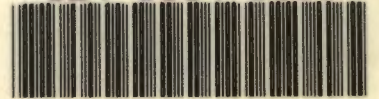


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The effect of elephant and goat herbivory
on the endemic component of subtropical
thicket in the south-eastern Cape

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ABSTRACT The effect of herbivory on plant groups overrepresented amongst endemics in subtropical thicket in the south-eastern Cape was investigated in terms of three treatments: Reserve (low intensity herbivory), elephant and goat browsed. The plant groups included geophytes and three succulent groups Crassulaceae, Mesembryanthemaceae and "other" succulents (Euphorbiaceae, Asteraceae and Lilliaceae). The highest percentage cover and species diversity of all three succulent groups were recorded in the reserve treatment; the geophyte group did not have any significant differences between treatments. The goat treatment had the lowest percentage cover and species diversity of the three treatments. Twenty-seven percent of the species recorded were endemic to the south-eastern Cape. Significantly less endemic species were recorded in the goat treatment as compared to the other treatments. Since the southeastern Cape is a centre of endemism for these large and important succulent families it is argued that greater protection of this vegetation is needed. Further, it is suggested that, given the severe decline of the endemic component under goat browsing, alternative uses, more compatible with the vegetation are required.

INTRODUCTION

Four biomes converge in the eastern Cape; Tongoland-Pondoland, Karoo-Namib, Cape and Afromontane. The area, which has representatives of all the major South African vegetation formations, is rich in species although endemism is relatively low (Hoffman & Cowling, 1990 and 1991). The plant community in this area with the largest number of endemics (30%) and threatened species (18%) is the Valley Bushveld (Lubke et al, 1986). This Subtropical Thicket has the highest conservation priority since it is being cleared at an increasing rate and is extremely vulnerable due to farming practises. Only some 3% of the region is protected and some of the vegetation types do not occur in the protected areas.

The Valley Bushveld is mostly confined to the hot dry river valleys. The vegetation is dominated by evergreen sclerophyllous shrubs, climbers and succulents especially species of *Euphorbia*, *Crassula*, *Aloe*, *Delosperma*; however, the spekboom, *Portulacaria afra*, is the most ubiquitous species both in terms of density and cover (see Cowling, 1983; Hoffman & Cowling, 1991; for a more detailed description of the region's phytochorology and physical attributes). *P. afra* is a fleshy, slightly woody shrub or tree up to three meters tall, but more often in a sprawling growth (Palgraves, 1988) and is the most important species in

this vegetation type with respect to forage production. This species has no thorns and its nutritious, succulent leaves are palatable, producing up to 59% of the browsable plant material in the valley bushveld (Aucamp & Howe, 1979). However, even though *P. afra* is eminently suited for browsing it is extremely sensitive to over-utilization by goats and its poor condition is often an indication of over-browsing.

a, b or c?

Stuart-Hill (1991) has shown that *P. afra* has a specific growth form or architecture which has enormous implications as to the browsing damage inflicted by different species of herbivores. Given that *P. afra* can have relative densities of between 20% to 60% and account for up to 60% of the canopy volume (Stuart-Hill, 1991) its demise from this vegetation type should hold severe implications for other species associated with this community.

The purpose of this investigation was to establish how the major succulent families; Crassulaceae, Mesembryanthameceae, Euphorbiaceae responded to goat browsing as compared to elephant browsing as well as to low intensity browsing. Before modern agriculture elephant probably had the greatest impact on plant community structure, this has now been replaced by goat herbivory. Elephants have been an integral part of this vegetation long before man it is reasonable to expect that the plant species have evolved under conditions of elephant browsing. Any

radical departure from this state may well lead to the demise of some species. The questions asked are whether the valley bushveld can actually support goat farming and if it cannot, what are possible alternative land usages which are compatible to long term utilization and conservation?

This investigation concentrates on geophyte and succulent species associated with the valley bushveld community. In the valley bushveld, the families Euphorbiaceae and Mesembryanthemaceae are overrepresented in terms of endemic species (Cowling and Holmes (1991) and Cowling (pers. comm.)). Further, Cowling and Holmes (1991) show that geophyte, succulent, dwarf shrub and ant-dispersed species are overrepresented as endemics in the subtropical thicket. Thus, an endemic in the valley bushveld is likely to be a low succulent shrub or geophyte with ant-dispersed seeds. Since the present study is aimed at the endemic component of the valley bushveld, I have concentrated on species with these attributes. Species with these attributes were collected and placed into one of four groups, namely Geophytes and three succulent groups, Crassulaceae, Mesembryanthemaceae and "Other" succulents. The "Other" succulents included the families Euphorbiaceae, Asteraceae and succulent members of the Lilliaceae. Taller shrubs and trees with bird-dispersed fruits (the dominant component in valley bushveld) are underrepresented as endemics (Cowling & Holmes, 1991) and thus these species were not taken into account.

