREV::
ENDIF
FIMP::
CLS
BEEP 2,100
PRINT "FIRE IMPACT"
INPUT FIIMP%
IF FIIMP%<1 OR FIIMP%>8
  GOTO FIMP::
ENDIF
FIREV::
IF FIIMP%=1
  FIREV%=OLDHT%
ELSE
  CLS
  BEEP 2,100
  PRINT "FIRE REVERSAL"
  INPUT FIREV%
  IF FIREV%>OLDHT%
    GOTO FIREV::
  ENDIF
ENDIF
RES::
IF FACT%<17 OR FIIMP%>1
  CLS
  BEEP 2,100
  PRINT "RESPONSE"
  INPUT RESP%
  IF RESP%<1 OR RESP%>4
    GOTO RES::
  ENDIF
  NEW::
  CLS
  BEEP 2,100
  PRINT "NEW HEIGHT CLASS"
  INPUT NEWHT%
  IF NEWHT%<1 OR NEWHT%>5
    GOTO NEW::
  ENDIF
ELSE
  NEWHT%=OLDHT%
  RESP%=2
ENDIF
AP::
CLS
BEEP 2,100
PRINT "ACCEPT RECORD Y/N"
INPUT A$
IF A$="Y"
CLS
C.D1%=GR% :C.D2%=M% :C.D3%=D% :C.D4%=Y% :C.D5%=SP% :C.D6%=OLDHT% :C.D7%=FACT%
:C.D8%=JUIMP% :C.D9%=JUREV% :C.D10%=FIIMP% :C.D11%=FIREV% :C.D12%=RESP% :C.D13%=NEWHT%
USE C :APPEND
ELSE
  REP%=0
  GOTO P2::
ENDIF
UNTIL SP%=0
CLS
```

```
BEEP 2,100
PRINT "EXIT REGROWTH Y/N"
INPUT A$
  IF A$="Y"
  CLOSE
  RETURN
ELSE
  GOTO P2::
ENDIF
```

3.6 Plant based main menu

This plant based main menu subroutine also called the animal-based subroutines when required.

```
FO6:
REM PLANT-BASED MAIN MENU
LOCAL M1%,N%,Q$(1)
QT::
CLS
DO
BEEP 2,100
M1%=MENU("ACTIVITY,A-BASED,QUIT")
CLS
BEEP 2,100
IF M1%=0 OR M1%=3
  PRINT "QUIT PROGRAM"
ELSEIF M1%=1
  PRINT "ACTIVITY SELECTION"
ELSEIF M1%=2
  PRINT "ANIMAL-BASED"
ENDIF
AT 1,3 :PRINT "ACCEPT (Y/N)"
INPUT Q$
IF Q$="Y"
  IF M1%=0 OR M1%=3
    HABKEY%=1
    RETURN
  ELSEIF M1%=1
    IF HABKEY%=0
      FO1:
    ENDIF
    HABKEY%=0
    FO2:
  ELSEIF M1%=2
    IF SWITCH%=1
      RETURN
    ELSE
      SWITCH%=2
      HABKEY%=1
      FO1:
      JU7:
      HABKEY%=0
    ENDIF
  ENDIF
ELSE
  GOTO QT::
ENDIF
UNTIL 0
```

3.7 Plant-based grass feeding data

This subroutine was used to record feeding on grass by elephant using the plant-based method.

```
FO7:
REM PLANT-BASED GRASS FEEDING DATA
CLS
```

```
IF NOT EXIST ("B:FOGRASS")
  CREATE "B:FOGRASS",D,G1%,G2%,G3%,G4%,G5%,G6%,G7%,G8%,G9%
ELSE
  OPEN "B:FOGRASS",D,G1%,G2%,G3%,G4%,G5%,G6%,G7%,G8%,G9%
ENDIF
D.G1%=GR% :D.G2%=M% :D.G3%=D% :D.G4%=Y% :D.G5%=HABTYPE% :D.G6%=HABCL%
D.G7%=H% :D.G8%=SEX% :D.G9%=AGE%
USE D :APPEND
CLOSE
RETURN
```

3.8 Plant-based phenological data

This subroutine was used to record phenological data using the plant-based data collection method.

