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An assessment of the browsing impacts of the *Loxodonta africana* (African Elephant) on woody vegetation structure and composition. A case study of Umfurudzi Safari Area in Mashonaland Central Province.

NAME : MUJEURI THEMBINKOSI

REG NUMBER : B192720B

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DEDICATION

I dedicate this thesis to the Almighty Father without him it would have been impossible to complete this research. I would love to dedicate to my mother Ms E.Gunge, my father Mr D. Mujeuri, and my sisters for supporting me through thick and thin.

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Abstract

An assessment of the browsing impacts of the *Loxodonta africana* (African Elephant) on woody vegetation structure and composition was made in Umfurudzi Safari Area. Study areas were selected in the elephants vicinity since they are tamed ,the study also compared the woody vegetation structure and composition before and the introduction of elephants in Umfurudzi Game Park using he study which was made by Mposhi *et al* (2014) on the vegetation structure and composition before the introduction of elephants in Umfurudzi Game Park. And, also to determine the type of damage which was being inflicted on the woody vegetation by the elephants. The results showed that the elephants were causing damage to the species which were available in the park which are the *Brachystegia boehmmi* and *Julbenardia globiflora* and these tree were mainly being pulled and debarked as for the comparison there was no significant difference before and after the introduction of elephants in Umfurudzi Game Park**.**

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Chapter one

1:1 Background

The feeding behaviour of elephants, which can range from very delicate to gross destruction when feeding on woody plants. The effects of elephant utilization are often referred to as "damage," which in this study refers to any removal of woody biomass, not only to suggest excessive destruction (Cumming & Jackson 2010). When feeding on shrubs, elephants generally pull off leaves and twigs, tearing off branches. With smaller plants, the stems may be broken off just above the ground or, with saplings, uproot the entire plant (Guldemond & van Aarde 2007; Nasseri et al., 2010).

Elephants are also known to excavate subterranean plant parts to expose roots and other parts, such as tubers of favoured plants in sandy soils. These feeding behaviours can have both positive and negative impacts on the ecosystem. For example, the excavation of subterranean plant parts can promote the growth of certain plant species and improve soil quality, but it can also lead to the destruction of rare or endangered species. The impact of elephant feeding behaviour on the ecosystem is complex and depends on various factors, including the availability of food, the density of elephant populations, and the type of vegetation in the area. (Mukwashi, Gandiwa , Kativu 2012)

When the foliage is out of reach, elephants may uproot or push over trees, or break off large branches. Shallow-rooted trees are more likely to be pushed over without breaking, while deeper-rooted trees are more likely to have their stems snapped, with coppice growth produced from the stump. The feeding behaviour of elephants can have a significant impact on the growth and survival of trees, especially if the bark is removed around the complete circumference of the trunk, which can lead to the eventual death of the tree above the ring barked point (Guldemond & van Aarde 2007).

Elephants browse on the bark of many trees, which they either tear off in long strips or break off in pieces depending on their preference. The removal of bark can also have a significant impact on the survival of the tree, as it can disrupt the flow of nutrients and water between the roots and the rest of the tree. Overall, the feeding behaviour of elephants can have both positive and negative impacts on the ecosystem, and it is important to understand these impacts when managing elephant populations and their habitat (Nasseri *et al*., 2010)

1:2 Problem statement

Ever since Elephants reintroduction in 2013, the animals have been living in a fenced area measuring 11 800 Hectares, although they browse outside the fenced area, most of their time has been spent within. The preferred areas have been left severely damaged as many trees are debarked, uprooted hence a modified vegetation structure, both negatively and positively. There has been no study done to investigate theses effects thus the purpose of this study.

1:3 Justification of the study

Since the introduction of the African elephant in Umfurudzi Safari Area, no study of the vegetation structure and composition in relation to these ecosystem engineers has been done, from the mere look there is a reduction in upper canopy cover, selected tree species utilisation and reduced tree density especially in areas near watering holes. This study wishes provide a basic ecological insight on the influence of and determine whether these mega herbivores are shaping the vegetation structure in a selected area in Umfurudzi Safari Area.

1:4 General Aim

To assess the browsing impacts of the *Loxodonta africana* on the woody vegetation structure and composition at Umfurudzi Safari Area.

1:5 Objectives

i) To identify the woody plant species selected by Elephants.

ii) To determine extent of damage being inflicted on the woody plant species by Elephants.

iii) To compare current woody structure and composition to that found by Muposhi *et al* (2014) prior to introduction of elephants within the preferred area.

1:6 Research question

Which tree species are mostly preferred by the elephants?

Which type of damage is being inflicted on the vegetation by the elephants?

What is the difference between the current woody structure and composition and the one found by Muposhi *et al* (2014) prior to introduction of elephants?

What are the ecological impacts caused by the browsing of the *Loxodonta africana* on the woody vegetation structure and composition in a preferred area?

CHAPTER TWO

Literature review

Elephants have a tendency to consume tree species that are rich in nutrients, which can increase the likelihood of damage to these preferred food sources (Boundja & Midgley, 2009). In areas where elephant herds browse, there are expected differences in the density, species number, turnover, and composition of woody vegetation (Lombard et al., 2001; Brits et al., 2002; Guldemond & van Aarde, 2007; Asner et al., 2009). As a result, some protected areas in southern and eastern Africa have observed the local extinction of certain tree species (Boundja & Midgley, 2009).

