CHAPTER 10

THE UTILISATION OF WOODY VEGETATION BY ELEPHANTS IN TEMBE ELEPHANT PARK, MAPUTALAND, SOUTH AFRICA

Abstract

The utilisation of vegetation and particularly trees in enclosed small reserves where elephant populations are confined is a contentious conservation issue. In Tembe Elephant Park in Maputaland, the biodiversity rich Sand Forest is considered the most valuable feature to conserve, yet it is considered at risk from increasing elephant utilisation of the park's vegetation. The mean canopy removal by elephants across the park was therefore studied over a recent period including the last 12 months prior to the study and an older period for all events prior to the past 12 months. The intensity of utilisation was also evaluated in relation to the distance to water. Results show that utilisation patterns have shifted in the recent period and a significant decrease in utilisation intensity is correlated to an increasing distance from water points in the park. Recent and old utilisation patterns are discussed.

Keywords

Canopy removal, elephant, Maputaland, Sand Forest, watering point distance, woodlands

Introduction

Tembe Elephant Park, in South Africa's Maputaland region, is home to a confined and growing population of African elephant *Loxodonta africana* (Blumenbach 1797)(Morley 2005). The park was initially created in 1983 to protect the last remnants of the elephant population in Maputaland, and to conserve the biodiversity rich Sand Forest vegetation, home to many endemic plants and animals (Matthews *et al.* 2001; Matthews 2006; Guldemond 2006; Guldemond and Van Aarde In Press).

The destructive effect of growing elephant populations on the vegetation and particularly on trees, is well documented (Leuthold 1996; Hall *et al.* 1997; Mosugelo *et al.* 2002; Western and Maitumo 2004; de Beer *et al.* 2006; Mtui and Owen-Smith 2006; Guldemond and Van Aarde In Press; Van Aarde and Jackson 2007; Western In Press) and is of paramount importance in small and fenced reserves (Lombard *et al.* 2001; Guldemond 2006; Guldemond and Van Aarde In Press; Van Aarde and Jackson 2007), where the animals are not afforded the space to roam.

The impact of elephants in Tembe Elephant Park and especially on the Sand Forest is a hotly debated subject (Van Rensburg *et al.* 1999a; Van Rensburg *et al.* 1999b; McGeogh *et al.* 2002; Gaugris *et al.* 2004; Matthews 2006; Botes *et al.* 2006; Guldemond and Van Aarde In Press). The elephant population in Tembe Elephant Park has been documented to utilise the vegetation in a destructive manner and the preponderance of visual damage was noted to be increasing (Morley 2005; Guldemond and Van Aarde In Press). While there is no clear change in terms of forest tree species composition (Gaugris *et al.* 2004), the general impression is that elephant utilisation will probably damage the Sand Forest, a forest type considered in "suspended animation" (Matthews 2006) due to its apparent lack of recruitment and expansion (Van Rensburg *et al.* 1999a; Van Rensburg *et al.* 1999b; Matthews *et al.* 2001; McGeogh *et al.* 2002; Matthews 2006; Botes *et al.* 2006). However, the study by (Guldemond and Van Aarde In Press) contradict the above perceptions. They established that while elephants clearly affected tree species, the effect of these mammals was not yet detrimental at the community level.

In the present study we aim to provide additional insight on the level of utilisation of the various vegetation units by elephant in Tembe Elephant Park. The impact of elephants in Tembe Elephant Park is investigated at the park level, and in different sectors of the park, as well as by vegetation unit. A correlation between distance to permanent water points and utilisation intensity is also attempted.

Study area

Tembe Elephant Park is situated in Maputaland, northern KwaZulu-Natal, South Africa (-26.85 º to -27.15 º South and 032.35 º to 032.60 º East) and a thorough description of the study area appears in Matthews *et al.* (2001).

