Appendix I: List of the dominant shrub and tree species recorded on the Marheya, Satara, Lindanda and Nwanetsi replications of the experimental burn plots in the Kruger National Park (Enslin 1999[3])

Replicate	**Plot**	**Dominant vegetation species (decline in dominance from left to right)**
Satara	F2	*Dichrostachys cinerea* subsp. *africana, Ormocarpum trichocarpum, Flueggea virosa* subsp. *virosa*
	F3	*Acacia nigrescens, Dichrostachys cinerea* subsp. *africana, Flueggea virosa* subsp. *virosa*
	A1	*Acacia nigrescens, Dichrostachys cinerea* subsp. *africana, Flueggea virosa* subsp. *virosa*
	A2	*Flueggea virosa* subsp. *virosa, Dichrostachys cinerea* subsp. *africana, Grewia villosa* var. *villosa*
	A3	*Dichrostachys cinerea* subsp. *africana, Acacia nigrescens, Flueggea virosa* subsp. *virosa*
	O6	*Acacia nigrescens, Flueggea virosa* subsp. *virosa, Combretum imberbe*
	C	*Acacia nigrescens, Dichrostachys cinerea* subsp. *africana, Flueggea virosa* subsp. *virosa*
Nwanetsi	F2	*Dichrostachys cinerea* subsp. *africana, Ormocarpum trichocarpum, Cassia abreviata*
	F3	*Dichrostachys cinerea* subsp. *africana, Acacia nigrescens, Ehretia obtusifolia*
	A1	*Dichrostachys cinerea* subsp. *africana, Ormocarpum trichocarpum, Combretum africana*
	A2	*Dichrostachys cinerea* subsp. *africana, Acacia nigrescens, Ehretia obtusifolia*
	A3	*Dichrostachys cinerea* subsp. *africana, Acacia nigrescens, Ehretia obtusifolia*
	O6	*Acacia nigrescens, Combretum africana, Dichrostachys cinerea* subsp. *africana*
	C	*Acacia nigrescens, Flueggea virosa* subsp. *virosa, Dichrostachys cinerea* subsp. *africana*
Lindanda	F2	*Acacia nigrescens, Dichrostachys cinerea* subsp. *africana, Grewia bicolor* var. *bicolor*
	F3	*Ehretia obtusifolia, Dichrostachys cinerea* subsp. *africana, Maerua parvifolia*
	A1	*Dichrostachys cinerea* subsp. *africana, Ormocarpum trichocarpum, Maerua parvifolia*
	A2	*Dichrostachys cinerea* subsp. *africana, Acacia nigrescens, Ehretia obtusifolia*
	A3	*Dichrostachys cinerea* subsp. *africana, Ehretia obtusifolia, Ormocarpum trichocarpum*
	O6	*Ehretia obtusifolia, Ormocarpum trichocarpum, Dichrostachys cinerea* subsp. *africana*
	C	*Maerua parvifolia, Grewia bicolor* var. *bicolor, Ormocarpum trichocarpum*
Marheya	F2	*Dichrostachys cinerea* subsp. *africana, Acacia nigrescens, Ehretia obtusifolia*
	F3	*Commiphora schimperi, Dichrostachys cinerea* subsp. *africana, Ormocarpum trichocarpum*
	A1	*Dichrostachys cinerea* subsp. *africana, Acacia nigrescens, Acacia tortilis*
	A2	*Dichrostachys cinerea* subsp. *africana, Ehretia obtusifolia, Flueggea virosa* subsp. *virosa*
	A3	*Dichrostachys cinerea* subsp. *africana, Ehretia obtusifolia, Commiphora schimperi*
	O6	*Dichrostachys cinerea* subsp. *africana, Maerua parvifolia, Ormocarpum trichocarpum*
	C	*Commiphora schimperi, Ehretia obtusifolia, Acacia nigrescens*

[3] Enslin, B. 1999. Unpublished data from surveys conducted on the Satara experimental burn plots of the Kruger National Park, Department of Research, Kruger National Park, Skukuza.

CONCLUSION

The combined effects of elephants and fire are documented to result in the loss of woodlands (Ben-Shahar 1996 and Barnes 1983). Beuchner & Dawkins (1961) stated that all woody vegetation is undergoing a process of conversion to grassland under the combined influence of elephants and fire. Major decline in tree densities in certain landscapes of the Kruger National Park were recorded by Trollope, Trollope, Biggs, Pienaar & Potgieter (1998) and Viljoen (1988). In both cases the decline occurred after the Kruger National Park experienced a highly significant increase in elephant densities and fire during the period 1960 to 1986/89 (Trollope *et al.* 1998). Viljoen (1988) speculated that the change in vegetation in the *Sclerocarya birrea/Acacia nigrescens* savanna between 1944 and 1981 could be ascribed to the intense drought during the 1960's in combination with frequent burning and elephant impact.