Elephants tend to browse selectively, pulling down tall, desirable branches, uprooting shrubs and small trees, and showing preference for certain plants, such as *Acacia* spp, *Aloes*, *Brachystegia* spp, *Colophospermum mopane*, *Spirostachys africana*, and *Commiphora merkerii* (O'Connor et al., 2007; Boundja & Midgley, 2009;Parker & Bernard, 2009). This leads to an increased abundance of woody plant species that are not selected by herbivore populations (Scogings et al., 2012).

ELEPHANT IMPACTS ON THE ENVIRONMENT

Elephants have a significant impact on vegetation but also positively through the creation of paths, digging to open up water sources, and have a habit of depositing large quantities of urine and dung. . Although they have a diet that includes both grass and woody plants, elephants tend to obtain the majority of their food from their surroundings. From woody plants during the dry season. However, as most grazing occurs during the wet or growing season, grasses can rapidly grow back and replace foliage that elephants have removed. Therefore, the impact of elephants on grasses during this time is typically not significant. As a result, their impact on grasses during this time is generally considered to be minimal (McComb. and Moss 1985)

With the rise in human populations, the available land area for elephants has diminished, leading to their confinement within protected areas. The number of elephants in these confined areas and their impact on vegetation can be significant due to limited resources and space. This situation can be a cause for concern as it may lead to overgrazing and depletion of vegetation, which can have negative consequences for both the elephants and other wildlife in the area (Witteyer, Elsen, Bean. *et al* 2008). Additionally, human-elephant conflicts can also arise as elephants may venture outside of protected areas in search of resources. As the density of elephant's increases, there is often a noticeable reduction in woody vegetation and a change in the structure of forest and woodland areas, resulting in the growth of shrub lands and wooded grasslands.

The reduction in woody vegetation can alter the composition of plant communities and affect the availability of food and habitat for other wildlife. The shift towards shrub lands and wooded grasslands can also impact soil-water relations, as these areas may have different water retention capabilities compared to forests and woodlands. In turn, this can affect nutrient cycling and the overall functioning of the ecosystem. The impact of elephants on habitat heterogeneity may increase biodiversity at low densities, while at higher densities, the opposite is likely to occur (Young 1992)

Elephant feeding also has positive effects, such as seed dispersal and facilitation of seed germination through the gut and subsequent deposition in dung. In Hwange National Park in Zimbabwe, for example, elephants have been known to disperse the seeds of 27 different woody plant species and one type of palm.

Impacts on Woody Vegetation

Elephants can have a significant impact on the vegetation in their habitat, both through direct feeding and damage to trees and other plants. The term "damage" is often used to refer to the effects of elephant utilization on woody vegetation, but it should be noted that this term encompasses any removal of woody biomass, not just excessive destruction. Elephants have a preference for certain plant species, and their feeding habits can lead to a reduction in woody vegetation and changes in forest and woodland structure (Cote, Rooney. Tremblay *et al* 2004)

In the Sengwa Wildlife Research Area in Zimbabwe, studies have shown that the impact of elephants on vegetation is strongly linked to their preferred food species. The impact on large trees is often more noticeable and causes concern since they are aesthetically appealing. Elephants can uproot or push over larger trees or break off the trunk or large branches, while with smaller plants, they may pull off leaves and twigs or break stems off just above the ground. Elephants can also excavate to expose subterranean plant parts such as roots and tubers of favoured plants in sandy soils (Douglas-Hamilton., Krink, and Vollrath.2005)

Elephants are known to consume the bark of many tree species, which they tear off in long strips or break off in pieces depending on the characteristics of the tree's bark. This behaviour can have significant impacts on the health and survival of trees, especially if elephants consume too much bark or repeatedly target the same trees. Additionally, the loss of bark can expose the underlying wood to pests and diseases, further compromising the health of affected trees. However, it is worth noting that the bark of some tree species may also have regenerative properties, and the removal of bark by elephants may actually stimulate the growth of new bark and other tissues (Sukumar 1989).

Studies in the Sengwa Wildlife Research Area have shown that elephant damage is strongly linked to their preferred food species. In Mopane woodland, which is a common habitat for elephants, a significant proportion of the five most important tree species had either died or been converted to shrubs, indicating a severe impact on the woodland structure. Similarly, in Miombo woodland and *Acacia-Grewia* riverine woodland, the impact of elephants on the most important tree species was also notable, with a substantial proportion of trees either dead or converted to shrubs. In contrast, in *Baikiaea-Baphia* communities where *Baikiaea* is the dominant tree species, the impact of elephants was relatively low, with only a small percentage of trees affected. Bark damage was assessed separately, and the three most affected tree species were *brachystegia boehmii*, *acacia tortilis*, and *a. nigrescens*. These tree species are known to be important food sources for elephants, and their bark is particularly vulnerable to damage. The loss of bark from these trees can have negative effects on their health and survival, as well as on the structure and composition of the woodland ecosystem. Therefore, it is important to consider the specific impacts of elephants on different tree species when developing management strategies for elephant populations and their habitats (Barnes and Barnes 1983)

To preserve the different vegetation types in the SWRA (Samburu-Laikipia-Wamba Rangelands Area), it was recommended to initially reduce the elephant population to around 40% of the existing population density. This reduction in elephant numbers was suggested as a way to mitigate the negative impact that elephants can have on certain types of woodland and to allow for the recovery of affected vegetation. However, it is important to note that any population management strategy must be carefully planned and implemented to ensure that it is both effective and humane (Barnes and Barnes 1983).