The park consists mainly of a sandy plain interspersed with ancient littoral dunes. It is covered by an Open to Closed Woodland, with patches of Short, Intermediate and Tall Sand Forest and the Muzi Swamp running along the eastern boundary (Matthews *et al.* 2001). Mean annual rainfall for the period from 1981 to 2003 is 721 mm in Matthews (2006). The summers are hot; with a mean mid-day temperature of 31°C in January. The winters are cool to warm, with a mean mid-day temperature of 24°C in July, and with June, July and August the coldest months. The total rainfall at the study site was measured at a high of 1391 mm in 2000, followed by an above average rainfall year of 904 mm in 2001. However, rainfall dropped to 246 mm in 2002 and 343 mm in 2003. More rain was received in 2004, with 623 mm precipitation. This was a noticeable reduction in rainfall over the four years preceding the present study, and a switch from exceptionally high rainfall in 2000, to a drought situation during most of 2003. Only waterholes with permanent water were used to measure distance from plot to the nearest waterhole (see below).

The Tembe Elephant Park has a confined elephant population (Morley 2005; Guldemond and Van Aarde In Press), which was estimated at 179 animals (95% confidence interval of 136 – 233) in 2001, and growing at 4.64% per year (Morley 2005). At the above estimated growth rate, the population at the time of the present study (2004) had most likely exceeded 200 animals (204 animals, 95% confidence interval of 156 – 266).

Methods

A total of 107 rectangular plots of varying length and width were sampled to evaluate the intensity of woody plant species utilisation by browsing herbivores throughout the park in 2004. In this manuscript only the utilisation by African elephant is evaluated. The plots were laid out at least 100 m from tourist tracks and 50 m from less used management tracks. Management restrictions at the time of the study forced the lay out of plots within the network of roads. The park is divided in two sections: a southern section (approximately 1/3 of the park) where tourists can visit the park through a fairly well-developed network of sandy tracks accessible to 4x4 vehicles, and a northern section considered a wilderness area where tourist visits are prohibited and where a minimalist network of management tracks allows access.

Each plot was subdivided in two subsamples. All trees with a height ≥ 0.4 m were sampled in the whole area defined by the plot dimensions, while those inferior to the defined cut-off mark were sampled in an area restricted to half that of the full plot size. All woody individuals encountered were identified to the species and measured. For each tree, the numbers of live and dead stems were counted and their diameters measured. The tree height and the height to the base of the canopy (defined as the height where the larger lowest branches are found) were measured, followed by the largest canopy diameter (D1) and the diameter of the canopy perpendicular to it (D2).

The level of utilisation by herbivores of each tree was evaluated. Any alteration or damage to the tree as a whole (canopy, trunk and roots) was labelled, described, quantified and aged (<12 months or >12 months since utilisation event). For each utilisation episode, an index of canopy removal at the time of damage was estimated to describe how much of the canopy was removed at the time of the utilisation, ranking from 1 (>0 to 10%), 2 (11% to 25%), 3 (26% to 50%), 4 (51% to 75%), 5 (76% to 90%), 6 (91% to 99%) to 7 (100%). Whenever possible, the animal responsible for the utilisation was identified. If positive identification proved impossible, the herbivore class most likely responsible for the utilisation was noted. The herbivores were classified in five classes ranging from: insects, small herbivore mammals, medium herbivore mammals, undetermined large herbivore mammals and elephants. Expert knowledge and judgement was used to define all these criteria. In the present manuscript only the elephant utilisation aspect will be discussed

The data were captured in Microsoft Excel spreadsheets. A triple error checking procedure was followed. These occurred during capture, back at the research facility while creating back-ups of the day's data, and before formatting once fieldwork was completed. All the data sets were assembled in a single information file and subsequently transformed into a Microsoft Access database for ease of utilisation and analysis.

Afzelia quanzensis clumps and Closed Woodland Thicket vegetation groups are not well represented in the Tembe Elephant Park sample and therefore not analysed further. The Sparse and Open Woodlands on Sand are grouped for further analysis

Queries were written to calculate a mean percentage canopy removal by elephant utilisation value for each plot for the following two periods:

- Recent: period of 12 months prior to when sampling started in May 2004
- Old: period preceding the recent period.

The mean canopy volume removal value was calculated from the midpoint percentage values of the 1 – 7 scale used in the field. The mean canopy volume removal utilisation value is then calculated at the vegetation unit level, and for each period described above.

The distance of each plot to permanent waterholes (at the time of study) was measured using Arc View GIS 3.2a, and we applied Spearman correlations (using Graph Pad Prism Version 4.00 for Windows, GraphPad Software, San Diego California USA, www.graphpad.com) between the mean canopy removal utilisation values and the distance to the nearest permanent waterhole of each plot. Correlations were calculated at the park’s level, and for the Sand Forest association, the Closed Woodland on Clay unit, the Closed Woodland on Sand unit, and the combined Open and Sparse Woodland units. Least square linear regressions were calculated for each of the above levels to illustrate the spread of data.