```
FO8:
REM PLANT-BASED PHENOLOGICAL DATA
LOCAL LF%,FL%,FR%,S
IF NOT EXIST ("C:FOPHENO")
  CREATE "C:FOPHENO",D,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%,B14%
ELSE
  OPEN "C:FOPHENO",D,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%,B14%
ENDIF
IF SPACEC%=1
  S=SPACE
  PRINT S
  BEEP 2,100
  AT 1,3 :PRINT "ANY KEY TO CONT"
  GET
  SPACEC%=0
  CLOSE
  RETURN
ENDIF
CLS
P1::
CLS
BEEP 2,100
PRINT "PHENO LEAVES"
INPUT LF%
IF LF%<1 OR LF%>5
  BEEP 2,100 :GOTO P1::
ENDIF
P2::
CLS
BEEP 2,100
PRINT "PHENO FLOWERS"
INPUT FL%
IF FL%<1 OR FL%>4
  BEEP 2,100 :GOTO P2::
ENDIF
P3::
CLS
BEEP 2,100
PRINT "PHENO FRUIT"
INPUT FR%
IF FR%<1 OR FR%>4
  BEEP 2,100 :GOTO P3::
ENDIF
CLS
D.B1%=GR% :D.B2%=M% :D.B3%=D% :D.B4%=Y% :D.B5%=HABTYPE% :D.B6%=FACT%
D.B7%=SEX% :D.B8%=AGE% :D.B9%=SP% :D.B10%=GF% :D.B11%=LF% :D.B12%=FL%
D.B13%=FR% :D.B14%=H%
USE D :APPEND
CLOSE
IF FACT%>=3 AND FACT%<=6
  FO9:
ENDIF
RETURN
```

3.9 Plant-based bark damage.

This subroutine was used to record bark damage as in section 2.10 above.

```
FO9:
REM PLANT-BASED BARK DAMAGE DATA
IF NOT EXIST ("C:FOBARK")
  CREATE "C:FOBARK",D,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%,B14%
ELSE
  OPEN "C:FOBARK",D,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%,B14%
ENDIF
CLS
BEEP 2,100
PRINT "CURRENT BARK DAMAGE"
INPUT CURR%
CLS
BEEP 2,100
PRINT "CURRENT+OLD DAMAGE"
INPUT CUOD%
CLS
D.B1%=GR% :D.B2%=M% :D.B3%=D% :D.B4%=Y% :D.B5%=HABTYPE% :D.B6%=HABCL% :D.B7%=FACT%
D.B8%=H% :D.B9%=SEX% :D.B10%=AGE% :D.B11%=SP% :D.B12%=GF% :D.B13%=CURR%
D.B14%=CUOD%
USE D :APPEND
CLOSE
RETURN
```

3.10 Plant-based foraging period selection

This subroutine was used to select the foraging period of feeding such as day or night.

```
FO10:
REM PLANT-BASED FORAGING PERIOD SELECTION
P::
CLS
BEEP 2,100
PRINT "FORAGING PERIOD"
AT 1,3 :PRINT "1 NIGHT 2 DAY"
INPUT H%
IF H%<1 OR H%>2
   GOTO P::
ENDIF
RETURN
```

3.11 Plant-based cover assessment

This subroutine recorded the grass, shrub and tree cover.

```
FO11:
REM PLANT-BASED COVER ASSESSMENT
LOCAL TREE%,GRASS%,SHRUB%
IF NOT EXIST ("B:COVER")
  CREATE "B:COVER",D,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%
ELSE
  OPEN "B:COVER",D,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%
ENDIF
CLS
C1::
CLS
BEEP 2,100
AT 1,1 :PRINT "COVER ASSESSMENT"
AT 1,3 :PRINT "GRASS COVER"
INPUT GRASS%
IF GRASS%<1 OR GRASS%>10
  BEEP 2,100 :GOTO C1::
ENDIF
C2::
CLS
BEEP 2,100
AT 1,1 :PRINT "COVER ASSESSMENT"
```

```
AT 1,3 :PRINT "SHRUB COVER"
INPUT SHRUB%
IF SHRUB%<1 OR SHRUB%>10
  BEEP 2,100 :GOTO C2::
ENDIF
C3::
CLS
BEEP 2,100
AT 1,1 :PRINT "COVER ASSESSMENT"
AT 1,3 :PRINT "TREE COVER"
INPUT TREE%
IF TREE%<1 OR TREE%>10
  BEEP 2,100 :GOTO C3::
ENDIF
CLS
D.B1%=GR% :D.B2%=M% :D.B3%=D% :D.B4%=Y% :D.B5%=HABTYPE% :D.B6%=GRASS% :D.B7%=SHRUB%
:D.B8%=TREE%
USE D :APPEND
CLOSE
RETURN
```

3.12 Plant-based cumulative usage

This subroutine recorded the seasonal present and past elephant impacts on woody species.