Each of these four groups were investigated in terms of their respective responses to no browsing (Reserve sites), elephant browsing and Goatbrowsing. All three these treatments occur in close proximity to each other in the same vegetation and thus comparisons between treatments are valid. Within each treatment three micro-habitats were identified, namely in the open (Open), under *Portulacaria afra* (*Portulacaria*) and under *Euclea undulata* (*Euclea*) trees. In other words, endemism as well as geophyte and succulent response to the different treatments within each habitat were investigated. The null hypotheses I used state that no difference in percentage cover, species diversity or endemism existed among the three treatments and on another level, the three micro-habitats identified did not show differences in geophyte and succulent community structure in response to treatment.

Stuart-Hill (1991) has established the different effects that elephant and goat browsing have on *P. afra*, as well as 23 other species. Since the present study is an extension of Stuart-Hill's (1991) initial research I summarize his findings. In his study Stuart-Hill (1991) compared elephant and goat browsing damage to *P. afra*. Essentially this species has a weak central trunk while branches from the crown droop down to the ground, forming a supportive "skirt". Elephants browse from the top inflicting great damage but leaving this "skirt" intact. Goats, because of their much smaller size, browse the spekboom from the

side severely damaging the "skirt". Not only is the "skirt" essential in the support of the plant, but *P. afra* reproduces almost only vegetatively and this occurs from the "skirt" edges (Midgley and von Malitz, 1991). Thus, damage of the "skirt" leads to reduced reproductive output and severe goat browsing can lead to an "umbrella" shaped tree which eventually collapses and dies under the weight of the crown. Overstocking of goats have thus caused severe damage to *P. afra*, decreasing both its density as well as cover.

In the same study Stuart-Hill (1991) investigated 23 agriculturally important ^{large shrub and tree} species other than *P. afra* and found that on the goat browsed sites seven of the species showed a decline in percentage frequency (relative to the other sites) and only the unpalatable *Zygothymus argenteus* seemed to have increased under goat browsed conditions. Most importantly, goat browsed sites showed a severe decline in *P. afra* density and cover, thus reducing forage (Stuart-Hill, 1991). The elephant browsed sites had less *P. afra* cover than the non-browsed sites, but a greater percentage cover and diversity than goat browsed sites.

In a non-modified or underbrowsed condition, the valley bushveld vegetation is dominated by *P. afra* which can reach relative canopy volumes of between 50 and 60% and a above-ground wet mass of between 80 000 and 200 000 kg ha⁻¹, this is about half of the total phytomass (Stuart-Hill, 1991; Penzhorn et al, 1974 and Aucamp 1979). However, only about 3.3% of the total phytomass is available as forage (Aucamp

Why is this?

and Tainton, 1984). This fact is a probable reason for the poor state valley bushveld is in; i.e. there seems to be much more forage than there actually is.

Coupled to the small amount of actual forage available is the slow growth and recovery rate of *P. afra* and thus periods of rest are necessary in order to allow the veld to recover. After a 50% defoliation it takes *P. afra* about 275 days to recover (Aucamp et al, 1980) and thus camps cannot be used as browse for the better part of a year. Aucamp et al (1980) suggest that given the Valley Bushveld's heterogeneous growth forms, farmers would do better by stocking different types of animals, that is, both browsers and grazers to exploit the grass and shrub components of this vegetation (Aucamp and Barnard, 1980).

Goat browsing *per se* is not damaging, but overstocking with these animals can lead to vegetation degradation. In the Valley Bushveld farmers with low stocking rates (relative to overstocked farms in the district) seldom if ever have irreparable damage to their vegetation (Stuart-Hill, 1991). But, it is not as simple to merely keep to low stocking rates since they are not always economically feasible; thus, the farmer has to contend with the opposite pressures of protecting his vegetation and stocking with enough goats so as to survive financially. Stuart-Hill (1991) suggests that Valley Bushveld cannot carry livestock economically without damage and thus it may be more feasible

to switch to game, especially elephant. Revenues coming from tourism and hunting.