The park was then subdivided in four sectors (Figure 1):

- the southeast Muzi Swamp sector, with permanent water in the Muzi Swamp
- the northeast Muzi Swamp sector, with permanent water in the Muzi Swamp

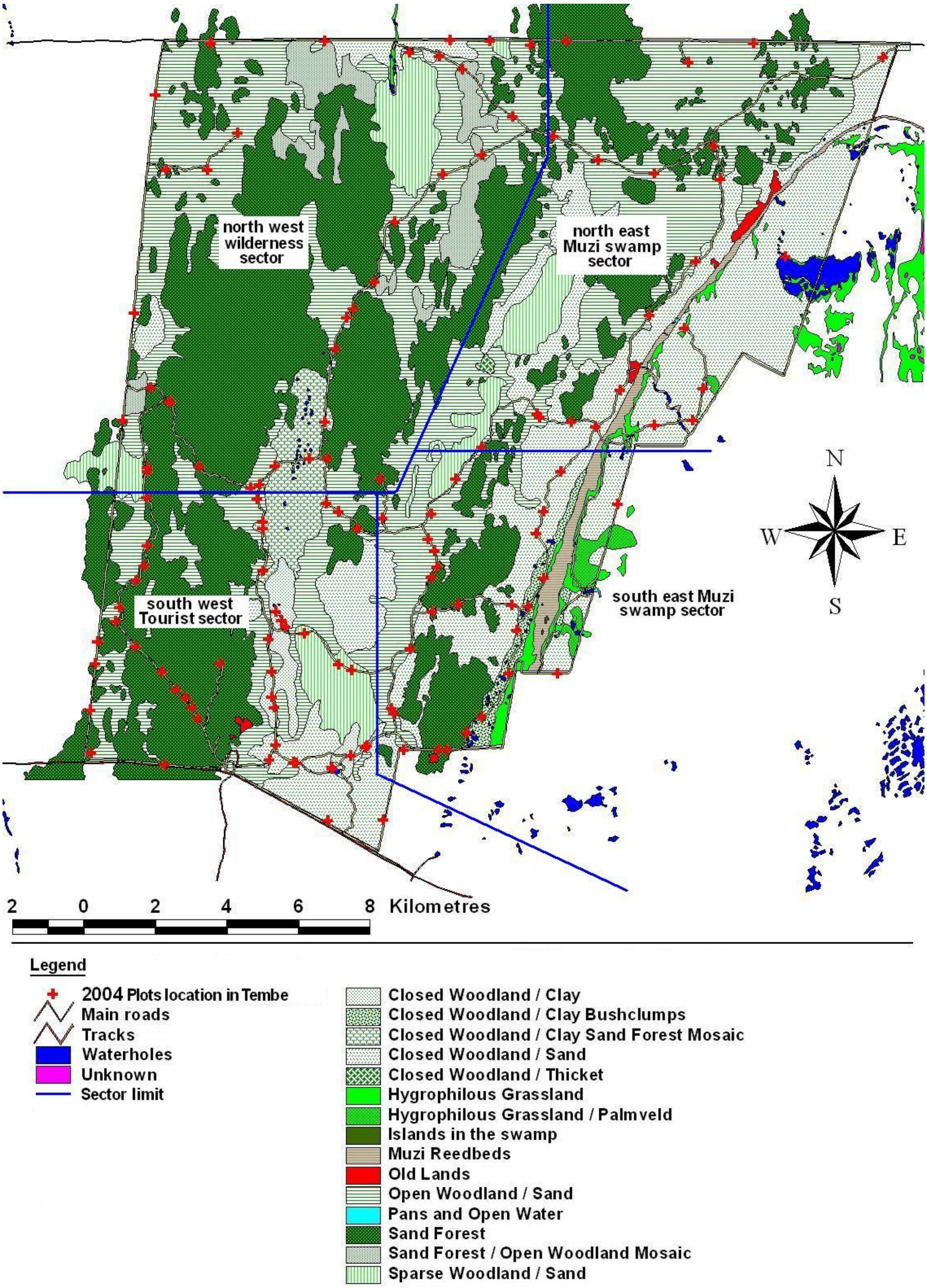


Figure 1: The sector limits used to calculate the distance to water and elephant utilisation relationship in Tembe Elephant Park, surveys of 2004. Maputaland, northern KwaZulu-Natal, South Africa (map adapted from Matthews *et al*. 2001).