```
FO12:
REM PLANT-BASED CUMULATIVE USAGE
LOCAL A$(1),CIMP%,PIMP%,REVS%,K%,FA%,PT%,HT%
LOCAL SP1%,GF1%,FACT1%,PART1%,PROP1%
IF NOT EXIST ("C:PASTUSE")
  CREATE "C:PASTUSE",A,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13$,B14%
ELSE
  OPEN "C:PASTUSE",A,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13$,B14%
ENDIF
REP%=0
IF PUKEY%=1
  GOTO QT::
ENDIF
SP1%=SP%
GF1%=GF%
FACT1%=FACT%
PART1%=PART%
PROP1%=PROP%
K%=IMKEY%
QT::
DO
CIMP%=1
CLS
BEEP 2,100
IF REP%=0
  REP%=1
  GOTO F1::
  ELSE
    PRINT "REPLICATE Y/N"
    INPUT A$
    IF A$="Y"
      GOTO AP::
      ELSEIF A$="N"
        GOTO F1::
      ELSE
        GOTO QT::
      ENDIF
    ENDIF
F1::
SPP::
BEEP 2,100
CLS
PRINT "PAST UTL : PATCH ";PATCH%
IF IMKEY%=0
```

```
  PRINT "SPP BY PART (0,E)"
  INPUT SP1%
  IF SP1%=0
    CLS
    BEEP 2,100
    PRINT "EXIT PAST IMPACT Y/N"
    INPUT A$
    IF A$="Y"
      CLOSE
      REP%=1
      RETURN
    ELSE
      GOTO QT::
    ENDIF
  ELSEIF SP1%>200
    GOTO SPP::
  ENDIF
ENDIF
GR::
IF IMKEY%=0
  CLS
ENDIF
IF IMKEY%=0
  BEEP 2,100
ENDIF
AT 1,3: PRINT "PAST HEIGHT CLASS"
INPUT GF1%
IF GF1%<1 OR GF1%>5
  GOTO GR::
ENDIF
IF IMKEY%=0
  FO13:
ELSEIF IMKEY%=1
  IF PART%=1
    FO13:
  ELSE
    COND%=1
  ENDIF
ENDIF
IF IMKEY%=0
  RP::
  CLS
  BEEP 2,100
  PRINT "NEW PLANT (Y/R)"
  INPUT RPT$
  IF RPT$="R"
    GOTO ACT1::
  ELSEIF RPT$="Y"
    GOTO ACT1::
  ELSE
    GOTO RP::
  ENDIF
ELSEIF IMKEY%=1
  IF RPT$="N"
    RPT$="Y"
  ENDIF
ENDIF
ACT1::
CLS
BEEP 2,100
PRINT "FEEDING ACTION"
  INPUT FACT1%
IF FACT1%<1 OR FACT1%>17
  GOTO ACT1::
ELSEIF FACT1%=17
  PIMP%=1
  PART1%=1
  REVS%=GF1%
  IF IMKEY%=1
    CIMP%=PROP%
    FACT1%=FACT%
```

```
    PART1%=PART%
    GF1%=GF%
    REVS%=GF%
   ENDIF
   GOTO AP::
 ENDIF
 IF IMKEY%=0
   PP::
   CLS
   BEEP 2,100
   PRINT "PLANT PART"
   INPUT PART1%
   IF PART1%<1 OR PART1%>12
     GOTO PP::
   ENDIF
 ENDIF
 PI::
 CLS
 BEEP 2,100
 PRINT "PAST IMPACT"
 INPUT PIMP%
 IF PIMP%<0 OR PIMP%>8
 ENDIF
 R::
 CLS
 BEEP 2,100
 IF PIMP%=8
   REVS%=0
 ELSE
   PRINT "PAST REVERSAL"
   INPUT REVS%
   IF REVS%>GF1%
     GOTO R::
   ENDIF
 ENDIF
 AP::
 CLS
 BEEP 2,100
 PRINT "ACCEPT RECORD Y/N"
 INPUT A$
 CLS
 IF A$="Y"
   IMKEY%=0
   A.B1%=GR% :A.B2%=M% :A.B3%=D% :A.B4%=Y% :A.B5%=PATCH% :A.B6%=SP1% :A.B7%=GF1%
:A.B8%=FACT1% :A.B9%=PART1% :A.B10%=PIMP% :A.B11%=CIMP% :A.B12%=REVS% :A.B13$=RPT$
:A.B14%=COND%
   USE A :APPEND
 ELSE
   IMKEY%=K%
   REP%=0
     IF IMKEY%=1
     BEEP 2,100
     GOTO GR::
   ELSE
     GOTO QT::
   ENDIF
 ENDIF
 IF K%=1
   REP%=0
   K%=0
 ENDIF
 IF BARK%=6 OR BARK%=11
   CLOSE
   RETURN
 ENDIF
 UNTIL SP1%=0
```

3.13 Woody plant condition selection

This subroutine attempted to categorize the condition of plant as good bad or not

applicable for a particular feeding activity i.e no leaf stripping would occur of the leaves had withered.

FO13:

