Report on the survival rate of large trees in relation to elephant occurrence, morphological attributes and environmental factors

2015

by
Michelle Henley
(PhD)

MANAGEMENT SUMMARY

This report highlights some of the preliminary findings related to a manuscript entitled: *Artificial tree refugia and elephant densities influence survival rates of large trees* currently being prepared by Henley, M.D., Van der Waal, C., Wall, J., Peel, M., Rucker, G., Durham, K., Edge, A.C. Schulte, B.A., De Boer, W.F. and Prins, H.H.T. As elephant impact on large trees can potentially threaten the biodiversity targets of a conservation area, management interventions aimed at reducing elephant impacts and the consequential response of biodiversity are required. We found that agents other than elephants could cause up to 2% of the annual mortality of large trees recorded across sites but with elephant impact having a significant effect on mortality rates at half of the study sites. Wire net protection made a 3% difference in annual mortality rates across all sites with as high as a 6% difference in mortality rates between protected and unprotected trees at one site. Elephant densities affected the type of impact that was inflicted and were tree species specific. These preliminary results show the potential of mitigation measures (wire net protection) as a management option to address the loss of tall trees. Other mitigation measures such as using bees to establish botanical reserves and seedling recruitment studies, requires further investigation.

INTRODUCTION

Elephants bark strip particular woody species, break large branches and uproot trees (Barnes 1982, Lewis 1986). Elephants in general have the ability to increase habitat complexity by modifying the woody structure (Pringle 2008). Their feeding habits can thus lead to physiognomic vegetation changes and result in 'hedging effects' (Smallie and O'Connor 2000, Styles & Skinner 2000, Lombard *et al*. 2001), changed tree shapes, reduced canopy height and volume and thereby increase the vegetation's sensitivity to fire and insect attack (Hatcher 1995, Jacob and Biggs 2002b, Gauargis & Van Rooyen 2009). Elephant impact can decrease the structural diversity of the landscape and in combination with various other factors, lead to the loss of tall trees (Van Wyk & Fairall 1969, Coetzee *et al*. 1979, Pellew 1983, Fenton *et al*. 1998, Trollope *et al*. 1998, Eckhardt *et al*. 2000, Asner & Levick 2012, Fisher *et al.* 2014).

In this study we consider the survival rate of three tree species, known to be heavily utilized by elephants and of concern to managers and private landowners alike (Owen-Smith 1988, O'Conner *et al.* 2007, Helm and Witkowski 2012). Using elephant distribution patterns from 30 GPS collared elephants, some of which were first collared in 1998, and individual records of *Acacia nigrescens* (Knob thorn), *Lannea schweinfurthii* (False marula) and *Sclerocarya birrea* (marula) trees, we studied changes in survival rates over time. Analyses were restricted to study sites with more than 100 trees and which have been monitored for a minimum of five years. We then set out to build a predictive model which explains large tree mortality in relation to elephant occurrence, morphological characteristics of the tree species themselves and various environmental factors known to affect large tree survival rates. As a number of these large trees have been protected by wire-netting wrapped around the stem of the tree, we also evaluate the efficiency of wire-net protection as a preventative method against elephant induced mortality.

METHODS

As the tree monitoring methods as well as the collection of GPS data records from elephants have been described elsewhere, I here focus on statistical analyses. We used GraphPad Prism 5.02 (GraphPad Software Inc. 2007) for the analysis of tree persistence where we constructed survival curves for each of the four largest long-term monitoring sites. To determine the annual mortality rate of trees per site, the natural log value of the survival proportions were plotted against time. Differences in slope (rates of mortality) were compared where:

- known elephant induced tree mortalities were considered versus mortalities of trees irrespective of the underlying cause of death which could include other agents such as fire, insect attack, wind or alternative unknown causes of death.
- trees were either wire-net protected or unprotected.

To further test if tree survival was affected by wire netting in combination with other environmental factors, generalized linear models assuming a binomial distribution and using a logit link function were used. Tree species were separately analysed with False marula trees excluded from the analyses due to small sample sizes on some sites. The survival assessment (dead or alive) of 2012 was used as the dependent variable. Independent variables included in models consisted of wire netting (present-absent), the site, fire (signs present-absent in 2012), road verge (within 15m of a road or not), distance to the nearest drinking water, DBH (Diameter at Breast Height with values for only single stem trees) and elephant density. Here we used Statistica 8.0 (StatSoft. Inc.(2006) for data analyses.

