Selective habitat utilisation and impact on vegetation by African elephant within a heterogeneous landscape

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Since 1992, a total of 33 elephants have been reintroduced to a 31 000 ha game-fenced section of the Songimvelo Game Reserve in the Barberton Mountainland, South Africa. The impact from elephant was assessed on the attainment of the primary management objectives which are the conservation of plant community and plant species diversity. A total of 160 semi-quantitative plots were systematically sampled along foraging paths. Vegetation was assessed in terms of dominant species composition and species utilised. Elephant activity is mostly confined to a rugged 1 200 ha portion of the reserve. Forest, thickets and woodlands are positively selected, whereas shrublands and grasslands are little utilised. A total of 73 woody species were recorded within the sample plots. Thirty-nine of these species were utilised in the woodlands, 31 in the forest and thickets, and only 18 in the shrublands. *Acacia ataxacantha*, *Dalbergia armata* and *Acacia caffra* are ranked highest in dominance and in utilisation values. In contrast, *Cussonia spicata* and *Pterocarpus angolensis* are less common but are much selected. Continued utilisation at present levels could significantly threaten their persistence. These preliminary results indicate that the present low overall density of elephants relative to many other conservation areas already has a marked effect on certain plant species. Absolute elephant density figures are relatively meaningless within a heterogeneous landscape. The specific community and species make-up of the landscape needs to be taken into account for the determination of bounds to elephant numbers in order to ensure the maintenance of present plant species diversity levels.

Keywords: elephant, landscape ecology, habitat selection, preference.

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Introduction

A total of 18 African elephant (*Loxodonta africana* Blumenbach), aged between six and eight years at the time of their introduction, were relocated from the Kruger National Park during 1992 and 1993. They were placed in a 31 000 ha game-fenced section of the 49 000 ha Songimvelo Game Reserve (SGR). During 1995, a breeding herd of nine individuals, together with four orphaned bulls of five to seven years as well as two adult bulls were released into the reserve. A total of 36 elephants were counted during the 1999 helicopter game census.

The elephants have been confining themselves mostly to an extremely rugged and remote part of the reserve that is only accessible on foot. As a consequence of their use of such an inaccessible area, very little is known about their foraging behaviour and impact on the vegetation. The prioritised management objectives for SGR are, firstly, the maintenance of plant community and species diversity, and secondly, the conservation of two cycad species (*Encephalartos* spp.) endemic to the Barberton Mountainland.

The aims of the study were therefore to identify the areas of elephant activity, to quantify the habitat and plant communities occurring in these areas, and to quantify the community and species preferences of elephants and their resultant impact.

Study area

The SGR is located in the south-eastern part of Mpumalanga on the South African-Swaziland border at latitude 25°45'S–26°5'S and longitude 30°46'E–31°16'E (Fig. 1). The reserve stretches across a diagonal of 50 km from the broad open Komati River Valley in the south-west to the narrow mountainous north-eastern apex. The terrain is generally rugged with elevation ranging from 600 m above sea level along the Komati River in the south to over 1800 m in the north and north-east. Geology is very diverse and ranges from alluvium and mafic and ultramafic lavas in the Komati Valley, to felsic lavas, gneisses, conglomerates, shales, sandstones and quartzites at higher elevations. Rainfall is concentrated between November and March, and varies from less than 800 mm/y in the south-west to over 1400 mm/y in the north-east (Gamble 1988). Mean minimum and maximum monthly temperatures are 5.4 °C and 7.9 °C in July and 22 °C and 34 °C in January for the highland and lowland areas respectively (Anonymous 1986). The generally acid and arenaceous geological substrates in the north-east, combined with a higher rainfall, result in leached and acid soils. In contrast, relatively nutrient-rich soils are found in the Komati Valley.