```
REM ANIMAL/PLANT BASED CONDITION SELECTION
CO::
CLS
BEEP 2,100
PRINT "SELECTION CONDITION"
AT 1,3 :PRINT "1 GOOD  2 BAD  3 NA"
INPUT COND%
IF COND% <1 OR COND%>3
  GOTO CO::
ENDIF
RETURN
```

4. SEVERE ELEPHANT IMPACTS ON CANOPY TREES

4.1 Severe impacts menu

The subroutine selected different menu for severe elephant impacts as detailed below.

SEVERE1:

```
REM PLANT-BASED SEVERE ELEPHANT IMPACT MENU
LOCAL K%,Q$(1),PTC%
GLOBAL TRAN%,HT%,CIRC%,DIAM%,PER%,IMP%,STATE%,CAUSE%,SITE%,REPKEY%,NP%,TYPE%,PT%
D%=DAY
M%=MONTH
Y%=YEAR
SPACEC%=0
SPACEB%=0
REPKEY%=0
PATCH%=0
NP%=0
PT%=0
TYPE%=0
SEVERE5:
DO
  BEEP 2,100
  CLS
  K%=MENU("PATCH,MAJORIMP,BPACK,CPACK,QUIT")
  IF K%=0 OR K%=5
     BEEP 2,100
     CLS

     PRINT "QUIT (Y/N)"
     INPUT Q$
     IF Q$="Y"
       RETURN
     ELSE
       CONTINUE
     ENDIF
  ELSEIF K%=1
    IF PATCH%=0
      TRAN%=TRAN%+1
    ENDIF
    JU1:
    CLS
    BEEP 2,100
    PRINT "TRAN ";TRAN%;" , ";"PATCH ";PATCH%
    AT 1,3 :PRINT "PRESS ANY KEY - CONT"
    GET
    TYPE%=1
    SEVERE2:
  ELSEIF K%=2
```

```
   PTC%=PATCH%
   TYPE%=2
   SEVERE2:
   PATCH%=PTC%
  ELSEIF K%=3
   SPACEB%=1
   SEVERE5:
  ELSEIF K%=4
   SPACEC%=1
   SEVERE4:
  ENDIF
UNTIL 0
```

4.2 Severe elephant impacts on plant species

SEVERE2:

The following subroutine recorded severe impacts by plant species, diameter size class, height class impact type, period of impact and related data.

```
REM PLANT-BASED SEVERE ELEPHANT IMPACT DATA
LOCAL Q$(1)
IF NOT EXIST ("B:SEV2")
  CREATE "B:SEV2",B,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%,B14%,B15%,B16$
ELSE
  OPEN "B:SEV2",B,B1%,B2%,B3%,B4%,B5%,B6%,B7%,B8%,B9%,B10%,B11%,B12%,B13%,B14%,B15%,B16$
ENDIF
CONT::
DO
  IF REPKEY%=1
    BEEP 2,100
    CLS
    PRINT "REPLICATE (Y/N/E)"
    INPUT Q$
    IF Q$="Y"
      GOTO APPEND::
    ELSEIF Q$="N"
      GOTO NP::
    ELSEIF Q$="E"
      GOTO EXIT::
    ELSE
      CONTINUE
    ENDIF
  ENDIF
  IF NP%=0
    RPT$="Y"
    NP%=1
    GOTO SP::
  ENDIF
  NP::
  CLS
  BEEP 2,100
  PRINT "NEW PLANT (Y/R/E)"
  INPUT RPT$
  IF RPT$="Y"
    GOTO SP::
  ELSEIF RPT$="R"
    GOTO HT::
  ELSEIF RPT$="E"
    GOTO EXIT::
  ELSE
    GOTO NP::
  ENDIF
  SP::
  BEEP 2,100
  CLS
  PRINT "PLANT SPECIES (0,E)"
  INPUT SP%
  IF SP%>200 OR SP%=0
    CONTINUE
```