PRELIMINARY RESULTS AND DISCUSSION

On average, large trees across all study sites are lost due to the effects of agents other than elephants at 2% per year (range 0.5-3.0%, depending on the study site under consideration). These results were obtained by subtracting the annual mortality rates known to be caused by elephants from the annual mortality rates due to all potentially impacting agents and then averaging across sites. On average, wire-net protection made a 3% difference in annual mortality rates across sites (range 1-6%). Mortality rates differed between sites with distance to waterholes and fire frequency being the most obvious factors contributing to the variability across sites. At all study sites other than Ntsiri, wire net protected trees had a significantly lower mortality rate than unprotected trees. Including other impacting agents other than elephants such as fire, insect attack, wind and death due to unknown causes, significantly increased large tree mortality rates at all the sites other than for Ntsiri and Charloscar (Table 1 and Figure 1).

Table 1: The annual mortality rates of all trees (irrespective of the species) at four sites. At each site, the slopes of regression lines were compared where elephants were known to be the primary cause of death to the tree, contrasted against mortality rates due to all impacting agents and irrespective of whether the tree was wire-net protected or not. Likewise, mortality rates of wire net protected trees were contrasted against trees that were not protected and where mortality could be directly attributed to elephants.

Study site	Impacting agent (tree treatment)	Equation for change over time y=(slope)x + intercept	Mortality per day (%)	Mortality per year (%)	R^2 (F test on deviation from zero)	Significance of difference in slopes (figure number)
Vlakgezight	Elephants (with and without netting)	y=-0.000166x + 4.63	0.017	6.059	0.889 ($F_{1,13}$ = 105, P<0.001)	Yes ($F_{1.26}$ = 7.69, P=0.010)
	All (with and without netting)	y=-0.000248x + 4.64	0.025	9.052	0.888 ($F_{1,13}$ = 103, P<0.001)	a
	Elephants (with wire netting)	y=-0.0000746x + 4.63	0.007	2.723	0.745 ($F_{1,10}$ = 29.2, P=0.0003)	Yes ($F_{1,22}$ = 31.7, P<0.0001)
	Elephants (no wire netting)	y=-0.000244x + 4.66	0.024	8.906	0.882 ($F_{1,12}$ = 89.7, P<0.001)	b
Sumatra	Elephants (with and without netting)	y=-0.0000955x + 4.60	0.010	3.486	1.000 ($F_{1,1}$ = 6021, P=0.0082)	Yes ($F_{1,2}$ = 139.667, P=0.007)
	All (with and without netting)	y=-0.000120x + 4.60	0.012	4.380	1.000 ($F_{1,1}$ = 5296, P=0.0087)	c
	Elephants (with wire netting)	y=-0.0000767x + 4.60	0.008	2.800	1.000 ($F_{1,1}$ = 14442, P=0.0053)	Yes ($F_{1,2}$ = 503.01, P<0.00198)
	Elephants (no wire netting)	y=-0.000129x + 4.60	0.013	4.709	1.000 ($F_{1,1}$ = 3328, P=0.011)	d
Ntsiri	Elephants (with and without netting)	y=-0.000136x + 4.64	0.014	4.964	0.783 ($F_{1,5}$ = 18.1, P=0.0081)	No ($F_{1,11}$ = 4.39, P=0.060)
	All (with and without netting)	y=-0.000219x + 4.62	0.022	7.994	0.871 ($F_{1,5}$ = 33.7, P=0.0021)	e
	Elephants (with wire netting)	y=-0.000104x + 4.63	0.010	3.796	0.69 ($F_{1,5}$ = 11.1, P=0.0207)	No ($F_{1,9}$ = 1,27, P=0.2888)
	Elephants (no wire netting)	y=-0.000208x + 4.68	0.021	7.592	0.83 ($F_{1,3}$ = 14.7, P=0.0311)	f
Charloscar	Elephants (with and without netting)	y=-0.0000606x + 4.61	0.006	2.212	0.918 ($F_{1,2}$ = 22.4, P=0419)	No ($F_{1,4}$ = 7.69, P=0.529)
	All (with and without netting)	y=-0.0000737x + 4.61	0.007	2.690	0.932 ($F_{1,2}$ = 27.5, P=0,0345)	g
	Elephants (with wire netting)	y=-0.000039 + 4.61	0.004	1.424	1.000 ($F_{1,1}$ = 525000, P=0.0003)	Yes ($F_{1,2}$ = 709389, P<0.0001)
	Elephants (no wire netting)	y=-0.0000649 + 4.61	0.006	2.369	1.000 ($F_{1,1}$ = 5250000, P=0.003)	h