- the southwest tourist sector, with permanent water in the Mahlasela hide and Vukazini Pan
- the northwest wilderness sector, with permanent water in the Enzinaleni Pans and northwest pans.

The mean canopy utilisation for each of the above sectors was calculated as the mean of the plots located within a sector for each of the two periods.

Results

From 107 plots sampled, 42 plots (39.25%) had no sign of recent elephant canopy removal, while only five plots (4.67%) had no recorded canopy removal in the old period (Table 1, Figure 2). A total of three plots (2.80%, one in Closed Woodland on Sand, one in Open Woodland on Sand and one in Sparse Woodland on Sand) showed no recorded signs of recent or old elephant utilisation.

The mean canopy utilisation values of the recent period were all smaller than those of the old period, but show that based on the 1 – 7 scale used in the present study, canopy removal during the recent period ranged between 10.67% and 23.47% of the available canopy. The Sand Forest and Closed Woodlands had more of their canopy removed than the Open and Sparse Woodland (Table 2) and the level of canopy removal for the Closed Woodland units was higher than the mean for the park. The older canopy removal utilisation values ranged from 27.23% in the Open and Sparse Woodland to 39.38% in the Closed Woodland on Sand unit. The maximum canopy removal values observed in a plot for the old period were 95.00% in the Sand Forest association and 83.00% for the Closed Woodland on Sand unit. The canopies of two plots (one in the Sparse Woodland unit and one in the Open Woodland unit) were completely removed during the past 12 months (utilisation index of 7 (100.00%), Table 2).

The correlations show that at the park level there was a significant negative relationship between distance to water and mean canopy utilisation during the recent period, whereby mean canopy removal values decreased with increasing distance to water (Table 3). A similar relationship was established for the Closed Woodland on Clay vegetation during the old period, and in the combined Open and Sparse Woodland on Sand vegetation group during the recent period (Table 3).

The regression analysis confirmed the relationships established above for Tembe Elephant Park at the park level (Figure 3), and for the Closed Woodland on Clay vegetation, but not for the combined Open and Sparse Woodland vegetation (Table 4).

Table 1: The number of transects that were not utilised by elephants in Tembe Elephant Park, by vegetation group, in the recent (<12 months) and old periods (>12 months) prior to the study. Maputaland, South Africa

	Total number of transects sampled	Number of transects not utilised by elephant	
		Recent canopy removal	Old canopy removal
Tembe Elephant Park (overall)	107	42	5
Afzelia quanzensis clumps	1	0	0
Sand Forest	26	8	0
Closed Woodland Thicket	1	0	0
Closed Woodland on Clay	15	1	0
Closed wooodland on Sand	16	2	1
Open Woodland on Sand	43	27	2
Sparse Woodland on Sand	5	4	2

NB: *Afzelia quanzensis* clumps and Closed Woodland Thicket vegetation groups are not well represented in this sample and therefore not analysed further. The Sparse and Open Woodlands on Sand are grouped for further analysis