Midgley and von Malitz (1991) note that not much is known about the Valley Bushveld. When they investigated this vegetation they found a puzzling lack of seedlings for most species, especially *P. afra*, the ground layer being mostly bare. *P. afra* reproduces mostly vegetatively even though it flowers profusely and produces seeds. Midgley and von Malitz (1991) found *P. afra* seedlings only in the Baviaanskloof in open habitats, suggesting that this tree can only establish in the open where there is a minimum of herbivore activity. Several other workers have noted the little or no recruitment through seedling establishment (eg. Everard & Hoffman, 1987; Stuart-Hill, 1991) and Palmer (1990) has suggested that this vegetation is a relict community from a wetter and warmer period (between 12000 and 6000 years ago). The community is able to persist by growing in "bush clumps" which create a micro-environment where essential community processes, such as seedling recruitment, can occur. Destruction of these clumps disrupts this process and the vegetation is not able to recover given the present climate. The practical implication of this is that once an area has been denuded by overbrowsing an important resource is lost forever.

Hoffman and Cowling (1990) investigated the desertification of the Sundays River Valley (which includes the Valley Bushveld); i.e. expansion of the karroid

shrublands into the adjacent succulent subtropical thicket. The Valley Bushveld which is dominated by longlived, perennial trees and shrubs has no marked fluctuations in populations and can be thought to be stable (especially relative to the Karoo communities). Whereas the Karoo with its fluctuating annual populations is resilient to grazing, the Valley Bushveld is sensitive to sustained grazing. Hoffman and Cowling (1990) found no evidence of the karroid invasion (except in the Noorsveld) at the expense of the subtropical thicket. However there is a trend of community change (mostly due to farming practises) where in general the cover of mid-high and tall evergreen trees and shrubs is decreasing and that of dwarf deciduous shrubs and annual grasses is increasing. This points to an alarming trend of the communities changing from perennial to ephemeral resource bases, that is, a decrease in grazing production and thus carrying capacity. In drought years all forage may disappear (Hoffman & Cowling, 1990).

The discussion about the destruction that overstocking with goats can cause, distracts one from the destructive power of elephants. Eating more than 300kg per day (Smithers, 1983) these behemoths have great ecological impact in their environments (Cohn, 1990). They are indeed only second to man in their capacity for altering their environment and when they exceed the carrying capacity they wreak devastation, thus controlling their populations in confined reserves is imperative. This destructive potential

has been an important feature in many African ecosystems over the millennia (Cumming, 1982). The absence of these mega-herbivores from their former habitats must have consequences we can only guess at. But, the continued confinement of these animals in small conservancies imposes conflicting pressures on managers of such areas, stocking at ecological sound levels cause tourists (the supposed financial justification for the park) to complain about too few actual observations of elephants or any other game for that matter.

The Addo Elephant National Park is the last refuge for elephants in the Cape Province (Figure 1). The park was proclaimed in 1931 in order to protect the last remaining elephants ten years after Major P.J. Pretorius was commissioned to "eradicate the entire population of 130-140 elephant", a "few months" later only 11 elephants were left to protect (Penzhorn et al, 1974). Prior to 1954 the park fence was not elephant-proof and many animals straying onto neighbouring farms had to be shot. The initial "elephant camp" was 2270 ha, but Penzhorn et al (1974) reported that the then population of 60 animals were over-utilizing the vegetation. Since then this camp has been expanded three times, in 1977, 1982 and 1984 reaching its present size of 8200 ha; a further 400 ha has been set aside as botanical reserves excluding elephants, Figure 1 (Novellie, 1991). At present almost 170 elephant roam the park, a density of about 2.3 elephants km^{-2} and current over-utilization of the

vegetation by elephants is evident (eg. Barratt & Hall-Martin, 1991; Stuart-Hill, 1991). Elephants seem to have eliminated some species, it has been noted (Penzhorn, 1974) that *Aloe africana* is absent from the Park while it is abundant outside. There is also evidence from aerial photographs (Midgley, 1991) that an arborescent *Euphorbia* species, either *E. tetragona* or *E. triangularis*, has also disappeared from the Park.