FACTORS AFFECTING ELEPHANT IMPACT ON VEGETATION

Vegetation Type and Geographic Area

The level of utilization of a particular plant species by elephants is likely to be affected by the availability of other plant species in the vicinity, which can vary between different localities and over time. Studies have examined the relationship between plant nutrient levels and elephant utilization, but the results have been inconsistent. Some studies have found a correlation between high mineral and sugar content and the selection of certain plant species by elephants (Pringle 2008)

The proportion of the tree population killed by elephants can correlate with tree density for some species, while for others, high numbers of trees continue to be killed even when the tree density is low. In some cases, a fixed number of trees are killed annually regardless of tree density, which can lead to the local extinction of the tree population .The studies mentioned in the passage highlight the complexity of elephant feeding behaviour and their impact on vegetation. While some studies have found significant correlations between elephant utilization and the chemical composition of plant species, others have found no significant relationship. The availability of water, human activities, and habitat fragmentation can also influence elephant feeding behaviour and their impact on vegetation (Schmitt, Denich, and Demissew 2016)

Elephant feeding behaviour can also vary between species in terms of their impact on tree mortality. Different patterns of mortality have been observed, where the proportion of trees killed by elephants can correlate with tree density for some species. In such cases, reducing the density of elephants in the area may help to reduce the number of trees that are killed each year. However, the impact of elephants on vegetation can be influenced by various factors such as the availability of water and other resources, and the behaviour of individual elephants (Western, and Fincham 1986).

Overall, the complex interactions between elephants and their environment highlight the importance of understanding the factors that influence elephant feeding behaviour and their impact on vegetation. Conservation strategies aimed at mitigating the negative impacts of elephants on vegetation should take into account the various factors that influence elephant behaviour and the specific patterns of tree mortality in different species.

Elephant Sex and Age Class

The selective feeding behaviour of adult male elephants on certain plant species and parts can have significant impacts on vegetation, including the uprooting and felling of trees. Studies have found that adult males are responsible for the majority of tree uprooting, with males pushing over trees more frequently than females (Chafota 2000, Stokke &du Toit 2000).

Differences in feeding behaviour have also been observed between adult males and other categories, such as family groups. Elephants are known to eat a variety of plant parts and tend to spend more time feeding on individual plants, which can result in greater damage to those plants. Adult male elephants have been observed to cause more damage than family units, as they tend to break larger branches, consume more roots, and uproot larger trees. This suggest that the impact of elephants on vegetation can be affected by their age and sex, as well as the availability of different plant species (Barnes 1982)

The prediction of baobab elimination in a section of Ruaha NP based on measurements taken between 1976 and 1982 highlights the long-term impacts of elephant feeding behaviour on vegetation. However, the lack of significant change in baobab numbers in 1989 despite relatively high elephant densities suggests that other factors, such as the loss of adult males to poaching, can also have significant impacts on elephant feeding behaviour and their impact on vegetation (Barnes *et al.* 1994)

Overall, the studies mentioned in the passage emphasize the need to understand the differences in elephant feeding behaviour between sexes and categories, as well as the long-term impacts of these behaviours on vegetation. Conservation strategies aimed at mitigating the negative impacts of elephants on vegetation should take into account these differences and the specific impacts of different categories of elephants on vegetation.

Variation in Annual Rainfall

The impact of low rainfall and a prolonged dry season on elephant feeding behaviour and their impact on vegetation. During dry seasons, elephants tend to eat more woody parts and do more damage to trees, which can have significant impacts on vegetation (Van Wyk & Fairall 1969, Cumming 1981a)

Studies have found that concerns about elephant damage often follow a season of low rainfall, as the extended dry season can exacerbate the negative impacts of elephant feeding behaviour on vegetation. For example, In Ruaha, (Barnes 1982) Tanzania, it was observed that bark stripping by elephants was more widespread during a dry season that followed a season of low rainfall. Similarly, in Linyanti, Botswana, there was an unusually high level of damage to riverine vegetation following a period of low rainfall and an early end to the wet season (Chafota 2000). These observations suggest that the impact of elephants on vegetation can be affected by environmental factors such as rainfall patterns and the availability of water. Therefore, it is important to consider such factors when developing management strategies for elephant populations and their habitats, as well as to monitor the impact of elephants on vegetation over time. This can help to ensure the long-term sustainability of both the elephant population and the ecosystem they inhabit.

Research suggests that baobab damage at Mana Pools National Park in Zimbabwe may have been more significant during periods of low rainfall (Swanepoel 1993). Similarly, there was extensive damage to trees, including Sclerocarya trees, in Kruger National Park during two consecutive years of low rainfall. These findings suggest that the impact of elephants on trees and vegetation can be aggravated by other environmental factors, such as drought and climate change (Owen-Smith 1988).

