The impact of an increasing elephant population on the woody vegetation in southern Sabi Sand Wildtuin, South Africa

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In 1961, a fence was erected between privately-owned Sabi Sand Wildtuin (SSW) and the Kruger National Park (KNP), which largely prevented elephants entering the SSW. In 1993, the fence was removed. This lead to a rapid influx of elephants into the SSW during the winter months, most of which move back into the KNP during the wet summer season. In 1993, the SSW elephant population was 1/1045 ha but increased to 1/305.8 ha in 1996. It more than doubled to 1/146 ha in 1998. This study was undertaken on the property Kingston, in southern SSW, to assess the impact of elephants on woody vegetation and determine why they show seasonal dietary preferences for specific tree parts. Vegetation utilisation was recorded on a five kilometer transect of vehicle track in 1996 and repeated in 1998. From the transect, species density was calculated for those trees impacted on. Trees that had been newly bark stripped were recorded in 1996 and 1998. Cambium samples were collected in summer and winter from eight tree species. Field observations of elephants impacting on woody vegetation augmented the data base. Transect analysis showed a strong correlation between tree utilisation and density. The most visual damage was of *Combretum apiculatum*, *Acacia burkei*, *Pterocarpus rotundifolius* and *Grewia* species. Tree damage increased by 73 % from 1996 to 1998. Significantly higher levels of nitrogen, sodium and magnesium were found in the species most regularly bark stripped. Bull elephants were responsible for 94 % of the trees seen uprooted. The results suggested that SSW can sustain the present elephant population, but further influx at the present rate of increase, will have a negative impact on the reserve.

Key words: elephants, woody vegetation, impact, cambium analysis.

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Introduction

In 1993, the boundary fence between the Kruger National Park (KNP) and Sabi Sand Wildtuin (SSW) in north-eastern South Africa, was removed. This fence, erected in 1961, largely prevented elephants entering the privately owned SSW. This is reflected in SSW's annual game census data, whereby elephant numbers prior to the fence's removal did not increase above 73 (Tavernor 1997). Since its removal, solitary bulls and breeding herds of elephants have entered SSW, in increasing numbers, during the winter months. Over the wet summer season, elephant numbers drop rapidly as they move from SSW back into KNP.

At the end of winter in 1993, the SSW elephant population size was 60 (1 elephant/ 1045 ha). By 1996, the population had reached 202 (1 elephant/305.8 ha) and increased by 52 % to 429 (1 elephant/146 ha) in 1998 (Tavernor 1998). In contrast, the KNP elephant population in 1998 was approximately 8869 (D. Pienaar *pers.com.*), which equates to roughly 1 elephant/131 ha.

This population increase in SSW has had a marked visual impact on the vegetation, especially in winter, and there is concern from landowners that elephant numbers are too high. But, too high compared with what? The physiognomical status of SSW's vegetation, prior to the removal of the fence, was largely artificial because of the lack of elephants. It is therefore necessary to determine what impact elephant populations have on SSW's vegetation in order to assess what levels can be successfully maintained. If the vegetation can sustain a given population, without a negative effect on its diversity or rate of recruitment, then the elephant density cannot be considered too high. Since 1989, an annual assessment of the reserve's vegetation has been undertaken (Peel *et. al.* 1998). This assists with providing a data base for pre and post elephant comparisons with vegetation, but has been primarily directed at the herbaceous layer.

This study was therefore undertaken with two aims in mind. Firstly, to determine what impact an increasing elephant population was having on the tree community, on the property Kingston in the south of SSW; especially in terms of uprooting and bark stripping of trees. General light browse of foliage was of no real concern. The second priority was to determine why elephants showed seasonal preferences for certain tree parts. This arose from observations of elephants showing a noticable preference, through the seasons, for different parts of certain woody species.

The impact of elephants on woody vegetation has received much attention in the literature (Barnes 1982; Okula & Sise 1986; Jachmann & Croes 1991; Trollope *et. al.* 1998). Why, on the other hand, elephants show dietary preferences for certain tree parts, has not been well documented (Meissner *et al.* 1990; Owen-Smith 1982).