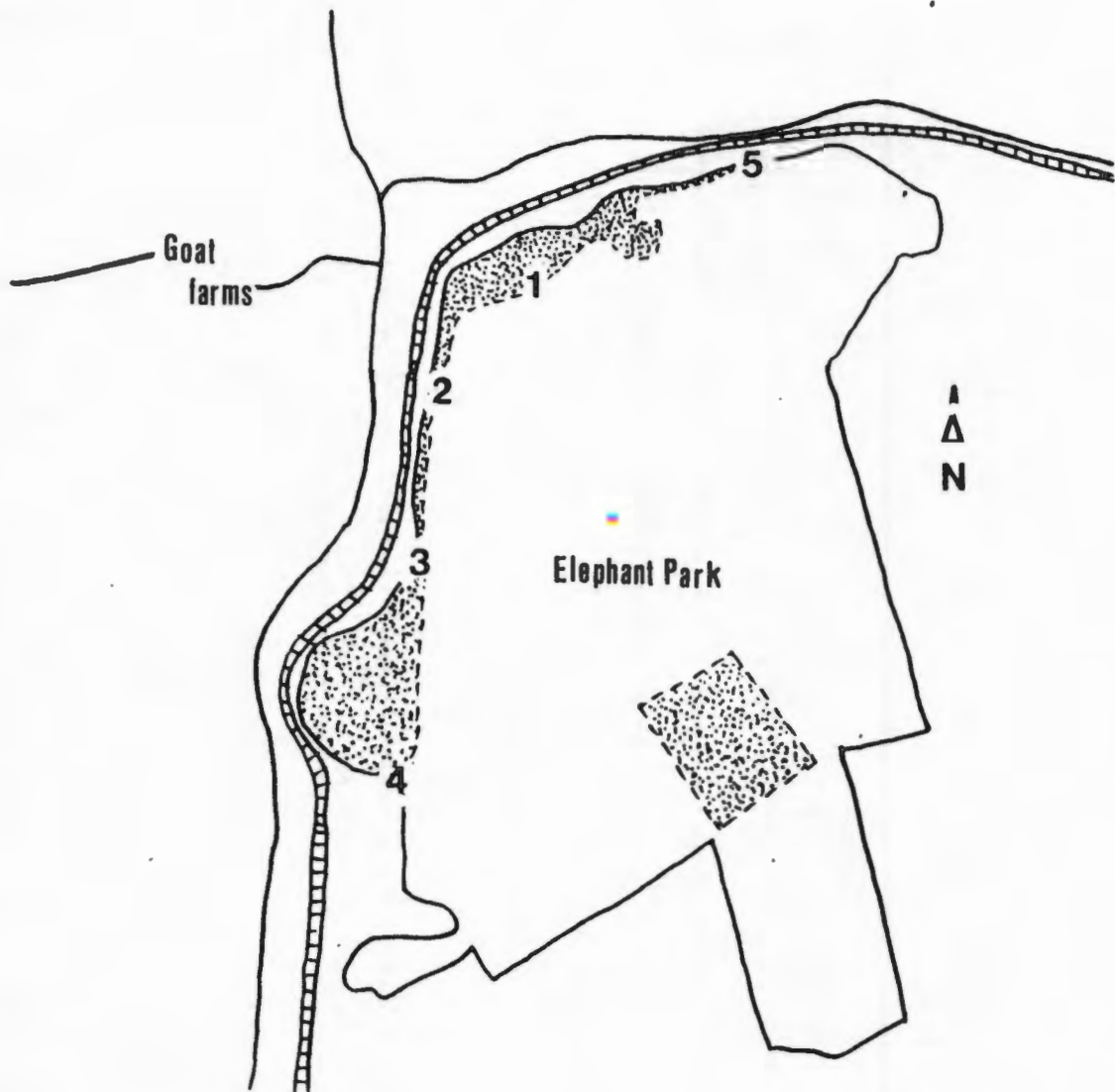


Figure 1 Map of the Addo Elephant National Park showing present boundaries. Sites sampled are marked with a number. The areas in which the different treatments of Reserve, Elephant and Goat browsing applied are marked on the map. The Botanical Reserves are shaded on the map. Modified from Novellie (1991) and Stuart-Hill (1991).

METHODS

VEGETATION DESCRIPTION

The vegetation in and around the Addo Elephant National Park is known as subtropical thicket (Everard, 1991), valley bushveld (Acocks, 1975) or succulent valley bushveld (Stuart-Hill, 1989). It is a dense, often impenetrable, vegetation consisting of a mixture of spinescent shrubs, low trees, vines and succulents. Structurally it is dominated by evergreen and semi-evergreen sclerophyllous shrubs and succulents with a low to mid-high (2-8 m) closed or near closed canopy. Floristically, this vegetation type is relatively rich with high species richness and alpha diversity (many species per plot), but is low in beta diversity (same species occur from plot to plot) (Everard, 1991). Endemics are generally few, most being succulents of karroid affinity (species of *Euphorbia*, *Crassula*, *Mesembryanthemaceae*, *Aloe*) (Everard, 1991; Cowling & Holmes, 1991).