```
  ENDIF
HT::
BEEP 2,100
CLS
PRINT "HEIGHT CLASS"
INPUT HT%
IF HT%<1 OR HT%>5
  GOTO HT::
ENDIF
BEEP 2,100
CLS
PRINT "CIRCUMFERENCE"
INPUT CIRC%
DIAM%=CIRC%*7/22
P::
CLS
BEEP 2,100
PRINT "PERIOD"
INPUT PER%
IF PER%>5
  GOTO P::
ELSEIF PER%=5
  IMP%=1
  CAUSE%=6
  STATE%=2
  PROP%=1
  REV%=HT%
  GOTO APPEND::
ENDIF
IMP::
BEEP 2,100
CLS
PRINT "IMPACT TYPE"
INPUT IMP%
IF IMP%<2 OR IMP%>6
  GOTO IMP::
ENDIF
CAUSE::
BEEP 2,100
CLS
PRINT "CAUSE OF IMPACT"
INPUT CAUSE%
IF CAUSE%<1 OR CAUSE%>6
  GOTO CAUSE::
ENDIF
STAT::
BEEP 2,100
CLS
PRINT "MORTALITY STATUS"
INPUT STATE%
IF STATE%<1 OR STATE%>4
  GOTO STAT::
ENDIF
PROP::
BEEP 2,100
CLS
PRINT "IMPACT PROPORTION"
INPUT PROP%
IF PROP%<1 OR PROP%>8
  GOTO PROP::
ENDIF
IF PROP%=8
   REV%=0
ELSEIF PROP%=7
  REV%=1
ELSE
  REV::
  CLS
  BEEP 2,100
  PRINT "REVERSAL"
  INPUT REV%
```

```
  IF REV%>HT%
    GOTO REV::
  ENDIF
ENDIF
APPEND::
CLS
BEEP 2,100
PRINT "ACCEPT RECORD (Y/N)"
INPUT Q$
IF Q$="Y"
  CLS
  B.B1%=TRAN% :B.B2%=M% :B.B3%=D% :B.B4%=Y% :B.B5%=SITE% :B.B6%=PATCH% :B.B7%=SP%
:B.B8%=HT% :B.B9%=DIAM% :B.B10%=PER% :B.B11%=IMP% :B.B12%=CAUSE% :B.B13%=STATE%
:B.B14%=PROP% :B.B15%=REV% :B.B16$=RPT$
  USE B :APPEND
  IF IMP%=5
    SEVERE3:
  ENDIF
  IF PER%<2
    PT%=1
    SEVERE4:
  ENDIF
  REPKEY%=1
ENDIF
UNTIL SP%=0
EXIT::
CLS
BEEP 2,100
IF TYPE%=1
  PRINT "END PATCH (Y/N)"
ELSEIF TYPE%=2
  PRINT "END MAJOR IMPACT Y/N"
ENDIF
INPUT Q$
IF Q$="Y"
  IF PATCH%=5
    PATCH%=0
  ENDIF
  TYPE%=0
  NP%=0
  REPKEY%=0
  CLOSE
  RETURN
ELSE
  GOTO CONT::
ENDIF
```

4.3 Severe impact bark damage

Amount of bark damage on different woody species was recorded by this subroutine**.**

```
SEVERE3:
LOCAL CURR%,CUOD%,Q$(1)
REM PLANT-BASED SEVERE IMPACT BARK DAMAGE DATA
IF NOT EXIST ("B:SEV3")
  CREATE "B:SEV3",C,C1%,C2%,C3%,C4%,C5%,C6%,C7%,C8%,C9%,C10%
ELSE
  OPEN "B:SEV3",C,C1%,C2%,C3%,C4%,C5%,C6%,C7%,C8%,C9%,C10%
ENDIF
START::
CLS
BEEP 2,100
PRINT "CURRENT BARK DAMAGE"
INPUT CURR%
CLS
BEEP 2,100
PRINT "CURRENT+OLD DAMAGE"
INPUT CUOD%
```