Study area

The 62706-hectare SSW is located in the Mpumalanga Province of South Africa, abutting KNP on its southern and eastern boundaries. Mean annual rainfall is 619 mm (Peel *et. al.* 1998). This study was undertaken on the property Kingston, situated on SSW's southern boundary and separated from KNP by 10 km of perennial Sabie River. Geographically, Kingston lies between 24°56'S—24°58'S and 31°28'E—31°33'E. The property covers 3386 ha of gently undulating, mixed *Acacia* and *Combretum* woodland. The dominant *Acacia* species are *Acacia burkei*, *Acacia tortilis* and *Acacia nigrescens*, while the *Combretum* woodland is comprised primarily of *Combretum collinum*, *Combretum zeyheri*, *Combretum apiculatum* and *Sclerocarya birrea*.

No elephants were recorded on Kingston during the 1994 aerial game census. Elephants were again absent on the day of the 1996 air count, but were present during winter at densities estimated at 1 elephant/300 ha (*pers. obs.*). By the end of winter in 1998, their numbers had increased to 1 elephant/67.7 ha (Tavernor 1998). This equates to 12 % of the SSW's 429 elephants being on Kingston, which covers 5.4 % of the reserve.

Methods

Transect tree damage

A five kilometer transect of meandering vehicle track was walked through mixed *Acacia* and *Combretum* woodland in October 1996 and again in October 1998. Trees that showed elephant damage, within 10 m each side of the track, were recorded. This gave a total recorded area of 10 ha. For each tree, the following was recorded; uprooting, whether the trunk/stem or major branches had been snapped and whether the tree was dead. Minor breakage of small branches and twigs was excluded, to eliminate the possibility of including kudu damage. No bark stripping was recorded on the transect, as this was noted separately elsewhere in the study.

Trees were defined as having a trunk diameter of > 6 cm and a height of > 3 m. Due to the abundance of young *Combretum apiculatum*, those with a stem diameter of < 6 cm and/or height of < 3 m were also recorded, but listed separately. This was to provide a more accurate interpretation of the species' density. The only shrubs included in the study were *Grewia* species, which have been incorporated under the term "tree" for convenience. Each multistemmed *Grewia* bush was therefore listed as one tree.

The density of tree species recorded in October 1998, which had been impacted on by elephants, was determined by counting all individuals of each species in 10 sample plots of 20 m x 100 m. The first plot started at the begining of the transect described above and at every 500 m interval thereafter, giving a total sampled area of two hectares.

Bark stripping

From December 1996 to the end of January 1997, all trees visible from a predetermined, meandering vehicle track, that had been bark stripped by elephants, were recorded. This route was selected due to the high diversity of vegetation types that it covered. No shrubs were included because the abundance of tall grass may have resulted in some being overlooked due to poor visibility, and hence cause biased results. For each tree, the species, circumference of the trunk where stripping had occurred and the amount of cambium removed were noted. The circumference was measured where bark stripping was at its maximum width. This was repeated, using the same vehicle track route, on newly bark stripped trees in December 1998. Trees newly bark stripped were easily recognised from those showing old elephant damage, by the different colour and texture of freshly damaged cambium. Recording stopped after the same number of trees had been measured as in 1996.

Cambium sampling

Cambium samples, averaging 3 x 6 cm in size, were removed from *Acacia nigrescens*, *Acacia burkei*, *Acacia tortilis*, *Acacia senegal*, *Schotia brachypetala*, *Combretum apiculatum*, *Sclerocarya birrea* and *Pterocarpus rotundifolius*. Samples were collected from five trees of each species during winter (July) and the same trees again the following summer (January). The samples were air dried and pooled for each species. Nutrient and trace element content of each sample was determined by atomic absorbtion spectrophotometry.

Elephant observations

Observations of elephants utilising woody vegetation were recorded at random, whenever elephants were seen, from May 1996 to January 1999. For each observation the following were recorded; whether the tree was uprooted, bark stripped or if twigs and leaves were ingested. One observation could therefore include more than one category of utilisation. Observations were divided into summer (November to March) and winter (May to September).

Results

Transect tree damage

The total number of trees damaged by elephants increased by 73 % in 2 years, from 292 in 1996 to 1078 being selected on the same transect in 1998 (Table 1). More specifically, the amount of elephant damage on the population of preferred trees, increased sharply from 5.7 % in 1996 to 21 % in 1998.