Conservation strategies aimed at mitigating the negative impacts of elephants on vegetation should take into account the potential impacts of climate variability and change, as well as the specific behaviours of different categories of elephants. Monitoring elephant feeding behaviour and vegetation responses to different environmental conditions can also help inform management decisions and conservation strategies.

Elephant Density

Studies have found that the number of trees felled is 14 times more dependent on elephant density than on tree density (Caughley 1976). It is challenging to accurately determine the level of damage to vegetation at specific elephant densities due to the influence of other factors that affect the impact of elephants. The relationship between elephant density and damage to vegetation is likely to be exponential, where an increase in elephant density leads to an increasing rate of damage to vegetation. At low densities, elephants may have a positive impact by creating gaps in the canopy and allowing for the growth of new plant species. However, as the density increases, elephants may consume more vegetation than the ecosystem can sustain, leading to overgrazing and damage to the vegetation (Anderson & Walker 1974).

Elephant densities are typically measured on a park-wide basis, while the impacts of elephants on vegetation are often measured in much smaller areas (Conybeare 1991). This can make it difficult to establish a direct relationship between elephant density and vegetation damage, as the impacts of elephants can vary depending on a range of factors, such as the availability of food and water, the type of vegetation, and the behaviour of individual elephants. Additionally, the impacts of elephants on vegetation may not be immediately apparent and can take years or even decades to manifest.

In Kruger NP, in order to avoid the total destruction of vulnerable areas near water, a maximum elephant density of 0.29 individuals per square kilometre was recommended. However, despite efforts to control elephant populations, their numbers increased to almost 9,000 in 1970 before being reduced by culling and maintained at around 7,500 individuals (0.4 per square kilometre) until 1994. Even at this lower density, conspicuous damage to vegetation was still observed in some areas, especially during low rainfall years. Damage to Sclerocarya trees, in particular, has been a major concern in Kruger National Park (van Wyk & Fairall 1969).

A review of elephant impacts on *Brachystegia* woodland in Zimbabwe revealed that the woodland was unable to survive when elephant density exceeded 0.5 individuals per square kilometre. At a lower density of 0.2 elephants per square kilometre, there may still be a decline in tree density in *Brachystegia* woodland. These findings suggest that the impact of elephants on *Brachystegia* woodland may be particularly significant, and that careful management of elephant populations is necessary to ensure the continued health and survival of this important ecosystem (Robertson 1993)

CHAPTER THREE

Study Area and Methodology

3.1 Study Area

The study took place in Umfurudzi Safari Area, a protected area located in the north-eastern region of Zimbabwe. This park spans an area of 760 square kilometres and is situated between 17º 15´ and 16º 50´ south and 31º 40´ and 32º 00´ north, with varying altitudes ranging from 740 to 1020 meters. The area falls under agro ecological region IV and is predominantly characterized by the miombo ecosystem, which is dominated by *Brachystegia boehmii* and *Julbernardia globiflora*, along with *Terminalia species*. Additionally, the area features a combination of *Combretum* woodland, *Mopane* woodland, and bamboo riverine forest.

Currently, the management of Umfurudzi Safari Area is under a public-private partnership initiative that began in 2010. This agreement involves the Zimbabwe Parks and Wildlife Management Authority (ZPWMA) and a private partner, Pioneer Travel and Tours (PTT), working together to reintroduce wildlife populations that had previously declined in the park. The initiative resulted in the reintroduction of various species between 2011 and 2015, with a significant number of reintroductions taking place in 2011-2012. Among the reintroduced species were the African elephant (*Loxodonta africana*) and African buffalo (*Syncerus caffer*), both of which had become locally extinct in the area.

To comply with the veterinary department's requirements for buffalo reintroduction, the park established a fenced paddock covering an area of 11,800 hectares. This paddock has also served as the enclosure for the elephants since their reintroduction.

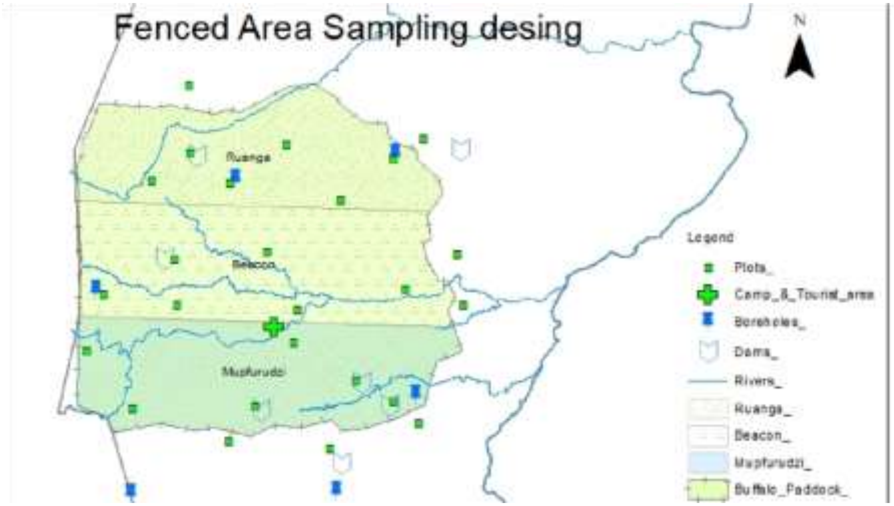


Figure 3.1 Map showing study area

3.2 Methodology

Vegetation was assessed from May to July 2022 when tree species composition was mostly conspicuous (Gandiwa and Kativhu, 2005). Using the stratified sampling method, the area was split into three strata 3.6km wide and 11.8km length. Each strata was named after significant geographic features that occur within.