Cowling and Holmes (1991) suggest that the biogeographical affinities of valley bushveld are extremely complex with the overstory shrub or tree stratum being largely derived from an African tropical thicket penetrating the south-eastern Cape along the coast and up the major river valleys. Few endemics are associated with this component. The understory shrubs and herbs are mainly of

Karoo-Namib affinity and endemic species are mostly associated with this component. The families Mesembryanthemaceae and Euphorbiaceae are overrepresented in terms of endemic species (Cowling & Holmes, 1991). Grasses are present, but sparse and mostly non-perennial (Acocks, 1975).

STUDY AREA

The Addo Elephant National Park (33°31'S, 25°45'E) is situated about 60 km north of Port Elizabeth in the eastern Cape Province. Rainfall in the region is low (annual mean 480 mm) and largely non-seasonal. Average daily temperature in January is 32.4°C, although temperatures above 40°C regularly occur; in July the daily average is about 13.5°C with frosts being extremely rare. An important feature of the eastern Cape climate is that rainfall is mostly unpredictable and the region is prone to droughts.

The park and surrounding areas consist of low undulating hills (altitude between 76 and 341 m). The soil is a light-red clay loam (Archibald, 1955) derived from sandstone and mudstone of the Sundays River Stage, Uitenhage Series, Cretaceous system (Toerien, 1972).

PROCEDURE

Since the present study builds on Stuart-Hill's (1991) investigation his procedure was used as a guide. Three treatments were identified: 1) botanical reserves from which

both elephants and goats have been excluded (Reserve); 2) areas in the park where elephants have access (Elephant); 3) areas outside the park where goat browsing predominates (Goat). Within each treatment other indigenous herbivores were present although probably at different stocking rates (Stuart-Hill, 1991). Elephants contribute about to 78% of the approximately 50 kg ha^{-1} stocking rate presently followed in the park and it is thus realistic to attribute most of the herbivore activity in the park to them (Stuart-Hill, 1991). Farms have different stocking rates, some exceeding the $36\text{--}50 \text{ kg ha}^{-1}$ recommended (Stuart-Hill, 1990).

Stuart-Hill (1991) identified seven sampling sites along the perimeter of the park using the following criteria: at each site all three treatments had to be in close proximity; none of the sites were previously cultivated; and sites represented different farms, and in the park, various histories of elephant usage. Two of the seven sites Stuart-Hill (1991) identified had no associated botanical reserve and the present study did not sample these sites. Instead, the five sites along the northern and western park perimeters were sampled. At each site all three treatments were in close proximity, Reserve and Elephant treatments were separated by a fence and access road at all sites where-as the Goat treatments at three sites were across a main road, but never more than 150 m away and always on the same contour line and aspect than the other two associated treatments.

Rectangular plots of approximately 100 m by 25 m parallel to the park fence were chosen in each of the treatments (i.e. Reserve, Elephant and goat) at all of the five sites (Figure 1). Thus, at each site three 100 m by 25 m plots; one for each treatment; were subsampled. Three micro-habitats were identified within each plot, namely open (Open), under *Portulacaria afra* (Portulacaria) and under *Euclea undulata* (Euclea) habitats. Each of these three habitats were sub-sampled with 20 one meter square quadrants, i.e. for each plot 60 and for each site 180 one meter square quadrants. These are pseudo-replicates and were not used statistically; the quadrants were placed as randomly as possible and only used as a means to sub-sample the plots; true replication for statistical purposes was obtained by having five sites for each treatment (i.e. $n = 5$).

Each growth form, as well as all growth forms collectively, were investigated in terms of their response to the treatments in each of the three habitat types. This response was measured in terms of percentage cover, number of species and number of species per square meter. In a square meter quadrant the percentage cover of all succulent species in the understory; i.e. excluding vines, grasses and woody plants; were recorded. Common and known species were identified in the field; unknown species were collected and identified in the Bolus Herbarium, University of Cape Town.