Table 1
The impact of elephants on woody vegetation, on the same transect in 1996 and 1998

	n	Uproot	Trunk	Branch	Dead
1996	292	41 %	25 %	34 %	26 %
1998	1078	35 %	27 %	38 %	31 %

Twenty-seven species of trees were damaged on the transect in 1996 compared with 37 in 1998 (Table 2). A strong correlation was found between trees impacted on by elephants in 1998 and tree density ($r_s = 0.56$, $P < 0.001$). In 1996, the *Pterocarpus rotundifolius* population was subjected to the greatest damage (21 %), which largely consisted of snapped stems/trunks. Next were *Acacia burkei* (14 %) and *Combretum apiculatum* (13 %), both of which were primarily uprooted.

Mature *Combretum apiculatum* were most commonly uprooted, with 70 (85 %) of 82 trees being uprooted in 1996 and 150 (90 %) out of 167 in 1998. The only other species regularly uprooted was *Acacia burkei*, where 18 (58 %) out of 31 damaged trees

Table 2

A comparison of elephant damage on trees, on a line transect (10ha), in 1996 and 1998

Species	Density /10ha	1996 *n*	1996 Alive	1996 Dead	1998 *n*	1998 Alive	1998 Dead
Acacia burkei	225	31	10	21 (10)	44	7	37 (16)
A. gerrardii	30	0			2	1	1 (4)
A. grandicornuta	5	0			2	1	1 (20)
A. nigrescens	115	5	0	5 (4)	3	3	
A. nilotica	5	0			1	1	
A. senegal	55	2	1	1 (2)	31	15	16 (29)
A. tortilis	120	2	1	1 (1)	27	13	14 (12)
Albizia harveyi	20	3	3		0		
Berchemia discolor	3	0			1	1	
Bolusanthus speciosus	45	3	3		6	6	
Cassia abbreviata	2	0			1	1	
Combretum apiculatum							
>3m	630	82	54	28 (2)	167	116	51 (5)
<3m	615						
Total	1245						
C. hereroense	35	0			1	1	
C. imberbe	20	3	1	2 (10)	18	13	5 (25)
C. zeyheri	11	0			11	10	1 (9)
Dalbergia melanoxylon	30	2	2		18	17	1 (3)
Dichrostachys cinerea	115	11	11		29	27	2 (2)
Diospyros mespiliformis	45	5	5		13	13	
Euclea divinorum	145	2	2		5	5	
Gardenia spatulifolia	40	1	1		4		4 (10)
Grewia spp. unidentified		5		5	91		91
G. bicolor	575	23	18	5 (1)	52	44	8 (1)
G. flavescens	65	4	4		5	1	4 (6)
G. hexamita	275	16	15	1	65	64	1
G. monticola	525	28	28		109	108	1
Grewia total	1140	76	65	11 (1)	322	214	108 (9)
Lannea schweinfurtii	65	1	1		1	1	
Lonchocarpus capassa	10	0			5	4	1 (10)
Manilkara mochisia	6	0			6	5	1 (17)
Maytenus heterophylla	60	1		1 (2)	11	9	2 (3)
Ormocarpum trichocarpum	35	1	1		12	12	
Pappea capensis	40	1	1		2	2	
Peltophorum africanum	45	4	3	1 (2)	7	6	1 (2)
Pterocarpus rotundifolius	145	31	31		94	93	1 (1)
Schotia brachypetala	35	0			2	2	
Sclerocarya birrea	120	10	7	3 (2)	19	14	5 (4)
Spirostachys africana	95	0			1	1	
Terminalia sericea	30	1	1		2	2	
Ziziphus mucronata	715	14	10	4	210	133	77 (10)
TOTAL	5152	292	214	78	1078	752	326

( ) = percentage of the species population that is dead.

were uprooted in 1996 and 41 (93 %) uprooted out of 44 in 1998.