The method was strengthened by systematic random sampling method whereby six plots measuring 20 m × 30 m (0.06 ha) where randomly located in each strata, systematically choosing areas with likely preferred habitat requirement features (Magwati, Zisadza and Chinuwo 2011). Control plots were also established within the vicinity of the fenced area to account for any utilization that occurred outside the fence. I monitored the plots twice with the first being in mid-May and the second interval being in mid-July.

Plot size was used in accordance with Walker's (1976) method of having at least 15–20 trees inside a plot. I also used the dead tree analysis, damage classification index and plant species status to differentiate various forms of damages inflicted to the trees. Damaged trees were identified, Circumference at Breast Height (CBH), measured, height was estimated. Impact done within three months was estimated recorded and classified.

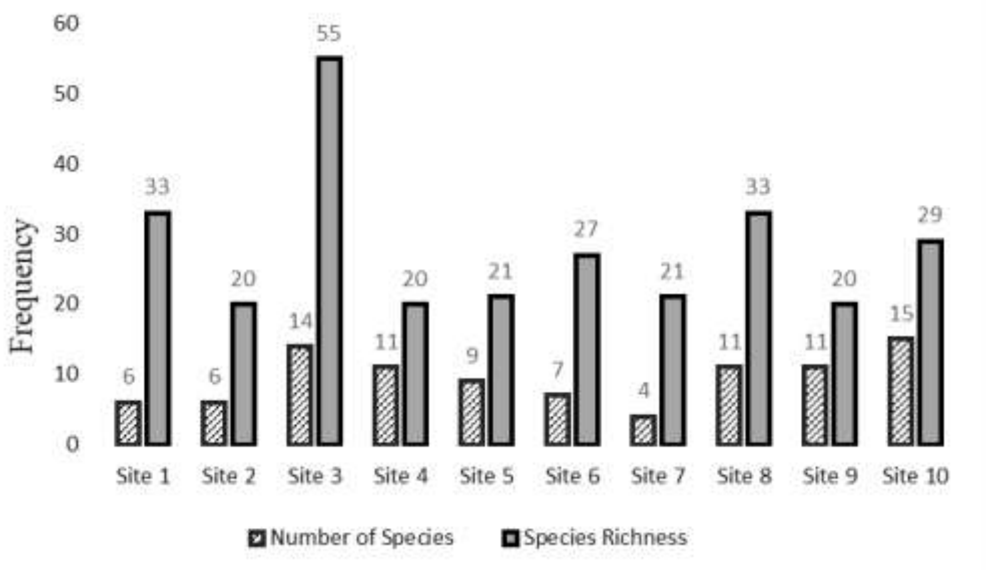
To compare current woody structure and composition before and after the introduction of Elephants in Umfurudzi Game Park. I used the study by Mposhi *et al* which was a study of vegetation structure and composition before the introduction of elephants in the Umfurudzi Game Park and compare them with the current woody vegetation in Umfurudzi after the introduction of elephants with the aid of a T-test.

Chapter 4

Results

A total of 31 tree species were identified to be foraged by elephants in all 10 sites sampled. Site 3 had the highest number of species foraged by elephants (n = 14) and the highest species richness of all sites (n = 55) (Figure 4.1), while site 7 had the least number of species browsed by elephants (n = 4) and sites 2, 4 and 9 had the lowest species richness (n= 20) (Figure 4.1).

Figure 4.1 Foraged tree species abundance and richness in Umfurudzi National Park



Elephants preferred woody species with height ranging from 0.8m to 8m with a mean height of 4.57m (± 0.13 standard error). Site 8 had the highest trees selected by elephants recorded (mean 5.48 ± 0.31) while site 10 had the shortest wood species recorded (mean 3.53 ± 0.5) selected by elephants (Table 4.1). The overall woody species diversity was 2.63 (based on Shannon Weiner diversity index) across all sites, however site 4 has the highest diversity (2.48) despite having a species richness of 20 (Figure 4.1) while site 3 with the highest woody species richness had a species diversity of 2 (Table 4.1).