Tree loss is undesirable as they are of aesthetic, economic and ecological importance (Barnes 1983). Trees provide shade, fruits, browse, and fallen leaves for herbivorous and detrivorous organisms, and play an essential role in the flow of nutrients within the system (Gadd 1997). The marula is one of the best known and most highly valued indigenous fruit trees and has been declared as a protective tree species (Coates Palgrave 1983). In the eastern lowveld of South Africa, the marula tree is regarded as a crucial element of the scenery, and game farm managers are hesitant to acquire more elephants if they jeopardise the abundance of these trees (Gadd 1997). In the Kruger National Park, existing TPC's for rare plants are based on the decline in numbers and recruitment of an order (taking into account the probable biology of the species) that would cause conservation concern, and obvious evidence of "non-natural" threats which constitute persuasive proof on a scale likely to be leading to such declines.

The current status of the marula population in the landscapes under review is as follows:

Landscape 23: It appears as though marula trees were historically present in this landscape, but that management practices such as increased elephant populations and a fixed fire policy have contributed to the removal of marulas from this landscape.

Landscape 12: An unstable population structure for the marula exists. Existing adult trees are mainly older trees at the end of their life cycle, and their death may in time lead to the extinction of the population as the seed source disappears. This process, which is believed to have led to the virtual extinction of marula trees in Landscape 23, may currently be taking place in Landscape 12. The amount of elephant damage in Landscape 12, reviewed in conjunction with the population structure, poses a serious concern as it appears that successful recruitment into the upper canopy is not occurring (O.S. Jacobs & R. Biggs In prep. 2000), while most of the older trees suffer bark damage, increasing their susceptibility to boring insects and fire.

Landscape 5 & 17: Although the population structures in Landscape 5 & 17 appear to be healthy, with a good distribution of individuals throughout the different height classes, results of this study further reveals that more than 60% of the trees in the 2 – 8 m height classes are suffering extreme elephant damage. It therefore appears as if the population structures of these landscapes are highly affected by elephant impact, and that they are not as healthy as suggested.

Results of this study indicate that sufficient regeneration of the marula is taking place in the Kruger National Park, but that a combination of factors is preventing successful recruitment into the upper canopy. Geology and rainfall appears not to be the dominant factors contributing to the differences in the population structure between the different landscapes. Results further indicate that seedling mortality can not be related to increased herbivory by small browsers such as impala, but that a combination of browsing pressure and fire influence the structure of the lower canopy. The main impact on the adult marula trees could be related to elephant densities as well as the vegetation diversity. The marula population in less diverse landscapes in the Kruger National Park appears to be more susceptible to herbivory impact. More than half of the marula trees sampled in the Kruger National Park are suffering elephant damage at the current stage, with elephants being the main cause of the 7% mortality recorded. Elephants appeared to alter the tree structure of marulas, resulting in a significant amount of trees coppicing between 2 – 5 m, hence increasing the amount of trees susceptible to fire and decreasing the amount of trees in the 5 – 8 m height class.

The inclusion of the effects and interaction of fire in this study is the general recognition that elephants and fire can have a highly significant impact on the species and structural diversity of tree and shrub vegetation. Results of this study support Bailey (1988) in stating that response of vegetation to fire depends upon frequency, seasonality and intensity, but showed that the interaction between the main effects of season and frequency was the incremental factor. The changes in the woody vegetation in response to fire did not involve a decrease in species diversity, but rather a change in vegetation structure and morphology. The triennial August burns appear to have the greatest impact on the marula seedlings, probably due to the extremely high fire intensities resulting in increased topkill. Between 1954 and 1992 the fire management policy of the Kruger National Park was to apply triennial burns during late winter on a rotational basis to the fire management blocks of the park (Trollope *et al.* 1998). The extremely high fire intensities, with the resultant low heights and crown diameters recorded on the August triennial treatments in this study, strongly suggest that this burning policy has hampered the establishment and development of marula seedlings in the park. This may largely explain the observed lack of marula recruitment in the park over the past eighteen years. This supports the results of Enslin, Potgieter, Biggs & Biggs (2000) who found that the woody vegetation is being transformed into a lower woodland community interspersed with a low density of large trees, together with significant changes in the proportion of single-stemmed individuals.

Overall results of this study therefore strongly supports the hypothesis that elephants are influencing the population structure by impacting on the adult marula trees, while fire is preventing recruitment of the trees into the upper canopy. It further appears as if the problem is more complex, where these factors, in combination with species diversity, global climate change and increased browsing pressure may be contributing to the change in the marula population of the Kruger National Park. The current *laissez faire* burning policy was introduced in 1994 where only fires ignited by lightning are permitted to burn and all other ignition sources are controlled as far as possible (Trollope, Biggs, Potgieter & Zimbatis 1995). This change in fire policy, together with the implementation of the elephant impact zones, may result in a turnaround in the observed marula population decline in the Kruger National Park.

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