The SGR is characterised by a long and diverse history of small-scale cropping and livestock in the more fertile lowlands (Van der Merwe & Retief 1995) which led to the virtual disappearance of wild herbivores and carnivores by 1985. Since the inception of the reserve in 1986, a total of 20 species of large herbivores have been re-introduced.

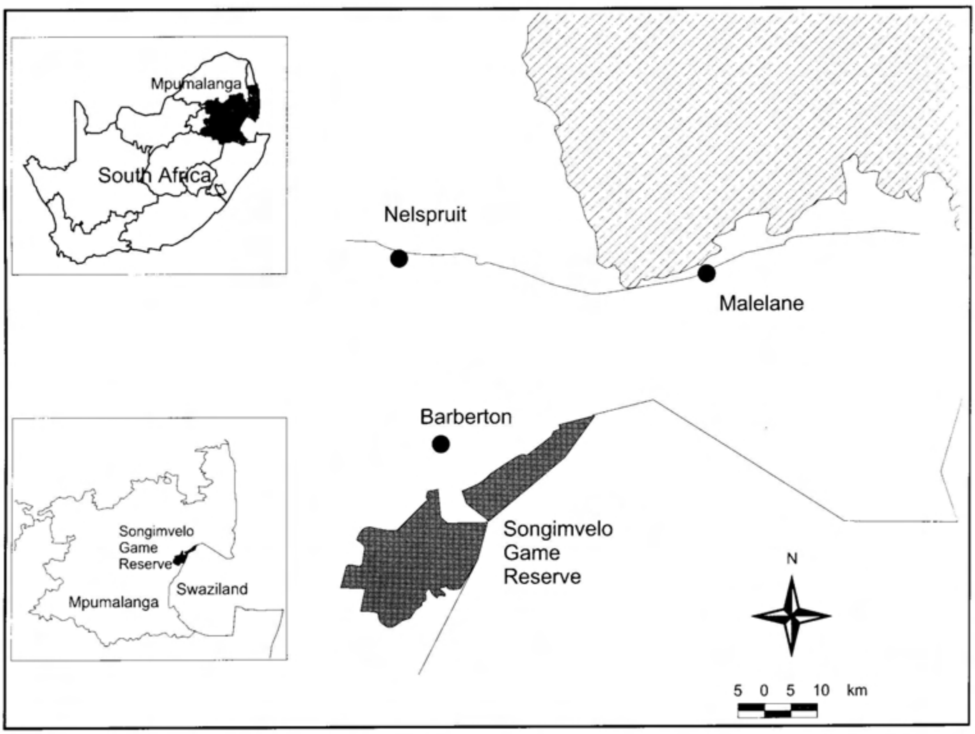

Fig. 1. Locality map of the Songimvelo Game Reserve.

Apart from elephant, these include white rhinoceros (*Ceratotherium simum* Burchell), buffalo (*Syncerus caffer* Sparrman), blue wildebeest (*Connochaetus taurinus* Burchell), zebra (*Equus burchelli* Gray), giraffe (*Giraffa camelopardalis* Linnaeus), eland (*Taurotragus oryx* Pallas) and impala (*Aepyceros melampus* Lichtenstein).

The vegetation of the higher-lying regions of the SGR belongs to the Grassland Biome. The lower-lying Komati valley falls within the Savanna Biome (Rutherford & Westfall 1986). The Forest Biome is represented by numerous isolated patches of forest, mostly at higher elevation and along drainage lines. Three of Acocks' (1988) veld types occur. Veld types 8 (North Eastern Mountain Sourveld) and 63 (Piet Retief Sourveld) correspond to the Northeastern Mountain Grassland of the Grassland Biome as defined by Low & Rebelo (1996). Veld type 9 (Lowveld Sour Bushveld) corresponds to the Sour Lowveld Bushveld of the Savanna biome. A total of 19 distinct plant communities have been described (Stalmans *et al.* 1999). The composition of these 19 communities is determined through an intricate combination of environmental factors. Firstly 'drainage line' position is critical, followed by land use history and further by the interplay between elevation and geology. These findings are in line with results obtained from other studies along the eastern Escarpment (Deall *et al.* 1989; Matthews *et al.* 1994). The Barberton Mountainland is considered to be one of five centers of endemism along the Transvaal escarpment (Fourie *et al.* 1988). The extremely diverse geology and rugged terrain contribute towards a high plant diversity which is known to exceed 1450 species in the SGR (K. Balkwill *pers. comm.*).