Table 4.1

Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Mean Tree Height(m)	4.41 ± 0.25	4.91 ± 0.34	3.81 ± 0.39	3.87 ± 0.27	4.46 ± 0.53	4.9 ± 0.45	5.6 ±0.37	5.48 ± 0.31	4.89 ±0.36	3.53 ± 0.5
Mean CBH(cm)	40.58 ± 4.02	35.92 ± 4.3	14.2 ± 2.66	39.15 ± 5.43	65.52 ± 8.85	44.51 ± 5.03	54.17 ± 5.24	52.76 ± 4.61	51.75 ±4.45	26.82 ±4.8
Canopy cover (m^2)	13.02 ± 2.19	38.35 ± 7.05	13.32 ±2.9	10.4 ± 2.2	16.48 ± 3.42	28.74 ±5.36	25.43 ±5.23	31.03 ± 4.92	15.55 ± 2.8	9.75 ± 2.8
Species Diversity (H') (Shannon Weiner)	2.27	1.44	2	2.48	1.73	1.49	0.57	1.88	2.21	2.2

The average circumference at breast height (CBH) was 40.92 cm across all sites. Site 5 had woody species with the highest CBH (65.52 ± 5.43) as it was characterised by more robust tree species though they were averagely short in height. Surveys show elephants preferring relatively tall woody species from bushes to trees in each and every site with the mean tree height not less than 3 metres while the mean circumference at breast height not less than 14 cm depicting more grown up woody species being preferred for foraging (Table 4.1). Canopy cover averaged $20m^2$ ± 1.4 m^2 for all the 10 sites combined. Site 2 had the highest average canopy cover (38.35 ± 7.05) with site 10 having the least canopy cover (9.75 ± 2.8) but with the second highest species diversity (Table 4.1).

Brachstegia boehmii species occurred in all 10 sampled sites along with *Julbernardia globiflora* which occurred in all sites except site 7 and showed signs of debarking and broken branches, meaning the dominant woodland species in the whole park is the Miombo woodland (Table 4.2). Species such as *Linnea discolor* and *Psuedolachnostylis maprouneifolia* were also common occurring in 8 sampled sites and showing signs of being foraged (Table 4.2). Other common species selected by elephants included, *Acacia karoo*, *Bauhinia petersiana, combretum molle, combretum zeyheri* and *colophospermum mopane* (Table 4.2). Site 10 has the highest number of species selected by elephants (n = 14) followed by site 1 (n = 13) while site 7 had the least number of species selected by elephants (n= 4).

Table 4.2 woody species occurrence in different sites (✓ - species present, x – species absent)

SPECIES	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7
A KAROO	✓	X	✓	✓	x	x	x
A.LINEARIS	X	X	x	✓	x	x	x
B.AFRICANA	X	X	✓	x	x	x	x
B.BOHEMII	✓	✓	✓	✓	✓	✓	✓
B.CATHARTICA	X	X	✓	x	x	x	x
B.GALPINII	✓	X	x	x	x	x	x
B.PETERSIANA	X	✓	✓	x	x	✓	x
B.SPICIFORMIS	X	X	x	x	x	x	x
C.MOLLE	✓	X	x	✓	✓	x	x
C.MOPANE	X	X	x	✓	x	x	x
C.ZEYHREI	X	✓	x	x	x	x	x
CRYSTAL BATH	X	X	x	✓	x	x	x
D.CINERIA	✓	X	x	✓	x	x	x
D.CONDLYCARPON	✓	X	✓	✓	✓	x	✓
D.KIRKII	✓	✓	✓	✓	✓	✓	x
D.MESPILIFORMIS	X	X	✓	x	x	x	x
D.SCENEA	✓	X	x	x	✓	x	✓
E.RESINIFERA	X	X	x	x	x	x	x
H.BRASILIENSIS	X	X	x	x	x	x	x
H.CORIACEA	X	X	✓	x	x	✓	x
J.GLOBIFLORA	✓	✓	✓	✓	✓	✓	x
K.ANTHOTHECA	X	X	x	x	x	x	x
L.DISCOLOR	✓	✓	✓	✓	✓	x	✓
P.ANGOLENSIS	X	X	x	x	1	x	x
P.MAPROUNEIFOLIA	✓	X	✓	✓	x	✓	x
P.THORNINGII	X	X	x	x	✓	x	x
S.MADAGASCANCIS	✓	X	x	x	x	x	x

T.FASSOGLENSIS	✓	X	x	✓	x	x	x
T. STENOSTACHYA	✓	X	✓	✓	x	✓	x
V.LANCIFLORA	X	X	✓	x	x	x	x

Table 4.3. Part utilized per plant species.

Plant species	**Family**	**Part utilized**
Acacia karoo	Fabaceae	roots, barks
Adansonia digitata	Malvaceae	barks
Amaranthus spinosus	Amaranthaceae	
Artabotrys branchypetalus	Annonaceae	twigs, barks
Bauhinia petersian	Fabaceae	

Brachystegia boehmii		
	Fabaceae	leaves,
Bridelia catharticus		
	Phyllanchaceae	
Burkea Africana		
		twigs, barks, roots, fruit
Colophospermum mopane	Fabaceae	
Combretum adenogonium	Fabaceae	
		twigs, roots, leaves, barks
Combretum apiculutum	Combretaceae	
Dichrostachys cinerea		
	Combretaceae	barks
Diplorhynchus condylocarpon		

Diospyros mespiliformis	Fabaceae	leaves, barks
Ficus sycomorus	Apocynaceae	
Friesodielsia obovata	Ebenacea	roots, twigs, leaves, barks
Flacourtia indica	Moraceae	
Hyphaene petersian	Annonaceae	leaves, barks
Julbernardia globiflora	Salicaceae	
Lantana camara	Arecaceae	twigs, leaves,