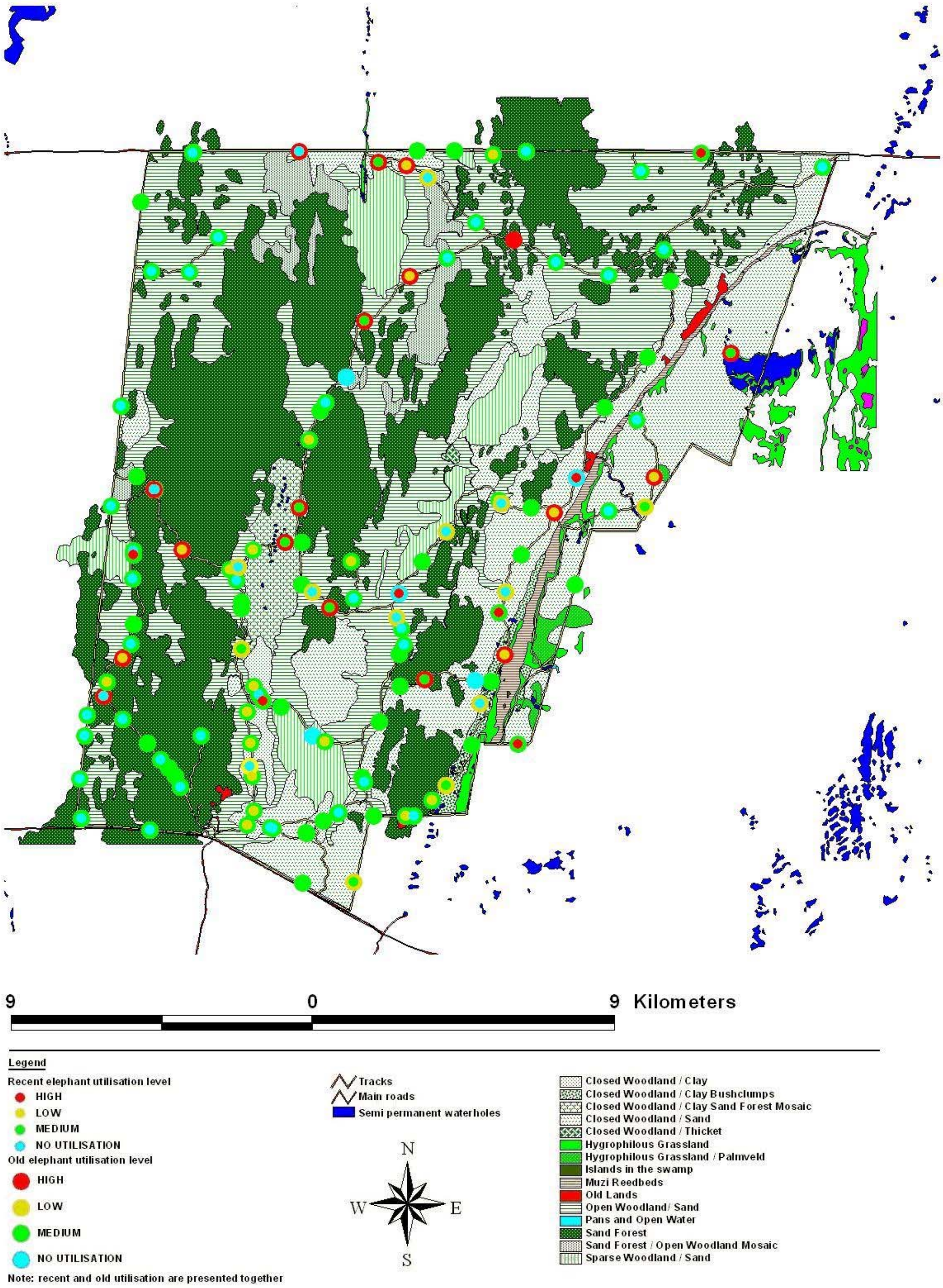


Figure 2: The recent and old elephant utilisation intensity (No utilisation = 0% canopy removal, low utilisation = 1% to 25% canopy removal, medium utilisation = 26% to 75% canopy removal, high utilisation = >75% canopy removal) observed in Tembe Elephant Park Maputaland, northern KwaZulu-Natal, South Africa, surveys of 2004. Recent (12 months prior to fieldwork) and old (>12 months prior to fieldwork) utilisation are presented together, circles that are homogenously coloured represent no change in utilisation intensity over the 12 months prior to the study. (map adapted from Matthews *et al.* 2001)

Table 2: The mean percentage canopy removal by elephants for Tembe Elephant Park and the various vegetation groups or units of the park. Maputaland, South Africa