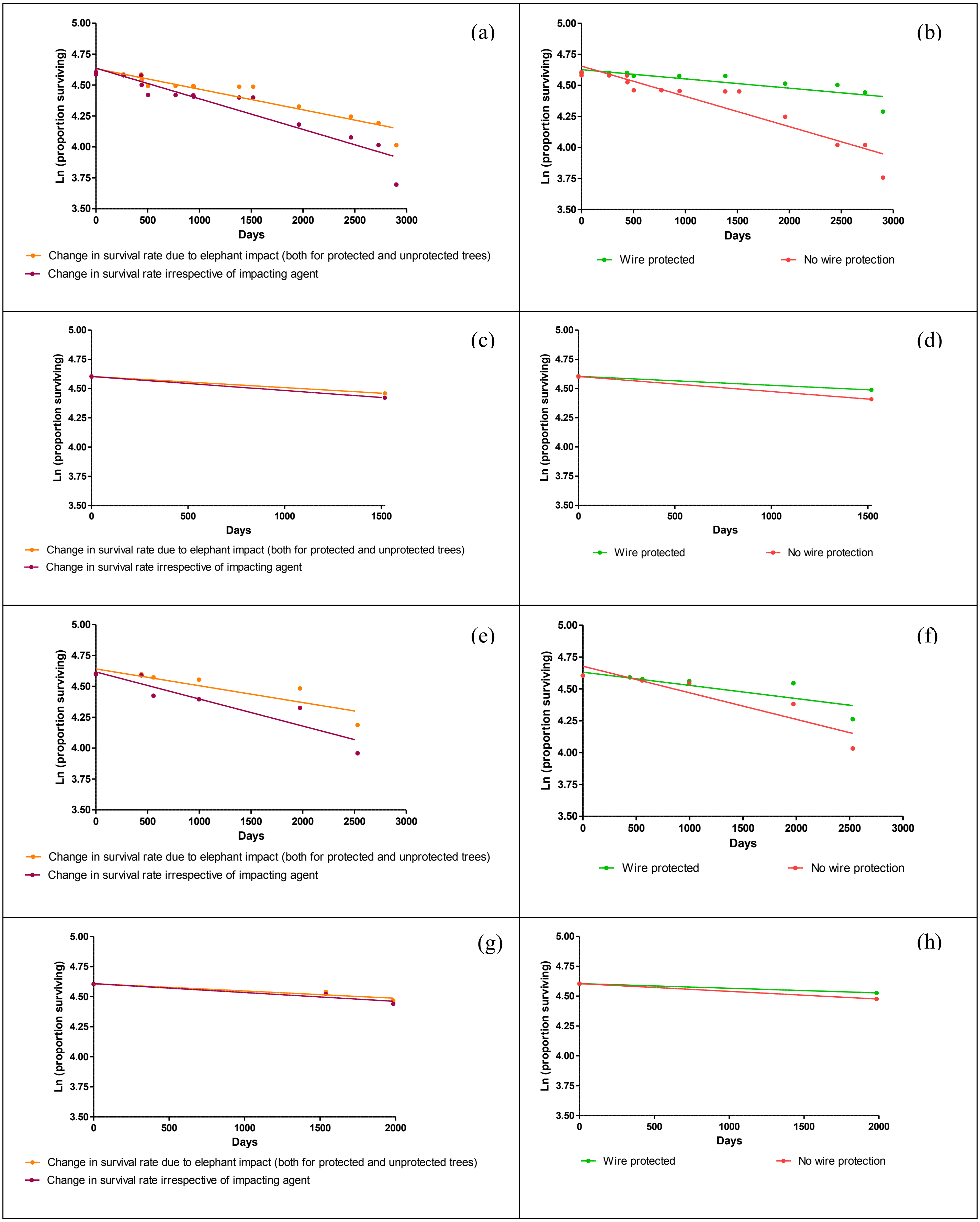

Figure 1: Changes in mortality rates of large trees over time for Vlakgezight (a-b), Sumatra (c-d), Ntsiri (e-f) and Charloscar (g-h) study sites within the Associated Private Nature Reserves.

Knob thorn survival was affected by the size (DBH) of trees (Wald = 79.8, d.f. =1, P<0.001), as well as wire netting (Wald = 6.0, P<0.05), but not by the other factors. In Knob thorn, wire netting increased survival, especially in intermediate DBH size classes (Figure 2). Overall, wire netting increased survival with about 10% for the period 2008 to 2012.

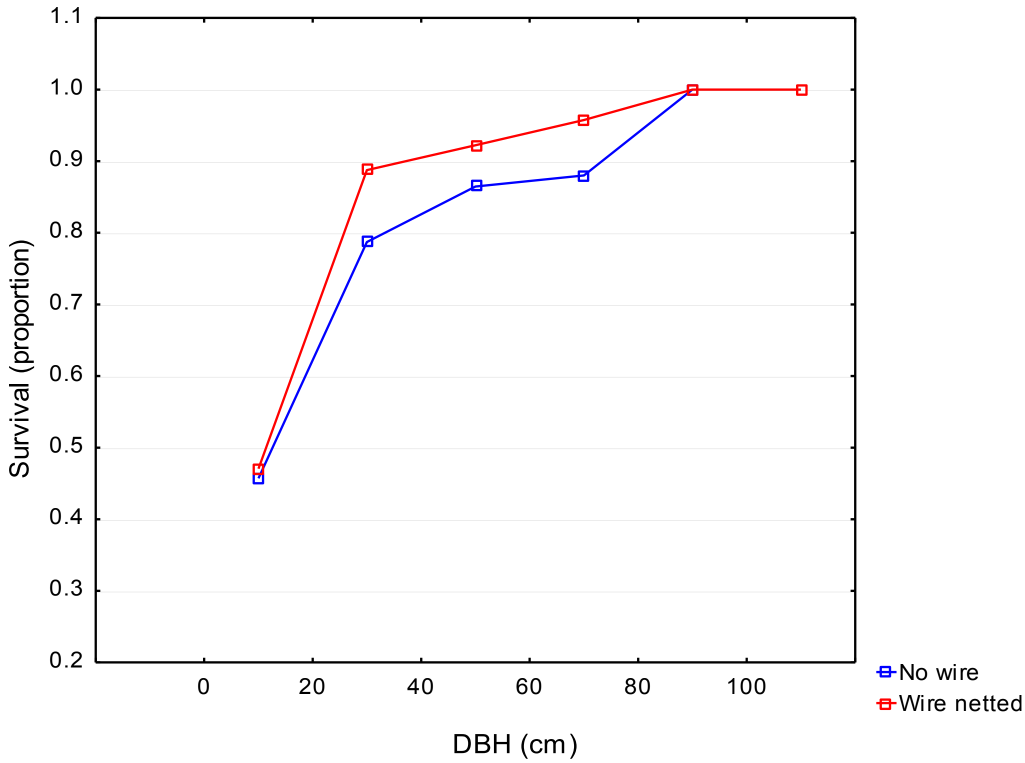

Figure 2: The survival of knob thorn trees in relation to DBH for control and wire netted trees.

For Knob thorn trees, the type of impact on trees by elephants was related to wire netting and other factors. Bark stripping by elephants was reduced by wire netting, but wire netting did not affect other types of elephant impact such as branch breaking, stem snapping or uprooting trees (Table 2). The frequency of bark-stripped Knob thorn trees was 83% lower in wire netted trees than control trees.

Table 2: Summary statistics of Generalized Linear Models relating the frequency of different elephant impact types on knob thorn trees to independent variables.