Lennea discolour		barks
	Fabaceae	
Ormocarpum trichocarpum		
	Verbanaceae	twigs, leaves, fruit, bark
Pseudolanchnostylis maprouneifolia	Anacardiaceae	
Terminalia sericea	Fabaceae	roots, leaves
Ziziphus mauritiana	Phyllanthaceae	leaves, twigs, fruits
		fruits,

Combretaceae	bark
Rhamnaceae	leaves
	leaves
	leaves, barks
	leaves and barks

leaves
roots, leaves, twigs, barks
roots, fruits, barks
leaves,

barks
leaves, barks
twigs, barks, fruits

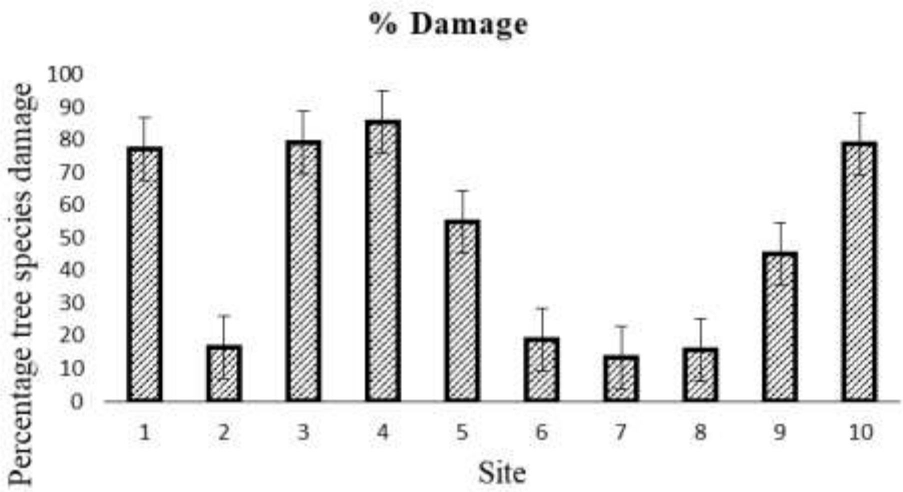
Elephant damages on woody species were observed through broken tree branches, debarked trunks and fallen trees branches which were observed through tree height and canopy cover. There was a strong correlation between height, CBH, and canopy cover which damage being done in the tree canopy affect the tree height or vice versa. CBH increase also corresponds with an increase in the height and canopy cover of tree species (Table 4.3) though the site had the highest diversity (H’ = 2.48).

Table 4.3 Pearson Correlation across all sites

Pearson Correlation (r)	Height (m)	CBH (cm)	Canopy cover (m^2)
Height (m)	1	0.455	0.544
CBH (cm)	0.455	1	0.475
Canopy cover (m^2)	0.544	0.475	1

The overall woody species damage for all the sites was 48.4 % as almost half of all the sampled woody species suffered some kind of damage from elephants ranging from debarking, broken branches, broken trunks to fallen and uprooted trees. Woody species damage was derived from the number of woody species damaged in relation to the total woody species per site(s). Site 4 has the most damaged tree species (damage = 85.2 %) with the average species height (3.87m) and the canopy cover (16.48 m^2) for the site being low.

Figure 4.2; Percentage wood species damage per site



The least damaged site was site 7 with 13.4 % damage and a diversity of 0.57 with the least species diversity (H’ = 0.57) and the average height of 5.6 metres which denotes a dominance of on woody species which is not preferred by elephants.

A comparison of the woody species composition before introduction of elephants and after introduction of elephants using a paired t test showed some of the most important species (as identified by Muposhi et al, (2014) before the introduction of Elephants in Umfurudzi Park) relative density, dominance and Importance Value Index (IVI) showing significant changes after the introduction of Elephants (Table 4.4)

	RELATIVE DENSITY			**RELATIVE DOMINANCE**			**IVI**		
SPECIES	**Before**	**After**	**p Value**	**Before**	**After**	**p Value**	**Before**	**After**	**p Value**
BAUHINIA PETERSIANA	38.24	3.94	**0.026**	24.46	0.59	**0.017**	70.48	1.16	**0.021**

BRACHYSTEGIA BOEHMII	16.44	27.24	**0.013**	10.66	29.55	**0.002**	33.21	12.46	**0.002**
COLOPHOSPERMUM MOPANE	4.31	5.73	0.07	5.08	11.29	0.065	16.97	32.34	0.301
COMBRETUM ZEYHERI	5.27	0.35	**0.012**	5	0.05	0.628	15.35	0.01	**0.043**
DIOSPYROS KIRKII	3.53	3.23	0.73	40.53	2.46	**0.001**	14.74	3.97	0.065
DIPLORHYNCHUS CONDLOCARPON	4.89	3.94	0.75	3.74	4.2	0.628	13.64	8.27	0.301
JULBERNARDIA GLOBIFLORA	3.84	19.71	**0.001**	3.2	22.93	**0.023**	11.51	226.01	**0.002**
LANNEA DISCOLOR	2.91	3.23	0.08	3.2	0.7	0.06	11.12	1.15	0.064
PSEUDOLACHNOSTYLIS MAPROUNEIFOLIA	3.07	3.94	0.75	4.01	2.22	0.632	10.97	4.38	0.301
TERMINALIA STENOSTACHYA	7.14	3.94	0.08	1.6	0.3	0.312	9.86	0.58	0.055