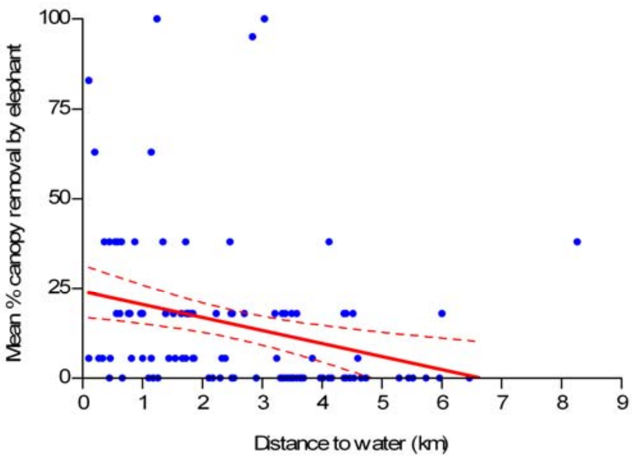
Site and Vegetation type	Recent canopy removal					Old canopy removal					Mean distance from transect to water by vegetation group				
	Mean	SE	Min	Max	Count	Mean	SE	Min	Max	Count	Mean	SE	Min	Max	Count
Tembe Elephant Park (overall situation)	14.78	2.05	0	100	107	31.34	1.84	0	95	107	2.58	0.16	0.10	8.26	107
Sand Forest	13.81	2.37	0	38	26	34.33	4.09	6	95	26	3.22	0.28	0.77	8.26	26
Closed Woodland on Clay	23.47	6.00	0	83	15	28.17	3.80	6	63	15	0.88	0.18	0.10	2.38	15
Closed Woodland on Sand	21.69	4.60	0	63	16	39.38	5.21	0	83	16	1.14	0.21	0.27	3.58	16
Open and Sparse Woodland on Sand	10.67	3.56	0	100	48	27.23	2.38	0	63	48	3.26	0.23	0.45	6.46	48

Table 3: The Spearman correlations between distance to water and elephant utilisation intensity for Tembe Elephant Park, at the park level and in the various vegetation communities, for recent (<12 Months) and old (12 months) utilisation

		Recent elephant utilisation		Old Elephant utilisation	
	Number of XY Pairs	Spearman r	P (2-tailed)	Spearman r	P (2-tailed)
Tembe Elephant Park (overall situation)	107	-0.47	<0.01 **	0.01	0.88
Sand Forest	26	-0.09	0.67	0.31	0.12
Closed Woodland on Clay	15	-0.30	0.28	-0.71	<0.01 **
Closed Woodland on Sand	16	-0.30	0.25	-0.08	0.77
Open and Sparse Woodland on sand	48	-0.43	<0.01 **	0.25	0.09

** highly significant

a)



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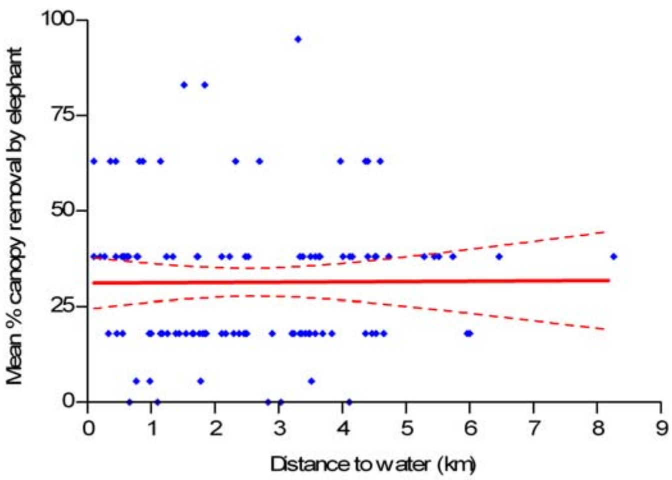

Figure 3: An overview of the percentage of canopy removal (CR) by elephants in Tembe Elephant Park (TEP), Maputaland, northern KwaZulu-Natal, South Africa, in the two periods studied (a): recent or 12 months prior to the study; b): old or >12 months before the study.

Table 4: Summary of the least square regressions fitted to the mean canopy utilisation and distance to water data for Tembe Elephant Park and the various vegetation units within the park Maputaland, South Africa