Methods

Field technique

The vegetation of the SGR generally has low quality for grazing, especially during the dry winter. The herbivores exhibit distinct preferences for specific habitat types such as old lands and old settlement sites, probably because of local nutrient enrichment (Stalmans *et al.*, *in press*). These patches represent only a small proportion of the total landscape. The larger background matrix is used following fires and in winter or under drought conditions when forage on the preferred patches has largely been depleted.

Elephants exhibit a similar pattern of utilisation of small patches within the background matrix. They follow a connecting network of paths from patch to patch. The very localised distribution of elephant, as well as the very rugged nature of the landscape precluded the use of a systematic or random sampling design. Such sampling designs would be very difficult from a practical point of view in terms of accessibility. They would also require an inordinate number of samples to capture elephant use. Therefore, the network of elephant paths was used as the basis for the sampling.

Foraging paths were walked for their entire length and sampling plots were systematically located at 200 m intervals. A locality reading was taken by means of a Global Positioning System (GPS). At each of those points, a sampling plot with a radius of 10 m was set out, regardless of whether elephant utilisation was observed or not. Values for the environmental parameters were documented, including landscape position, aspect, topography, slope, rockiness and land-use history. Forest/thickets, woodlands, shrublands and grasslands were distinguished. Woody density, canopy height and grass length were recorded. All structural terminology follows Edwards (1983). The five dominant woody and five dominant grass species (in terms of cover) were listed in descending order of importance for each sample plot. Utilisation by elephant was recorded in the following manner. For each of the woody species utilised in a specific plot, a rating was given on a three point scale (<10 %; 10–50% and >50 %) as to the proportion of this specific species that was actually utilised within the 10 m plot radius. Type of impact was recorded as snapped stem (irrespective of height or size), pushed over, debarked and debranched. The percentage of impacted trees relative to the total number of trees in each plot was rated on the three-point scale for each type of impact.

Data analysis

The GPS points were incorporated into the IDRISI (Eastman 1997) Geographical Information System (henceforth GIS) set up for the SGR. This allowed visual display of the activity patterns and preference areas. Due to limitations in the avaiable GIS data, habitat availability based on landscape position, slope, rockiness and several other parameters could not be calculated at a scale appropriate to the sampling. The proportion of forest/thickets was known from previous habitat analysis using remote sensing (Stalmans *et al.* in press.) and could be compared to the proportion of forest/thickets found along the foraging paths.

The analysis of the vegetation data concentrated on the comparison between availability and actual utilisation values. Proportional representation of the structural vegetation types as well as their utilisation was derived from the total sample. The relative importance rank of each species was determined by calculating a composite value based on the dominance (in terms of cover) and the frequency of occurrence across each cover class in each plot. This was done per vegetation type. This relative availability of each specific species was then compared with the actual utilisation of this species. Utilisation was similarly calculated as a composite of frequency of impact across cover classes in each plot. Proportional impact, specific plant parts, as well as the main type of impact per species were established.