From these data the number of species and species per square meter; in each of the habitats in each of the treatments; were calculated and every species collected assigned to one of the following growth-form/taxon classes: geophytes, Crassulaceae, Mesembryanthemaceae and "other" succulents (i.e. Euphorbiaceae, succulent Asteraceae and Liliaceae). From the three types of data (% cover, no. spp and spp m⁻²) the fate of the different growth forms in the different habitats within each treatment were graphically illustrated. Two-way analyses of variance were applied to detect differences between treatments as well as between habitats for each growth-form/taxon group. In the case of percentage cover, percentages were converted to arcsin values before analyses of variance were done.

Species endemic to the south-eastern Cape were identified (from Bolus Herbarium records; Hoffman & Cowling, 1991; Bond & Goldblatt, 1984) and assigned to one of the growth-form/taxon classes. From these data the fate of endemic species in the different habitats within each treatment were plotted. A two-way analysis of variance was used to detect differences between treatments as well as habitats in terms of endemics. Chi-square analyses firstly compared treatments and then habitats in terms of endemic ^{categories} species.

The data collected were also used to compile a species by treatment/habitat table which was then used to obtain similarity and dissimilarity tables. This was done by using

the co-efficient of community (eg. Smith, 1980) to determine the degree of similarity among communities:

$$C = 2W/(a+b)$$

where

a = sum of scores for one stand

b = sum of scores for second stand

W = sum of lower scores for each species

communities were compared pairwise and placed in a matrix of similarity from which a matrix of dissimilarity was determined by subtracting similarity values from one.

The position of the communities along the ordination axes were determined by calculating values for each community along the x and y axes using the Bray-Curtis method (eg. Smith, 1980). First the terminal points were chosen: dissimilarity values between each and every other stand were summed and the stand with the highest total of dissimilarity values was placed at the 0 point (A) along the x axis (the Elephant treatment - Open habitat community). The site with the greatest dissimilarity to the above 0 point was placed at the end point (B) of the x axis (i.e. Goat - Portulacaria community). The remaining stands were placed along the x axis a given distance, D, from the 0 point using the equation

$$D_x = (L^2 + DA^2 - DB^2)/2L$$

where

L = dissimilarity value between A and B

DA = dissimilarity value between A and stand in question

DB = dissimilarity value between B and stand in question

Calculation of the y coordinate went as follows: the stand with the poorest fit along the x axis was determined by calculating a poorness of fit value, e , for each stand using the equation

$$e = \sqrt{DA^2 - x^2}$$

the stand with the largest e value was placed at the 0 point (A') along the y axis (Reserve - Euclea community). The stand with the greatest dissimilarity to A' and located (0.1)L of A' along the x axis was chosen as the end point (B') along the y axis (i.e. Goat - Open community). The remaining stands were positioned at a given distance, D_y , from A' (as with the x axis), using the equation

$$D_y = (L^2 + DA'^2 - DB'^2)/2L$$

where

L = dissimilarity value between A' and B'

DA' = dissimilarity value between A' and stand in question

DB' = dissimilarity value between B' and stand in question

With the x and y coordinates for each stand calculated communities were plotted in two-dimensional ordination space.

RESULTS

ENDEMISM

Of the seventy-three geophyte and succulent species recorded, twenty were endemics; i.e. 27.3% of the geophyte

and succulent species recorded were endemics. Of the endemics recorded 50% belonged to the Mesembryanthemaceae; Crassulaceae and Euphorbiaceae also had a high proportion of endemics, 20% and 15% respectively (endemics are marked on the species list in appendix). Table 1 shows Chi-squared analyses comparing treatments and habitats in terms of endemics. There were no significant differences between the treatments; Reserve, Elephants and goats; in the frequency of endemics, i.e. endemics were not over- or under-represented in any particular treatment. Furthermore, no habitat had more or less endemics (frequency-wise) as compared to the other habitats. Only ten (50%) of the endemic species occurred in the Goat treatment whereas nineteen (95%) endemics were recorded in the Reserve treatment.

The number of endemic species in each growth-form/taxon group; and all groups collectively; in the different treatments are graphically illustrated in Figure 2. See Table 2 for two-way ANOVA's testing whether differences between treatments as well as habitats, apparent from the graphs, are significant.

All groups collectively had more endemic species in the Reserve treatment as compared to both the other two treatments, whereas the Elephant treatment had more endemic species than the Goat treatment (Figure 2 a). Geophyte endemics did not show any significant differences between treatments, but all three succulent groups had significantly

more endemic species in the Reserve treatment as compared to the Elephant and Goat treatments (Figure 2 b], c], d] and e]; see Table 2 for significance tests). Most of the endemic species recorded were found in Open habitats across all treatments and this trend is also apparent in both Crassulaceae and Mesembryanthemaceae.