By 1998, those species with over 25 % of their population uprooted or the trunk and/or major branches snapped by elephants, were *Combretum apiculatum*, *Diospyros mespiliformis*, *Berchemia discolor*, *Cassia abbreviata*, *Grewia* species, *Lonchocarpus capassa*, *Maytenus heterophylla*, *Ormocarpum trichocarpum*, *Ziziphus mucronata*, *Acacia senegal*, *Combretum imberbe*, *Combretum zeyheri*, *Dalbergia melanoxylon*, *Pterocarpus rotundifolius* and *Manilkara mochisia*. The

Table 3

Bark stripping of trees by elephants, recorded at the widest point of damage on the trunk, in 1996 and 1998

Species	*n*	Percentage of bark removed from trunk circumference 1	2	3	4	5	R
1996							
Acacia burkei	84	1	6	16	21	28	12
A. nigrescens	24	2	0	5	3	11	3
A. grandicornuta	13	0	0	2	5	3	3
A. nilotica	7	0	0	0	2	3	2
Albizia harveyi	5	0	0	2	0	2	1
Acacia tortilis	3	0	0	1	0	2	0
Spirostachys africana	2	0	0	0	1	1	0
Total	138	3	6	26	32	50	21
1998							
Acacia burkei	102	8	25	30	12	7	20
A. robusta	8	1	2	1	1	0	3
A. nilotica	7	2	2	0	0	1	2
A. nigrescens	6	0	5	0	1	0	0
A. tortilis	5	1	0	2	1	1	0
Lannea schweinfurtii	2	0	1	1	0	0	0
Acacia senegal	2	0	0	2	0	0	0
Schotia brachypetala	2	0	2	0	0	0	0
Sclerocarya birrea	2	1	1	0	0	0	0
Acacia grandicornuta	1	0	0	1	0	0	0
Manilkara mochisia	1	1	0	0	0	0	0
Total	138	14	38	37	15	9	25

1 = 1-12%, 2 = >12-25%, 3 = >25-50%, 4 = >50-75%, 5 = >75-99%, R = ring barked.

last six species had over 50 % of their trees impacted on. Visually, the number of *Pterocarpus rotundifolius*, *Combretum apiculatum*, *Acacia burkei* and *Grewia* species damaged was particularly noticeable.

Elephant impact on tree species showed much variation. Certain species with low densities, such as *Manilkara mochisia* and *Dalbergia melanoxylon* were highly preferred, i.e, 100% and 60% respectively. Mortality among these species though was low. An exception was *Combretum imberbe*, where 90% of available trees showed elephant damage and 25% were dead.

Bark stripping

The number of tree species debarked in 1996, compared with 1998, increased from seven to 11 (Table 3). *Acacia* species accounted for 93 % of the total number of trees stripped in both years, with *Acacia burkei* comprising 61 % and 74 % of the trees in 1996 and 1998 respectively. In 1996, elephants showed some interest in the bark of *Acacia nigrescens* and *Acacia grandicornuta*, but in 1998 only *Acacia burkei* bark stripping was of any significance.

In 1996, 75 % of the trees bark stripped had over 50 % of their bark removed at the widest stripped section of the trunk circumference. This decreased to 36 % in 1998. The number of trees ring barked, showed no marked difference between 1996 (15 %) and 1998 (18 %). All trees ring barked in 1996 were dead by 1998.

Cambium samples

The eight tree species were categorised, according to their bark stripping preference by elephants, as preferred (*Acacia burkei*, *Acacia senegal* and *Pterocarpus rotundifolius*), less preferred (*Acacia tortilis* and *Acacia nigrescens*) and rarely stripped (*Combretum apiculatum*, *Sclerocarya birrea* and *Schotia brachypetala*). Season had no marked effect on nutrient concentrations and was therefore not considered for further analysis. Multiple ANOVA showed no significant difference ($P < 0.05$) between the tree species for calcium (Ca), potassium (K), phosphorus (P), zinc (Zn), copper (Cu) and manganese (Mn). There was a significant difference, however, in nitrogen (N), magnesium (Mg) and sodium (Na) concentrations between the three categories. Cambium from the more preferred species had higher levels of these three nutrients than species which were less frequently bark stripped (Table 4).