Variable	Degr. of Freedom	Wald statistics			
		Bark stripping	Branch breaking	Main stem snapping	Uprooting
Intercept	1	28.3***	82.4***	27.9***	14.7***
DBH	1	0.1	48.2***	6.4*	10.4**
Elephant presence index	1	0.0	23.8***	2.9	0.1
Wire netting	1	16.4***	1.0	2.0	1.6
Site	3	6.7	67.2***	0.1	3.7

* P<0.05; ** P<0.01; *** P<0.001

Marula tree survival was influenced by the DBH (Wald = 203.455231, d.f. = 1, P<0.001), by site (Wald = 21.5, d.f.=1, P<0.001) and fire (Wald = 15.1, d.f. =1, P<0.001). None of the other factors, including wire netting, were related to marula survival. Survival increased as tree size (DBH) increased (Figure 3). Evidence of recent fire was related to a lower survival of marulas.

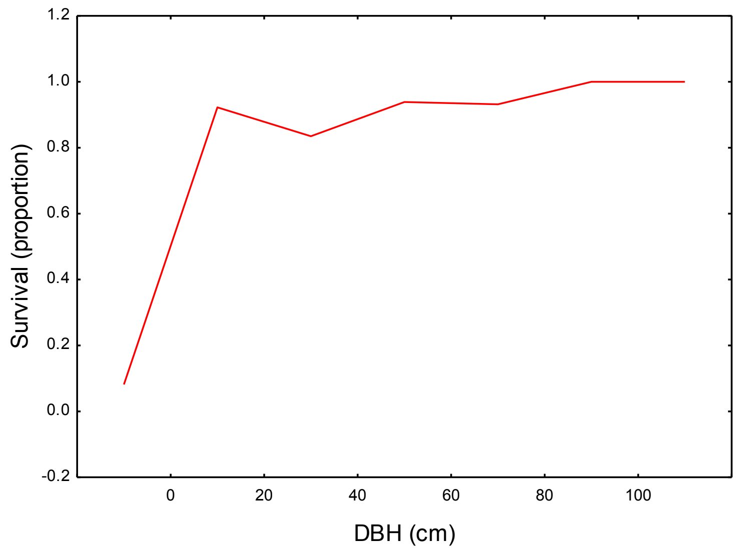

Figure 1: The survival of marula trees in relation to the DBH of trees.

For marula trees, the type of impact on trees by elephants was related to the size (DBH) of trees, wire netting and site, but not to elephant density (Table 3). In marula, bark stripping by elephants was reduced by wire netting. The frequency of bark stripping was highest at the Hancock site and lowest at the Sumatra site, with Charloscar intermediate (Ntsiri was not considered due to low sample numbers). Marula branch breaking was strongly related to the size (DBH) of trees and the site where trees occurred (Table 3). The proportion of trees with branches broken by elephants increased with tree size, but decreased in very large trees. Branch breaking of marula was frequently encountered at the Sumatra site, compared to trees at the Charloscar and Vlakgezight sites. Main stem snapping of marula trees by elephants was affected by wire netting (Table 3). Fewer trees suffered main stem snapping when wire netting was fitted to stems, compared to control trees. Uprooting of marula trees by elephants was also related to wire netting and the size (DBH) of trees. Wire netted trees were less frequently uprooted than control trees and smaller trees more frequently uprooted than larger trees.

Table 3: Summary statistics of Generalized Linear Models relating the frequency of different elephant impact types on marula trees to independent variables.

Variable	**Degr. of Freedom**	**Wald statistics**			
		Bark stripping	**Branch breaking**	**Main stem snapping**	**Uprooting**
Intercept	1	47.8***	22.9***	70.7***	54.9***
DBH	1	0.7	132.4***	0.4	7.6**
Elephant presence index	1	0.04	0.8	1.0	0.01
Wire netting	1	4.0*	0.1	9.8**	13.8***
Site	2	8.8*	18.7***	4.3	4.9

* P<0.05; ** P<0.01; *** P<0.001

REFERENCES

Asner, G. P., & Levick, S. R. 2012. Landscape-scale effects of herbivores on treefall in African savannas. *Ecology Letters* 15: 1211-1217.