Table 4.4: Woody species structure and composition for most important species before and after the introduction of Elephants in Umfurudzi National Park. Bold values indicate significant differences. (Data from before introduction was extracted from Muposhi et al, (2014

Chapter five

Discussion

5.1.1 Woody species preferred by elephants (*Loxodonta Africana*)

Studies have shown that these mega herbivores are selective feeders that feed on diverse plant species. The present research conducted at Umfurudzi Park in Zimbabwe indicates that elephants feed on 25 plant species belonging to 14 families. The elephants exhibited a strong utilisation of *Colophosphermum mopane, Brachystegia boehmmi, Acacia karoo*, and *Julbernardia globiflora* plant species, which may be due to their wide distribution and high protein content.

The family that had many species selected by the elephants during the study period was the Fabaceae, which may be due to its availability and palatability. Combretaceae also had a significant number of species selected in the study, accounting for their palatability. However, the Apocynaceae family had few species that were selected, possibly due to the strong viscous smell in their leaves.

The elephants at Umfurudzi Park showed more preference for *Brachystegia boehmii* and *Julbernardia globliflora* plant species. The correlation relationship between frequency of occurrence and frequency of forage was strong, indicating that selection is mostly linked to availability. The feed preference indices for all species were less than 1, showing that no species were over-utilised in the environment. The findings suggest that although elephants are generalist feeders, they select feed that has high nutritional value per area.

5.1.2 Type of damage being inflicted by elephants (*Loxodonta africana*)

The passage highlights the different plant parts that elephants, *Loxodonta africana*, feed on. The research shows that elephants foraged on leaves, barks, twigs, roots and fruits in selected plant parts. The statistical analysis found no significant difference among the selected parts, which is consistent with a study done by Chinweba (2022) in OMO reserve where bark and leaves were largely eaten by elephants.

Barks and leaves were the most selected plant parts in this study and this is in line with findings from Makoshane *et al.* (2018), which showed that barks are the frequently consumed parts during the dry season. The preference for barks may be due to the fact that they store water and have high calcium content. Fruits were the least selected plant parts, which may be due to the lack of fruit availability during the study period. Jackal berry fruit (*Diospyros mespiliformis*) was the most consumed fruit and it plays a special role in seed dispersal. Grasses were not recorded as being consumed by the elephants in this study as it was conducted during the dry season prior to the sprouting of grass species. Roots were also less selected, possibly because they are dug up for mineral salts, which are micro nutrients that are not required in large amounts by the body.

The damage caused by elephants in this study was mainly debarking and browsing. These findings suggest that elephants are opportunistic feeders that consume a variety of plant parts, but their preferences may vary depending on factors such as availability and nutritional content.

5.1.3 Comparison

According to the results above it shows that the Umfurudzi game park is a Miombo Woodland which is dominated by the Fabacea family which were also the quiet similar to the finding of Mposhi *et al*.   However *Bauhinia petersiana* and *Brachystegia boehmii* showed a significant decline in the relative density (p= 0.026, p= 0.013 respectively), relative dominance (p=0.017, p = 0.002 respectively) and in Importance Value Index (p= 0.021, p = 0.002 respectively), while *Julbernardia globiflora* showed significant increases in the relative density (p= 0.001), relative dominance (p= 0.023) and in importance value index (p = 0.002) after the introduction of elephants (Table 4.4). Other species such as *Combretum zeyheri*, *Psuedolachnostylis maprouneifolia and Terminalia stenostachya* showed some declines in the relative density, dominance and IVI after the introduction of elephants though some declines were not statistically significant.

CHAPTER SIX

Conclusion and Recommendations

6.1 Conclusion

The findings of this study exhibited that though the elephants (*Loxodonta africana*) in Umfurudzi Game Park feed on many species in the game park they are a few species which are mostly preferred. This is because of their availability and palatability.

This leads to having more of these preferred species being debarked and browsed leading to the death of this trees and scarcity. However not only are the trees being destructed the elephants are also helping in the dispersal of seeds through their dung.

The current study also shows that there has not been a significant change to the vegetation structure and composition after the introduction of elephants in the park and before the introduction of elephants in Umfurudzi Game Park which is a study which was made by Mposhi *et al.*

6.2 Recommendations

Human and elephant conflict (HEC), land degradation and fragmentation are threats to the survival of elephants (*Loxodonta africana*). Habitat loss leads to an increased risk of loss of nutritious plant of the elephants hence the writer recommends that plant species favoured by the elephants (*Loxodonta africana*) should be assessed frequently to ensure that their existence continues and their occurrence is increased so as to attain an increment in the elephant population.

The writer also recommends that the law enforcement team in the park should thoroughly deal with all wood poachers and other illegal intruders that do activities that contribute to the elephant habitat loss.

It is also recommended that studies concerning the impacts of elephants (*Loxodonta africana*) on woody vegetation be done in wet seasons in order to have an insight of species foraged in all year seasons.

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