Table 4

ANOVA cambium results of nitrogen (N), sodium (Na) and magnesium (Mg), expressed as a dry matter percentage, for preferred, less preferred and rarely utilized cambium of certain tree species

Nutrient	Preferred mean	Less preferred utilized mean	Rarely mean
N	1.31	1.31	0.49
Na	0.15	0.07	0.07
Mg	0.30	0.15	0.14

Preferred = *Acacia burkei*, *Acacia senegal* and *Pterocarpus rotundifolius*
Less preferred = *Acacia tortilis* and *Acacia nigrescens*
Rarely utilized = *Sclerocarya birrea*, *Schotia brachypetala* and *Combretum apiculatum*

Elephant observations

A total number of 454 observations of elephants impacting on woody vegetation was recorded. One hundred and twenty observations were made during the wet summer season and 334 during the dry winter period (Table 5).

Table 5

Summer and winter observations of elephant utilization of trees from May 1996 to January 1999

	n	Uproot	Bark	Browse
Summer	120	39(30%)	22(17%)	66(53%)
Winter	334	58(14%)	105(24%)	261(62%)

n = the number of individual elephant observations. Each single observation includes one or more of the plant catergories listed.

A significant difference was found between the seasons and bark stripping, uprooting and browsing ($X^2 = 19.94$, $df = 2$, $P < 0.001$). Most observations were of light browsing, with no major impact on the vegetation. The actual number of trees uprooted increased from summer (39) to winter (58), with bulls responsible for 91 (94%) of the 97 trees seen uprooted. Although uprooted vegetation formed a smaller overall percentage of the trees damaged, absolute numbers did increase in 1998. Bark stripping also increased over the winter months. The most noticeable stripping was seen in *Pterocarpus rotundifolius* and *Acacia burkei*.

Discussion

The visual impact of elephants on SSW vegetation appears severe in winter, but only 21 % of the selected tree species population was heavily damaged in 1998. *Grewia* species and *Pterocarpus rotundifolius* damage appeared particularly visual in the shrub stratum of vegetation. This was a true reflection, for example, of the 65 % of *Pterocarpus rotundifolius* impacted on, but not for the 28 % of *Grewia* species utilised. Although these species are an important component of the vegetation community, other species with lower densities, such as *Dalbergia melanoxylon*, showed a higher percentage of damage to their populations, which was not initially realised from observations.

Visual observations can therefore be misleading when not supported by data analysis, as was also noted by Trollope *et. al.* (1998). Their field observations suggested a decline in the density of preferred trees due to elephants and fire. In contrast, their data showed that neither had a significant effect on overall woody vegetation density, but did negatively impact on the density of large trees. The change was therefore more structural than density related.

An assessment of tree damage caused by elephants throughout SSW in 1998, showed that 88 % of the trees surveyed were not impacted on (Peel *et al.* 1998). Woody plant density in 1998 was also found to be similar to that recorded in 1989. In addition, Peel *et. al.* (1998) found that *Combretum apiculatum*, *Acacia nigrescens*, and *Grewia* species were the most preferred species, with percentages of utilisation being 17.2 %, 15.7 % and 10.9 % respectively.

Why there is a difference in preference between the two studies is not clear. Possibly, the high woody species diversity on Kingston may account for a wider selection of species by elephants, and therefore less pressure on *Acacia nigrescens*, relative to the less diverse *Combretum* woodland that dominates much of SSW. This does require further study though, before conclusions can be drawn.

As noted on Kingston and in other studies (Guy 1976; Van Wyk & Fairall 1969), not all trees uprooted were fed on. This suggests that feeding may not always be responsible for tree damage. Possibly other factors such as dominance displaying among bulls may be involved. On Kingston, bulls were responsible for 94 % of the trees uprooted and cows 6 %. Barnes (1982), suggests that bulls are possibly more destructive than cows. By being larger and therefore having a higher food intake, bulls tend to have a greater impact on vegetation.

Similarly, Guy (1976) reported that bulls accounted for 80 % of the trees being uprooted in his Zimbabwean study area. He suggests that solitary bulls are largely responsible for the damage because in male groups it is not necessary for all individuals to push over trees to feed. The formation of herds therefore, may lead to a decrease in the number of trees being uprooted. Although not quantified in this study, this was not the impression gained from elephant bulls on Kingston. Various bulls, in loose aggregations, were observed felling trees simultaneously and feeding on their trees alone, with no interest being shown by other group members. Rarely was more than one bull observed feeding on the same felled tree.