	Tembe Elephant Park		Sand Forest		Closed Woodland on Clay		Closed Woodland on Sand		Open and Sparse Woodland on Sand	
	Recent utilisation	Old utilisation	Recent utilisation	Old utilisation	Recent utilisation	Old utilisation	Recent utilisation	Old utilisation	Recent utilisation	Old utilisation
Slope	-3.66	0.08	0.72	2.57	-14.72	-14.37	-6.67	-0.16	-3.61	1.84
Y-axis intercept	24.25	31.13	11.48	26.05	36.43	40.82	29.30	39.56	22.44	21.23
r^2	0.08	0.00	0.01	0.03	0.19	0.46	0.09	0.00	0.06	0.03
F	9.71	0.01	0.18	0.78	3.13	11.07	1.42	0.00	2.72	1.54
DF_n	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DF_d	105.00	105.00	24.00	24.00	13.00	13.00	14.00	14.00	46.00	46.00
P value	<0.01	0.94	0.68	0.39	0.10	<0.01	0.25	0.98	0.11	0.22
Deviation from zero	**	ns	ns	ns	ns	**	ns	ns	ns	ns

ns Not significant

** Highy significant ($p \leq 0.01$)

The northwest and southwest sectors had the highest number of plots not utilised by elephants (Table 5). The mean canopy removal in the recent period is highest in the eastern sectors (Table 5) and lowest in the western sectors. In the old period, mean canopy removal was highest in the northern and lowest in the southern sectors. The mean distance from plot to water was highest in the west and lowest in the east.

Discussion

The canopy utilisation of trees by elephants is highest in the Closed Woodlands, followed by the Sand Forest and the Open and Sparse Woodland during the recent period. The older period values show that utilisation was greatest in the Closed Woodland on Sand, followed by Sand Forest, Closed Woodland on Clay and Open and Sparse Woodland. The results suggest elephants have concentrated on the Closed Woodlands on Clay and Sand during the recent drier period, where mean distance to permanent water holes was the lowest. The recent utilisation values indicate a gradient of utilisation away from permanent water (Table 2).

The level of utilisation in the recent period is between 10 and 24% of the potential maximum canopy removal. However, the level of utilisation in the older period is closer to 30% and up to 40%. It is believed that the former does not imply a decrease in canopy removal but rather represents a phenomenon described as accumulation of scars in several studies (Smallie and O'Connor 2000; Styles and Skinner 2000; Barnes 2001; Sheil and Salim 2004; Makhabu *et al.* 2006), which results in shaping of trees, a reduced canopy height and volume, and ultimately a greater sensitivity of trees to fire (Eckhardt *et al.* 2000; Lombard *et al.* 2001; Western and Maitumo 2004; Birkett and Stevens-Wood 2005; Western In Press). Such repeated utilisation of trees produces a “hedging” effect (Smallie and O'Connor 2000; Styles and Skinner 2000) that may be conducive to repeated breakages in a short time span in areas of intense utilisation. Hedged trees are more attractive to elephants, and in case of pronounced over-utilisation may lead to important physiognomic vegetation change (Smallie and O'Connor 2000; Styles and Skinner 2000; Lombard *et al.* 2001; Gadd 2002; Sheil and Salim 2004). While hedging has mainly been described for woodlands in southern Africa, the repeated use of trees by elephants has been documented in central and east African forests (Sheil and Salim 2004; Lawes and Chapman 2006) and a similar pattern of use has been observed in Europe and North America by moose *Alces alces* and various deer species (Hornberg 2001b; Hornberg 2001a; Joys *et al.* 2004; Kraft *et al.* 2004).

Table 5: The mean elephant canopy utilisation (% canopy removal) by sector in Tembe Elephant Park, and the mean distance from plot to water in each sector, Maputaland, South Africa

Sectors	Number of plots per sector	Number of not utilised plots per sector				Mean canopy use and distance from plot to water per sector											
		Recent		Old		Mean recent canopy utilisation by sector				Mean old canopy utilisation by sector				Mean distance (km) from plot to water by sector			
		Number	%	Number	%	Mean	SE	Min	Max	Mean	SE	Min	Max	Mean	SE	Min	Max
Southeast	21	3	14.29	3	14.29	30.86	6.60	0	100	30.79	4.30	0	63	1.80	0.40	0.10	8.26
Southwest	35	15	42.86	1	2.86	9.50	1.97	0	38	24.34	2.18	0	63	2.64	0.24	0.45	5.96
Northeast	17	5	29.41	0	0.00	17.41	4.35	0	63	40.65	4.85	18	83	2.16	0.36	0.27	4.65
Northwest	34	19	55.88	1	2.94	8.96	3.27	0	100	34.22	3.65	0	95	3.23	0.29	0.33	6.46