```
CLS
BEEP 2,100
PRINT "ACCEPT RECORD (Y/N)"
INPUT Q$
IF Q$="Y"
  CLS
  C.C1%=TRAN% :C.C2%=M% :C.C3%=D% :C.C4%=Y% :C.C5%=SITE% :C.C6%=PATCH% :C.C7%=SP%
:C.C8%=HT% :C.C9%=CURR% :C.C10%=CUOD%
  USE C :APPEND
  CLOSE
  RETURN
ELSE
  GOTO START::
ENDIF
```

4.4 Severe impact plant part selection

The following subroutine recorded plant parts selected during severe elephant impacts on woody species.

```
SEVERE4:
REM PLANT-BASED SEVERE ELEPHANT IMPACT DATA
LOCAL Q$(1),S
IF NOT EXIST ("C:SEV4")
  CREATE "C:SEV4",D,D1%,D2%,D3%,D4%,D5%,D6%,D7%,D8%,D9%,D10%,D11%,D12$
ELSE
  OPEN "C:SEV4",D,D1%,D2%,D3%,D4%,D5%,D6%,D7%,D8%,D9%,D10%,D11%,D12$
ENDIF
IF SPACEC%=1
  S=SPACE
  PRINT S
  BEEP 2,100
  AT 1,3: PRINT "ANY KEY TO CONT"
  GET
  SPACEC%=0
  CLOSE
  RETURN
ENDIF
CONT::
DO
  PART::
  BEEP 2,100
  CLS
  PRINT "PLANT PART (0,E)"
  INPUT PART%
  IF PART%>12
    CONTINUE
  ELSEIF PART%=0
    IF PT%=1
      CLS
      BEEP 2,100
      PRINT "PART NOT ENTERED"
      AT 1,3 :PRINT "ANY KEY TO CONT"
      GET
      GOTO CONT::
    ENDIF
    BEEP 2,100
    CLS
    PRINT "QUIT PART (Y/N)"
    INPUT Q$
    IF Q$="Y"
      CONTINUE
    ELSE
      GOTO CONT::
    ENDIF
  ENDIF
CLS
BEEP 2,100
```

```
PRINT "ACCEPT RECORD (Y/N)"
INPUT Q$
IF Q$="Y"
  CLS
  D.D1%=TRAN% :D.D2%=M% :D.D3%=D% :D.D4%=Y% :D.D5%=SITE% :D.D6%=PATCH% :D.D7%=SP%
:D.D8%=HT% :D.D9%=PART% :D.D10%=PER% :D.D11%=IMP% :D.D12$=RPT$
  USE D :APPEND
  RPT$="R"
  PT%=0
ENDIF
UNTIL PART%=0
CLOSE
RETURN
```

4.5 Severe impact general data

This subroutine recorded general data for severe impacts such as transect number, date, habitat type, distance from water, map reference and elephant social group and group size if known.

```
SEVERE5:
REM PLANT-BASED SEVERE ELEPHANT IMPACT GENERAL DATA
LOCAL Q$(1),HAB%,S
IF NOT EXIST ("B:SEV1")
  CREATE "B:SEV1",A,A1%,A2%,A3%,A4%,A5%,A6%,A7%,A8%,A9$
ELSE
  OPEN "B:SEV1",A,A1%,A2%,A3%,A4%,A5%,A6%,A7%,A8%,A9$
ENDIF
IF SPACEB%=1
  S=SPACE
  BEEP 2,100
  PRINT S
  AT 1,3 :PRINT "ANY KEY TO CONT"
  GET
  SPACEB%=0
  CLOSE
  RETURN
ENDIF
START::
BEEP 2,100
CLS
PRINT "TRANSECT NUMBER"
INPUT TRAN%
IF TRAN%=0
  GOTO START::
ENDIF
TRAN%=TRAN%-1
D%=DAY
M%=MONTH
Y%=YEAR
SPACEC%=0
REPKEY%=0
PATCH%=0
NP%=0
CLS
BEEP 2,100
PRINT "SITE NUMBER"
INPUT SITE%
CLS
BEEP 2,100
PRINT "MAP REF"
INPUT GRID$
D::
CLS
BEEP 2,100
PRINT "DIST. FROM WATER"
INPUT DIST%
IF DIST%<1 OR DIST%>4
  GOTO D::
```