Trees with exposed roots or subjected to bark stripping are susceptible to secondary infections and fire (Campbell *et al.* 1996). Mortality from such parameters can lead to trees dying, regardless of the amount of root system exposed (Okula & Sise 1986). When uprooting trees, elephants show a preference for large, mature trees, over that of saplings (*pers. obs.*). Similarly, Trollope *et. al.* (1998) found elephants largely responsible for killing trees over 3 m in height, in the arid sections of the Kruger National Park. Determining future levels of damage can therefore be looked at as primarily involving this group of woody plants. Hence, it may be relevant in future studies to determine the rate of recruitment of young preferred tree species into the category of mature trees.

The increase in preference for bark through winter, which decreased rapidly after the onset of summer rains, suggests that nutrient levels are involved. Such trends have been reported elsewhere, for example, Van Hoven *et. al.* (1981) noted that seasonal food preferences in elephants were related to protein content. Barnes (1982) also reported this trend, with bark stripping increasing before and during flowering of *Cassia abbreviata* and just prior and during leaf production in *Acacia tortilis*. A significant correlation between utilisation of certain tree species by elephants and protein and Na content has been found in Malawi (Jachmann & Bell 1985).

An increase in winter bark stripping on Kingston, particularly of *Acacia burkei* and *Pterocarpus rotundifolius*, further supports these observations. Both species show higher levels of N than other species sampled, excluding *Acacia nigrescens*. Their Mg and Na levels were also high. Although not statistically significant, high winter levels of all trace elements and nutrients tested, except Ca in *Pterocarpus rotundifolius* may further explain its preference by elephants.

Another species with high Na and N levels, which was heavily debarked, was *Acacia senegal*. Of all the *Acacia*'s tested, this was the only one that showed a decrease in N from winter to summer. *Acacia senegal* has a relatively clumped distribution on Kingston, and was therefore unintentionally excluded from the bark stripping section of the study. Its utilisation though, is reflected in the transect results, where 56 % of the trees were damaged.

Although only a small sample, the *Acacia* and *Pterocarpus rotundifolius* cambium was higher in N throughout the year than the species not bark stripped, which probably contributes to their palatability. The nitrogen fixing abilities of *Acacia* trees would explain their N concentrations, but that of *Pterocarpus rotundifolius* is surprisingly high. Why *Acacia burkei* is subjected to such rigorous bark stripping is not clear, as the nutrient and trace element results do not provide a complete answer. This certainly requires further investigation.

Schotia brachypetala, *Sclerocarya birrea* and *Combretum apiculatum*, which were subjected to little or no bark stripping, tended to have lower nutrient levels than bark-stripped species. This may suggest, why their bark was largely excluded. Care should be taken with such conclusions though, as other chemical components, for example secondary plant compounds, may be exerting an influence on dietary selection.

Conclusion

SSW existed without a natural elephant population for 32 years, because of the boundary fence. Had elephants been present during this period, their visual impact on the vegetation would probably have been accepted as part of the ecological succession of the reserve. In contrast, a rapid influx of elephants into the area has caused concern. After being devoid of such an integral component of the reserve's ecology for so long, SSW is now possibly returning to a more natural balance between megaherbivores and vegetation diversity and density.

However, Kingston and SSW as a whole, appears to be able to sustain the present population of elephants over the winter months. An elephant increase in the reserve from 1/305.8 ha to 1/146 ha in two years though, does require attention. From this study, it appears that for the mixed woodland types described, *Acacia burkei* and *Combretum apiculatum* could be used as indicator species, to assist in determining elephant carrying capacities. Until data are available on recruitment rates of trees, it is suggested that severe tree damage, such as uprooting and bark stripping, of mature *Acacia burkei* and *Combretum apiculatum* trees be kept below 20–25 % of their populations. This is approximately the damage percentage of these two tree species on Kingston at present. An elephant population responsible for damage above this level would be perceived as having a negative impact on an area. Elephant numbers in SSW therefore, do need to be monitored closely in conjunction with ongoing vegetation monitoring, to ensure that no degradation of habitat takes place.

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