Barnes, R.F.W. 1982. Elephant feeding behaviour in Ruaha National Park, Tanzania. *African Journal of Ecology* 20: 123-136.

Coetzee, B.J., Engelbrecht, A.H., Joubert, S.C.J. & Retief, P.F. 1979. Elephant impact on *Sclerocarya caffra* trees in *Acacia nigrescens* tropical plains thornveld of the Kruger National Park. *Koedoe* 22: 39–60.

Eckhardt H.S., Van Wilgen B.W. & Biggs H.C. 2000. Trends in woody vegetation cover in the Kruger National Park, South African, between 1940 and 1998. *African Journal of Ecology* 38: 108-115.

Fenton, B.M., Cumming, D.H.M., Rautenbach, I.L., Cumming, G.S., Cumming, M.S., Ford, G., Taylor, R.D., Dunlop, J., Hovorka, M.D., Johnston, D.S., Portfors, C.V., Kalcounis, M.C. & Mahlanga Z. 1998. Bats and the loss of tree canopy in African Woodlands. *Conservation Biology* 12: 399-407.

Fisher, J.T., Erasmus, B.F.N., Witkowski, E.T.F., Van Aardt, J., Asner, G.P., Wessels, K.J. & Mathieu, R. 2014. Management approaches of conservation areas: Differences in woody vegetation structure in a private and a national reserve. *South African Journal of Botany* 90: 146-152.

Gaugris, J.Y. & van Rooyen, M.W. 2009. Effects of water dependence on the utilization pattern of woody vegetation by elephants in the Tembe Elephant Park, Maputaland, South Africa. *African Journal of Ecology* 48: 126-134.

Hatcher, P.E. 1995. Three-way interactions between plant pathogenic fungi, herbivorous insects and their host plants. *Biological Reviews of the Cambridge Philosophical Society* 70: 639-694.

Helm, C.V. & Witkowski, E.T.F. 2012. Continuing decline of a keystone tree species in the Kruger National Park South Africa *African Journal of Ecology*. 51: 270-279.

Jacobs, O.S. & Biggs, R. 2002b. The impact of the African elephant on marula trees in the Kruger National Park. *South African Journal of Wildlife Research* 32: 13–22.

Lewis, D.M. 1986. Disturbance effects on elephant feeding: evidence for compression in Luangwa Valley, Zambia. *African Journal of Ecology* 24: 227–241.

Lombard, A.T., Johnson, C.F., Cowling, R.M. & Pressey, R.L. 2001. Protecting plants from elephants: botanical reserve scenarios within the Addo Elephant National Park, South Africa. *Biological Conservation* 102: 191–203.

O'Connor, T.G., Goodman, P.S. & Clegg, B. 2007. A functional hypothesis of the threat of local extirpation of woody plant species by elephant in Africa. *Biological Conservation* 136: 329–345.

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

Pellew, R.A. 1983. Modelling and the systems approach to management problems: the *Acacia*/elephant problem in the Serengeti. In *Management of Large Mammals in African Conservation Areas.* Owen-Smith R.N., ed. Pretoria: Haum.

Pringle, R.M. 2008. Elephants as agents of habitat creation for small vertebrates at the patch scale. *Ecology* 89: 26-33.

Smallie, J.J. & O'Connor, T.G. 2000. Elephant utilization of *Colophospermum mopane*: possible benefits of hedging. *African Journal of Ecology* 38: 352–359.

Styles, C.V. & Skinner, J.D. 2000. The influence of large mammalian herbivores on growth form and utilization of mopane trees, *Colophospermum mopane*, in Botswana's Northern Tuli Game Reserve. *African Journal of Ecology* 38: 95–101.

Trollope, W.S.W., Trollope, L.R, Biggs, H.C, Pienaar, D. & Potgieter, A.L.F. 1998. Long-term changes in the woody vegetation of the Kruger National Park with special reference to the effects of elephants and fire. *Koedoe* 41: 103-112.

Van Wyk, P. & Fairall, N. 1969. The influence of the African elephant on the vegetation of the Kruger National Park. *Koedoe* 12: 57–89.