Results

Habitat selection

A total of 160 plots were sampled along 35 km of paths (Fig. 2). The main areas of activity were concentrated in the northwestern section of the game-fenced area which consists of a very rugged and isolated area, only accessible on foot. Elevation ranges from 930 m to 1 500 m above sea level. The area is bisected by the perennial Msoli River. A number of smaller perennial streams also occur. No part of the study area is further than 5 km from permanent water. The elephant paths traverse a great variety of habitats with different environmental parameters. Almost 54 % of the plots were positioned in drainage lines. The 160 sample plots covered all aspects, but the majority (64 %) were south and east facing. Slopes varied from level (23 %), gentle (33 %), steep (31 %) to very steep (13 %). Relatively even terrain (58 %) was favored to broken

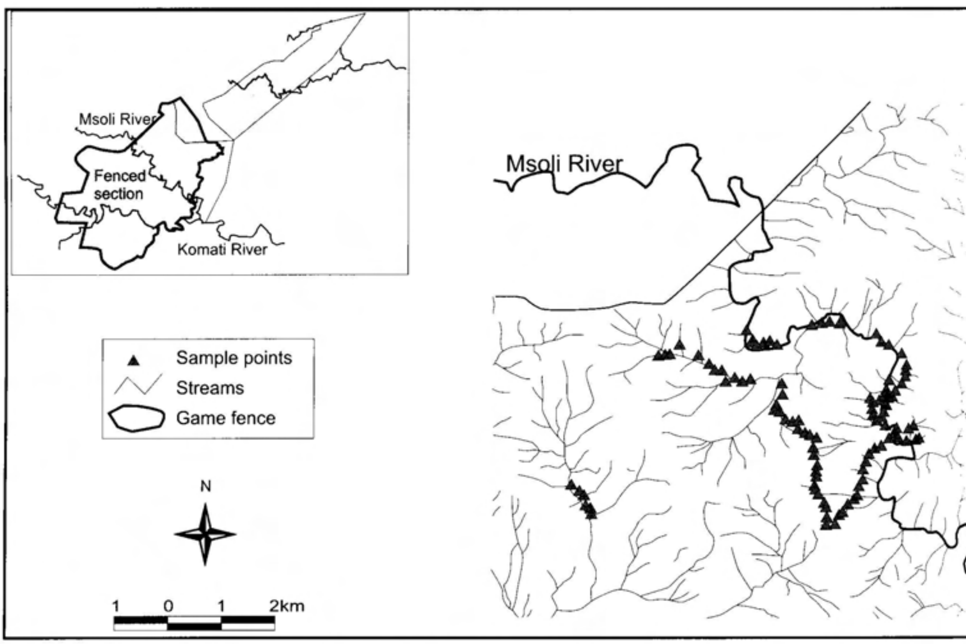

Fig. 2. Elephant trails and position of sample plots in the Songimvelo Game Reserve.

Table 1
Ranking of woody species in terms of their utilisation by elephant and their relative importance within woodlands (n = 68 sample plots)

Woody plant species	Utilisation rank	Importance rank
Acacia ataxacantha	1	3
Dalbergia armata	2	5
Acacia caffra	3	2
Dombeya rotundifolia	4	2
Euclea crispa	5	1
Acacia nilotica	5	9
Cussonia spicata	6	19
Unknown species	6	17

Table 2
Ranking of woody species in terms of their utilisation by elephant and their relative importance within shrublands (n = 44 sample plots)

Woody plant species	Utilisation rank	Importance rank
Acacia davyii	1	1
Aloe marlothii	2	7
Acacia caffra	3	5
Faurea rochetiana	4	7
Dombeya rotundifolia	5	3
Heteropyxis natalensis	5	12
Peltophorum africanum	5	14
Euclea crispa	6	2
Acacia ataxacantha	6	6
Rhamnus prinoides	6	11
Rhus rehmanniana	6	14
Acacia nilotica	6	16
Dovyalis lucida	6	16
Protea gaguedii	6	16
Ozoroa sphaerocarpa	6	17
Erythina lysistemon	6	17
Dalbergia armata	6	19
Gymnosporia sp.	6	19

terrain (42 %). Extremely rocky areas (26 %) were generally avoided, while most areas had medium rock cover (42 %) or none to very little rock cover (32 %).