Table 1 Number (% in brackets) of endemic and non-endemic species in the different treatments in each of the habitats; percentage endemism is also given. Two Chi-squared analyses were done: the different treatments; Reserve, Elephant and Goat; were compared with habitats combined. The second Chi-square analysis combined the different treatments and compared the habitats; Open, *Portulacaria* and *Euclea*.

<u>Treatment</u>	<u>Reserve</u>	<u>Elephant</u>	<u>Goat</u>
Endemics	19 (31.2)	12 (24.5)	10 (28.6)
Non-endemics	42 (68.8)	37 (75.5)	25 (71.4)
Chi-square comparison of treatments:			
$\chi^2 = 0.055$ $df. = 2$ $p = 0.972$			
<u>Habitat</u>	<u>Open</u>	<u>Portulacaria</u>	<u>Euclea</u>
Endemics	18 (24.6)	8 (28.5)	14 (26.9)
Non-endemics	55 (75.3)	20 (71.5)	38 (73.1)
Chi-square comparison of habitats:			
$\chi^2 = 0.675$ $df. = 2$ $p = 0.713$			

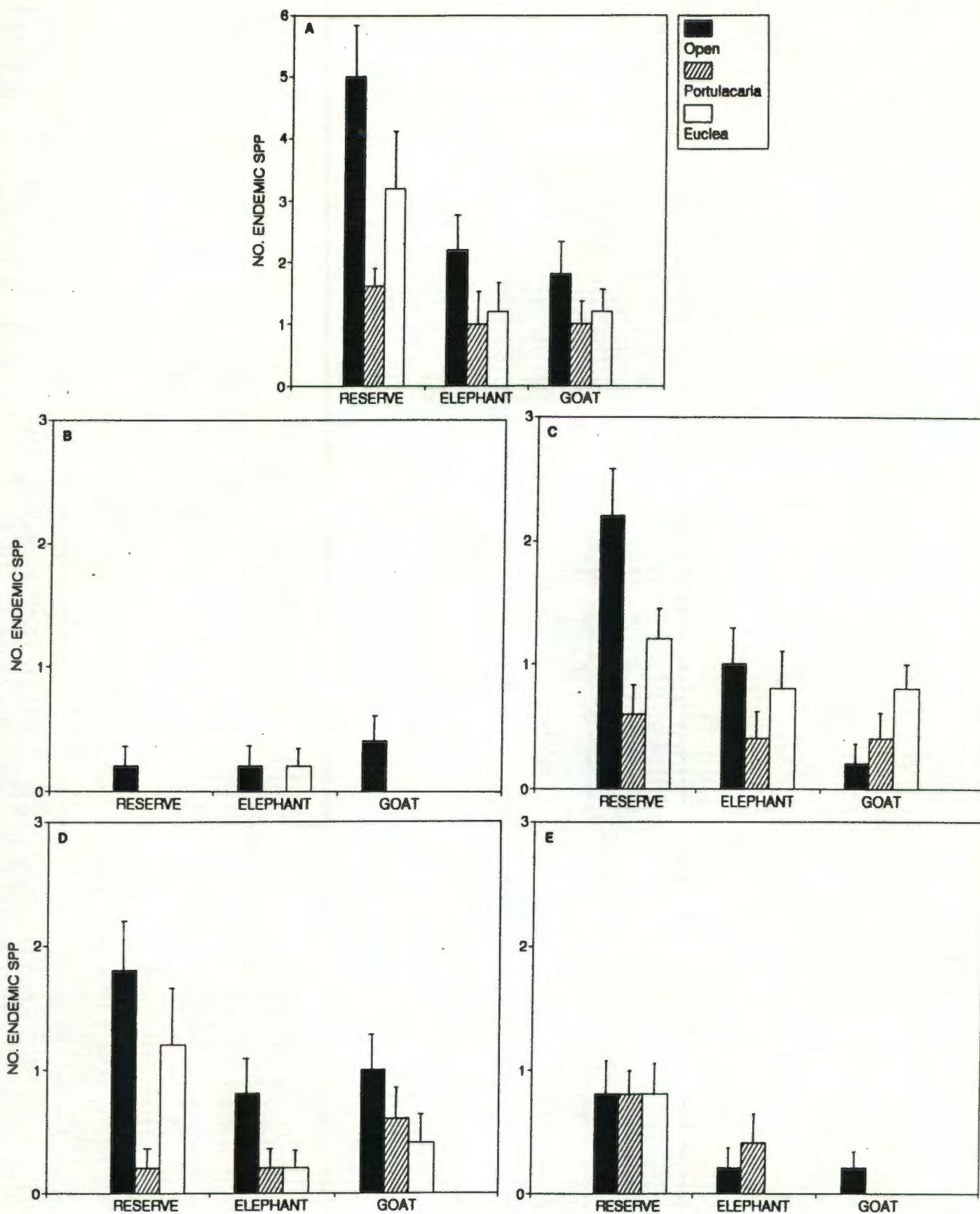


Figure 2 Number of endemic geophyte and succulent species in each of the three different treatments, namely: Reserve (low browsing intensity), Elephant and Goat. a) no. endemics of all geophyte and succulent species; b) no. Geophyte endemics; c) no. Crassulaceae endemics; d) no. Mesembryanthemaceae endemics and e) no. "Other" succulent species. Response within each treatment has been divided into the three habitat types identified: Open, *Portulacaria* and *Euclea*. Note the difference in y axis in a) as compared to the other graphs.

Table 2 Two-way analyses of variance comparing the number of endemic species of the different growth-forms in terms of treatment (Reserve, Elephant and Goat) and habitat (Open, *Portulacaria* and *Euclea*). n = 5

	df.	F-value	P.
a) <u>All groups:</u>			
Treatment	2	7.949	0.0014
Habitat	2	5.646	0.0074
Interaction	4	1.131	0.3572
b) <u>Geophytes:</u>			
Treatment	2	0.222	0.8018
Habitat	2	2.889	0.0686
Interactions	4	0.556	0.6963
c) <u>Crassula:</u>			
Treatment	2	9.172	0.0006
Habitat	2	5.448	0.0086
Interactions	4	3.793	0.0113
d) <u>Mesembryanthemaceae:</u>			
Treatment	2	2.621	0.0866
Habitat	2	4.586	0.0168
Interactions	4	1.069	0.3861
e) <u>Other succulents:</u>			
Treatment	2	7.357	0.0021
Habitat	2	0.286	0.7532
Interactions	4	0.286	0.8853

ORDINATION