Elephants are water-dependent animals, and the provision of artificial permanent waterholes in many reserves has exacerbated the utilisation of trees by elephants due to the absence of natural plant refuges where water is scarce (Eckhardt *et al.* 2000; Guldemond 2006). The utilisation of the landscape by elephants varies, but in general is limited by water availability, with bulls usually ranging further than family herds but rarely further than 15 km from water (Eckhardt *et al.* 2000; Stokke and du Toit 2000; Tedonkeng Pamo and Tchamba 2001; Stokke and du Toit 2002; Smit *et al.* In Press). Elephant ranging behaviour appears to be influenced by rainfall and rainy season length (Dudley *et al.* 2001; de Beer *et al.* 2006), ambient temperature (Kinahan *et al.* 2007), and food resources availability during dry and wet periods (Babaasa 2000; Tedonkeng Pamo and Tchamba 2001; Stokke and du Toit 2002; Galanti *et al.* 2006; Guldemond 2006; Van Aarde and Jackson 2007; Smit *et al.* In Press).

In Tembe Elephant Park there are strong indications that utilisation patterns have changed recently. The increased intensity of utilisation closer to water appears noticeable at the park level (Table 3), and especially in the Open and Sparse Woodlands in the recent period (Table 3). Utilisation by elephants appears to have shifted from the northern sectors to the eastern sectors where the mean distance to water was the lowest, especially along the Muzi Swamp. The precipitation pattern in the region has changed from exceptionally high in 2000/2001, to near drought and drought from 2002 until 2004 (Gaugris 2004). The changed utilisation pattern observed in the park in general, coincides with the change in rainfall and the associated reduction of permanent water points. While in 2000 all water points of natural origin as well as man-made ones were filled to capacity and water was available throughout the park, as the drought set in, the natural waterholes dried up and only the Muzi Swamp contained permanent water. The man-made water holes of Mahlasela Pan and Vukazini Pan were kept full by management decisions, and the northwest waterhole still had water at the time of the study but was drying fast (Pers. obs.). It is suggested that due to the drought, elephants in Tembe Elephant Park utilised the eastern sectors of the park where permanent water was abundant in the Muzi Swamp, and restricted their movements to the western sectors and westernmost areas to short feeding forays.

The case of the Closed Woodland on Clay vegetation shows a reverse trend, whereby utilisation intensity decreased with distance in the old period, and is found relatively constant in the recent period. The clay cells are the areas where waterholes are common and occur mostly along the Muzi Swamp and along the eastern side of the centrally located Sihangwane dune cordon bisecting the park along a north-south axis (Matthews *et al.* 2001). It appears possible that clay areas along the Sihangwane dune cordon were utilised more heavily during the period of high rainfall due to their central location. This would have led to the observed effect as animals move from neighbouring vegetation types to the clay areas to drink, and possibly utilised these areas more intensively, as the clay soils vegetation is most likely more nutritious than on adjacent sandy soils (Matthews *et al.* 2001). As the natural waterholes of the central clay areas dried up with the drought, animals only used these areas for temporary feeding forays, without highly localised utilisation, thus explaining the absence of correlation between increased utilisation intensity and distance to water in the recent period.

In conclusion, it appears that a shift of vegetation utilisation by elephants has occurred in the Tembe Elephant Park during the last 12 months prior to the fieldwork for the present study due to the transition in precipitation regime, and now follows a gradient of utilisation related to the distance to water. The gradient is apparent at the community, sector and park levels and shows that over the 12 months prior to the present study's fieldwork, the canopy utilisation increased close to permanent water. These results are similar to those of other studies (Eckhardt *et al.* 2000; Stokke and du Toit 2000; Tedonkeng Pamo and Tchamba 2001; Stokke and du Toit 2002; Smit *et al.* In Press) but are of further interest due to the small size of the Tembe Elephant Park (300 km^2). The small size means that only a minor part of the park is further than 6 km from permanent water (Shannon 2001), which is well below the acknowledged maximum distance from water observed for bulls during dry season spells (Stokke and du Toit 2000; Mosugelo *et al.* 2002; Stokke and du Toit 2002; de Beer *et al.* 2006; O'Connor *et al.* 2007). Yet, a noticeable water dependence has been shown for elephants in Tembe despite the small distances involved. The conservation implications for management are interesting, as it appears that controlling the supply of water in the park could change utilisation patterns by elephants.

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