```
ENDIF
HAB::
CLS
BEEP 2,100
PRINT "HABITAT"
INPUT HAB%
IF HAB%<1 OR HAB%>45
  GOTO HAB::
ENDIF
GR1::
CLS
BEEP 2,100
PRINT "GROUP STRUCTURE"
PRINT "1 BULLS   2 COWS"
PRINT "3 UNKNOWN"
INPUT GST%
IF GST%<1 OR GST%>3
  GOTO GR1::
ENDIF
CLS
BEEP 2,100
PRINT "GROUP SIZE (0=U)"
INPUT GSIZE%
CLS
BEEP 2,100
PRINT "ACCEPT HEADER (Y/N)"
INPUT Q$
IF Q$="Y"
  A.A1%=M% :A.A2%=D% :A.A3%=Y% :A.A4%=SITE% :A.A5%=HAB% :A.A6%=DIST% :A.A7%=GST%
:A.A8%=GSIZE% :A.A9$=GRID$
  USE A :APPEND
ELSE
  GOTO START::
ENDIF
CLOSE
RETURN
```

5. DATA CAPTURE PROGRAM VARIABLE CODES

5.1 Habitat type codes

1	Riparian fringe woodland
2	Alluvial terrace woodland
3	*Baikiaea plurijuga* woodland
4	*Colophospermum mopane* woodland
5	*Burkea africana*
6	*Burkia/Brachystergia/Mopane*

5.2 Habitat utilization classification

1	Light
2	Moderate
3	Heavy

5.3 Plant height classes (m)

1	0.0 - 0.5
2	0.5 - 1.0
3	1.0 - 2.5
4	2.5 - 5.0
5	>5.0

5.4 Feeding actions

1	Branch breaking
2	Uproot whole/part of plant
3	Bark stripping
4	Ring-barking
5	Bark abrasion
6	Bark fraying
7	Snap trunk
8	Stem twisting
9	Leaf stripping
10	Plucking or picking fruits
11	Snap stem(s)
12	Snap shoots
13	Snap branchlets
14	Digging for roots
15	Pick dry leaves from ground
16	Push down trees
17	Nil
18	Unknown

5.5 Plant parts eaten

1	Nil
2	Leaves
3	Shoots/branchlets
4	Woody material

5	Woody material and leaves
6	Bark of trunk, branches
7	Roots
8	Flowers
9	Fruits
10	Fallen leaves
11	Bark of roots
12	Tubers

5.6 Phenological assessment

	Leaves	**Flowers**	**Fruits**
1	Buds	Buds	Unripe
2	Young	Blossoming/open	Ripe
3	Mature	Faded	Disseminating
4	Senescence/drop	Flowerless	Fruitless
5	Leafless		

5.6. Distance from river/water (m)

1	0-100
2	100-500
3	500-1000
4	>1000

5.7 Proportion of whole plant/plant part removed (%)

1	0
2	1-10
3	10-25
4	25-50
5	50-75
6	75-90
7	90-99
8	100
9	Unknown

5.8 Plant cover assessment (%)

1	0
2	1-10
3	10-20
4	20-30
5	30-40
6	40-50
7	50-75
8	75-90
9	90-99
10	100

5.9 Severe impact codes

5.9.1 Impact period

0	Current impact
1	Nov (sites 1-3), mid Oct-Nov (sites 4-5)
2	Within the last 12 months
3	12-24 months
4	Over 24 months
5	Not applicable i.e. no impact on plant

5.9.2 Impact Type

1	Nil
2	Snap stem
3	Pushed over
4	Uprooted
5	Debarked
6	Other (branch breaking,leaf stripping, burned etc.)

5.9.3 Cause of Impact

1	Fire
2	Elephant
3	Wind
4	Elephant and fire
5	Unknown
6	Not applicable

5.9.4 Regrowth after impact

1	Dead
2	Nil
3	Coppice
4	New branches

5.10 Woody plant species

The following are the woody plant species which are known to occur in the elephant range of northern Botswana. Each species was assigned a code for the purpose of data collection. The species nomenclature is based on Palgrave (1983).

CODE	WOODY SPECIES
1	*Acacia erioloba*
2	*Acacia fleckii*
3	*Acacia nigrescens*
4	*Acacia tortilis*
5	*Acacia schweinfurthii*
6	*Adansonia digitata*
7	*Afzelia quanzensis*
8	*Amblygonocarpus andongensis*
9	*Azanza garckeana*
10	*Baikiaea plurijuga*