Vegetation types

Woodlands (43 %) represented the single largest vegetation type encountered in the sample plots, followed by shrublands (27 %), forest and thickets (16 %) and grasslands (14 %). Most of the woodlands were closed (63 %). Canopy height ranged from 2–5 m. *Euclea crispa*, *Dombeya rotundifolia*, *Acacia caffra* and *A. ataxacantha* dominated (Table 1). Other important species are *Dalbergia armata*, *Diospyros whyteana*, *Faurea rochetiana*, *Heteropyxis natalensis* and *Catha edulis*. Density in the shrublands ranged from closed, to open and sparse, with canopy heights predominantly in the 1–2 m category. The shrublands are dominated by *Acacia davyi*, *Euclea crispa*, *Dombeya rotundifolia*, *Acacia caffra*, *A. ataxacantha* and *Aloe marlothii* ssp. *marlothii* (Table 2). Canopy heights were 2–5 m in the thickets and exceeded 5 m in the forest communities. Important species in the forest and thickets are *Acacia ataxacantha*, *Dalbergia armata*, *Diospyros whyteana*, *Catha edulis*, *Rhus pentheri*, *R. chirindensis* and *Heteropyxis natalensis* (Table 3).

Vegetation and species selection

Some form of utilisation by elephant was recorded within 73 % of all sample plots. Grasslands and shrublands were relatively little utilised, whereas most of the woodland plots exhibited elephant use. All forest and thicket samples were impacted upon (Fig. 3).

Table 3
Ranking of woody species in terms of their utilisation by elephant and their relative importance within thickets and forests (n = 26 sample plots)

Woody plant species	Utilisation rank	Importance rank
Dalbergia armata	1	2
Acacia ataxacantha	2	1
Cussonia spicata	2	12
Catha edulis	3	4
Rhus chirindensis	4	6
Unknown species	4	10
Diospyros whyteana	5	3
Heteropyxis natalensis	5	7
Rhus pentheri	6	5
Ficus sur	6	12
Acacia caffra	6	13
Brachylaena transvaalensis	6	15

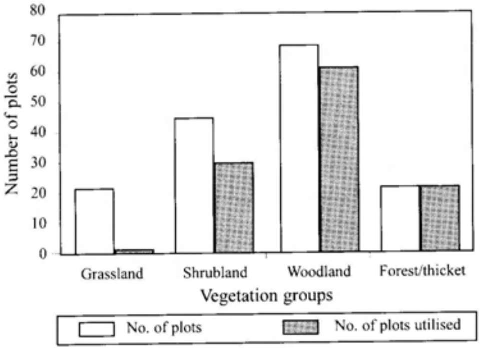

Fig. 3. Proportion of sample plots utilised by elephant in different vegetation types of the Songimvelo Game Reserve.

In the woodlands, 77 % of the dominant species (40 of the 52 species) showed signs of utilisation. The most favoured species, *Acacia ataxacantha*, *Dalbergia armata*, *Acacia caffra*, *Dombeya rotundifolia* and *Euclea crispa* are also ranked highest in importance (Table 1). *Heteropyxis natalensis* and *Faurea rochetiana* are utilised in line with their occurrence. *Acacia nilotica* spp. *kraussiana*, *Cussonia spicata* and *Aloe marlothii* spp. *marlothii* are very low in importance values, but show definite signs of being selected. *Pterocarpus angolensis* was found in only 5 plots (8 %), which explains its low importance value, but every individual specimen was utilised. A similar pattern was observed for *Cussonia spicata*. The 'unknown' species refers to a group of woody species that could no longer be identified, because they have all died, presumably as a result of utilisation. Although they appear high in utilisation rank, as individual species their importance is shared between a number of species.

Within the shrubland, 56 % (18 out of 32) of the most important species showed signs of utilisation (Table 2). *Acacia davyi* is ranked highest in terms of dominance. It is also rated as the most utilised species. *Aloe marlothii* spp. *marlothii* was also clearly preferred. It ranks only seventh in terms of importance, but is second only to *A. davyi* in the number of plots in which it is utilised.