11	*Baphia massaiensis*
12	*Bauhinia petersiana*
13	*Bauhinia thonningii*
14	*Berchemia discolour*
15	*Boscia albitrunca*
16	*Bridelia mollis*
17	*Burkea Africana*
18	*Canthium frangula*

CODE	WOODY SPECIES
19	*Capparis tomentosa*
20	*Colophospermum mopane*
21	*Combretum apiculatum*
22	*Combretum celastroides*
23	*Combretum collinum*
24	*Combretum elaeagnoides*
25	*Combretum fragrans*
26	*Combretum hereroense*
27	*Combretum imberbe*
28	*Combretum molle*
29	*Combretum mossambicense*
30	*Combretum zeyheri*
31	*Commiphora mossambicensis*
32	*Crossopteryx febrifuga*
33	*Croton gratissimus*
34	*Croton megalobotrys*
35	*Dalbergia melanoxylon*
36	*Dialium engleranum*
37	*Dichrostachys cinerea*
38	*Diospyros batocana*
39	*Diospyros lycioides*
40	*Diospyros mespiliformis*

CODE	WOODY SPECIES
41	*Diplorhynchus condylocarpon*
42	*Elephantorrhiza goetzei*
43	*Erythrophleum africanum*
44	*Erythroxylum zambesiacum*
45	*Euclea divinorum*
46	*Friesodielsia obovata*
47	*Garcinia livingistonei*
48	*Gardenia spatulifolia*
49	*Grewia flavescens*
50	*Grewia monticola*
51	*Guibourtia coleosperma*
52	*Kigelia africana*
53	*Jasminum stenolobum*
54	*Xeroderris stuhmannii*
55	*Lonchocarpus capassa*
56	*Lonchocarpus nelsii*
57	*Markamia acuminate*
58	*Markamia obtusifolia*
59	*Maytenus senegalensis*
60	*Ochna pulchra*
61	*Paropsia brazzeana*
62	*Pseudolachnostylis maprouneifolia*

CODE	WOODY SPECIES
63	*Psydrax livida*
64	*Pterocarpus angolensis*
65	*Pterocarpus lucens*
66	*Pterocarpus rotundifolius*
67	*Securidaca longipedunculata*
68	*Securinega virosa*
69	*Schrebera trichoclada*
70	*Sclerocarya burrea*
71	*Sterculia Africana*
72	*Strychnos cocculoides*
73	*Strychnos madagascariensis*
74	*Strychnos potatorum*
75	*Strychnos pungens*
76	*Terminalia sericea*
77	*Tricalysia cacondensia*
78	*Trichilia emetica*
79	*Vangueria infausta*
80	*Vitex payos*
81	*Xeromphis obovata*
82	*Ximenia Americana*
84	*Ziziphus mucronata*
85	*Ptelepsis myrtifolia*

CODE	WOODY SPECIES
88	*Kirkia acuminate*
89	*Julbernadia globiflora*
90	*Terminalia randii*
91	*Combretum schumannii*
92	*Commiphora pyracanthoides*
94	*Combretum celastroides*
95	*Ochna cinnabarina*
96	*Baissea wulfshorstii*
97	*Grewia flava*
98	*Hippocratea buchanannii?*
99	*Commiphora Africana?*
100	*Grasses*
101	*Terminalia mollis*
102	*Ancylanthes bainesii*
103	*Canthium burti*
104	*Mugongo tree*
105	*Brachystegia boehmii*
106	*Cissus cornifolia*
107	*Lannea schiwelnfurthii*
108	*Acacia nilotica*
109	*Vangueriopsis lanciflora*
110	*Lannea discolor*

CODE	WOODY SPECIES
111	*Pavetta schumanniana*
112	*Peltophorum africanum*
113	*Annona stenophylla*
114	*Commiphora edilus*
115	*Albizia brevifolia*
117	*Commiphora mollis*
119	*Bridelia carthatica*
121	*Albizia harveyi*
122	*Pteleopsis mytifolia*
123	*Acacia nilotica*
124	*Acacia galpinii*
125	*Swartzia madacascariensis*
126	*Acacia arenaria*
127	*Acacia hebeclada*
128	*Mundulea sericea*
129	*Terminalia prunioides*
134	*Brachstegia spiciformis*