In the forest and thickets, 82% of the dominant species were utilised by elephant. As in the woodland, the species which are most utilised are *Dalbergia armata* and *Acacia ataxacantha*. They are also the most important species (Table 3). *Cussonia spicata* is second only to *Acacia ataxacantha* in terms of utilisation although its overall importance ranking is much lower. *Catha edulis*, *Rhus chirindensis*, *Diospyros whyteana*, *Heteropyxis natalensis* and *Rhus pentheri* are utilised in proportion to their importance. They all are important species with high frequencies and cover values. Species such as *Ficus sur*, *Acacia caffra* and *Brachylaena transvaalensis* are as high in utilisation as for example *Diospyros whyteana*, *Heteropyxis natalensis* and *Rhus pentheri*, but are less than half as important in terms of dominance.

Current levels of utilisation by elephant often lead to the death of the individuals of *Cussonia spicata*, *Pterocarpus angolensis*, *Acacia nilotica* and *Aloe marlothii* ssp. *marlothii*.

Cussonia spicata occurs over the whole Reserve in woodland and forest/thickets, but only as single individuals, so that they are never dominant in frequency or cover. It has a high utilisation rank which clearly indicates that this is one of the most preferred species by elephant. The utilisation leads to a die-off of 47 % of the species in the sampling plots, and a proportional utilisation of 75 %. The impact occurs in a sequence: first the tree would be debarked, then pushed over or the main stem broken, leading to a complete annihilation of the individual. *Pterocarpus angolensis* occurs at much lower densities and was recorded in only six of the sample plots. Their proportional utilisation though, is 75 %, with the main type of damage being debarking and pushing over of the trees, with the death of the tree becoming unavoidable (33 % of the individuals in the sampling plots). A proportional utilisation of 71 % was recorded for *Acacia nilotica* ssp. *kraussiana*. Trees are mainly debranched, debarked or pushed over resulting in 33 % of the individuals being dead in the sample plots. *Aloe marlothii* ssp. *marlothii* occurs as a single-stemmed individual. When the trees are shorter than 1.7m, their heads/crowns are broken off and eaten. When they are taller, they are more readily pushed over. In both instances death follows.

Discussion

The elephant use a well-defined network of trails in the Songimvelo Game Reserve. Specific elephant trails connecting preferred feeding areas have been documented elsewhere, in particular in forest environments. Ruggiero & Fay (1994) found elephant trails connecting areas of damaged vegetation and modified soils, waterholes, and salt licks in the Manovo-Gounda - St. Floris National Park in the Central African Republic. Similarly, Van Leeuwen & Gautier-Hion (1998) documented forage paths running through preferred foraging sites. Babaasa (2000) systematically sampled along 120 km of fresh elephant trails to evaluate habitat selection by 22 elephant on a 33 100 ha with very steep topography. The sampling strategy applied in the SGR was efficient in terms of focusing on the actual areas used and vegetation selected. The high percentage of plots (76 %) with some form of utilisation is not surprising, as only the actively utilised paths were followed. This figure would differ greatly should the whole reserve be included in the sampling, as only certain areas are presently frequented by elephant.

The 1 200 ha area selected by the elephants seems in no way unique to other parts of the reserve. Water is generally plentiful throughout the SGR. All plant communities and individual species encountered within the selected area have also been documented in other parts of the reserve (Stalmans *et al.* 1999). The selection of this particular part of the SGR might therefore reflect social and behavioural aspects rather that habitat suitability.

Few woody species occur in the grassland. The sampling method used did not allow for any quantification of the use of the grass layer by elephant. Such utilisation has been recorded extensively, particularly during the wet, summer months (Barnes 1982; Field & Ross 1976). Utilisation was a little more in the shrubland communities. The real impact, however, was on the woodland and forest/thickets. Based on remote sensing, the forest/thickets occupy 25.3 % of the landscape in the study area (Stalmans *et al. in press.*). Forests (16 % of the sample plots) therefore seem to be selected less than their representation within the landscape would suggest. However, every single sample plot located within a forest exhibited clear signs of utilisation by elephant.

The most favoured species such as *Acacia ataxacantha*, *Dalbergia armata*, *Acacia caffra*, *Dombeya rotundifolia* and *Euclea crispa* are also dominant in terms of frequency and cover. It is likely, that because of their widespread occurrence, high frequencies and large cover values, these species will be able to withstand heavy utilisation. In contrast, the future of less common species which are highly selected such as *Cussonia spicata*, *Pterocarpus angolensis* and *Aloe marlothii* is uncertain within the present area favoured by elephant. These species are all fairly widespread in the SGR but they never represent the dominant species.

Although not directly considered within this study, fire can be an important cause of indirect mortalities of trees previously utilised or ringbarked by elephant (Buechner & Dawkins 1961; Spinage & Guinness 1971). It is important not to lose sight of the fact that fire influences the vegetation just as profoundly as elephants do (Van Wilgen *et al.* 2000). By using fire in different seasons, elephant can be induced to utilise other, less favored areas, to decrease the pressure on certain areas (Lewis 1987). Such a patchy fire pattern, both in time and space, does exist on the reserve (Stalmans *et al.* 1993).

The overall density of elephant across the SGR is only 0.11 elephant/km^2. This is low compared to the density figure of 0.5 elephant/km^2 at which savanna woodlands are converted to shrublands or grasslands (Cummings *et al.* 1997). Under present conditions however, the elephants occupy only a restricted range of about 1200 ha which translates to a density figure of 2.75 elephant/km≈. The severe impact on particular species is therefore not surprising.

Although an area of 31 000 ha is theoretically accessible to elephants, in practice 60.4 % of the vegetation consists of 'sour' communities which are not favoured by herbivores (Stalmans *et al. in press*.). This is reflected within the study area with only 4.5 % of the 'sour' grassland plots having been utilised by elephant. The main impact was on the forest/thickets (100 % of the sampled plots showing impact) and 'mixed' areas (90 % of the woodland sample plots with impact). These cover less than 10 000 ha of the SGR. Using the density figures of Cummings et al. (1997) for this area, a maximum of 50 elephants for the SGR could be compatible with the reserve's primary vegetation conservation aims.

In terms of modern approaches to landscape ecology (e.g., Christensen 1997), and in terms of the concern to maintain diversity and flux in African landscapes (Van Wilgen *et al.* 1998), the present patchy utilisation by elephant in the SGR seems appropriate. Certain areas are very obviously and very significantly impacted upon, whereas the vast majority of the reserve is not being traversed at all by elephant. It is important to address the question of elephant impact and appropriate densities by considering the constituent elements of a heterogeneous landscape. The use of 'average' elephant density norms across the landscape would result in localised high densities with an impact sufficient to cause the demise of individual plant species. This would be contrary to the primary conservation aims of the SGR.

Conclusions

The use of the SGR by elephants is patchy in terms of area selection, with some parts of the reserve being distinctly favoured. This might be because of social or behavioral reasons, as other parts of the reserve supports similar vegetation communities. Within favoured areas, individual vegetation communities and woody species are selected differentially. Utilisation of certain of these species impacts negatively on its numbers with many individual plants being killed. This is partly because certain species do not coppice (*Aloe marlothii* spp. *marlothii*), whilst other are physically annihilated (*Cussonia spicata*).

Overall density figures for elephant within a heterogeneous landscape as found in the SGR are meaningless in terms of quantifying their likely impact. A detailed assessment in terms of the actual areas and species selected is necessary to evaluate their impact. This must be put in perspective with the management objectives set for each area.

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