The positions of the sites in two-dimensional ordination space are shown in Figure 3. Treatment appears to have had the greatest effect, ^aseparating the Goat sites from the Reserve and Elephant sites. Habitat differences were the next most important in determining community structure, Open habitats being the most dissimilar from the other habitat types. If there had been no treatment effect one would expect the sites to cluster according to habitat; further, had there been no treatment or habitat effect one would expect sites to either cluster close together or spread out randomly in ordination space. In other words, factors such as treatment and habitat are thought to be affecting community structure.

Ordination axis 2 in Figure 3 seems to be related to treatment with the Goat treatment separating vertically from the Reserve and Elephant treatments. Ordination axis 1 appears to be related to habitat differences; i.e. the understory habitats (*Portulacaria* and *Euclea*) are close together in ordination space, separated horizontally from Open habitats.

While geophyte and succulent community structure is similar under Reserve and Elephant treatments, community structure under the Goat treatment is changed. That Open habitats are dissimilar from the under canopy habitats (*Portulacaria* and *Euclea*) is not unexpected given the

respective presence or absence of an overstory which can change micro-habitat conditions dramatically.

In other words, the Reserve and Elephant treatments are in general much more similar to each other than either is to the Goat treatment. Within each treatment the *Portulacaria* and *Euclea* habitats are more similar to each other than to the Open habitats; this is especially true for the Reserve and Elephant treatments, as compared to the Goat treatment. In all three treatments the Open habitats are more dissimilar than their other respective habitats and in both the Elephant and Goat treatments this trend is particularly pronounced; i.e. Elephant and Goat Open-habitats are very dissimilar than the rest of the treatment/habitats, further both of these two treatment/habitats are very dissimilar from each other.

GEOPHYTE AND SUCCULENT RESPONSE

The percentage cover, number of species and species m^{-2} , of each growth form; and all growth forms collectively; in the different treatments, are illustrated graphically in Figures 4 - 6. Each treatment has been divided into the three habitat types: Open, *Portulacaria* and *Euclea*. See Tables 3 - 5 for two-way ANOVA's testing whether differences between treatments as well as between habitats, evident from the graphs, are significant.

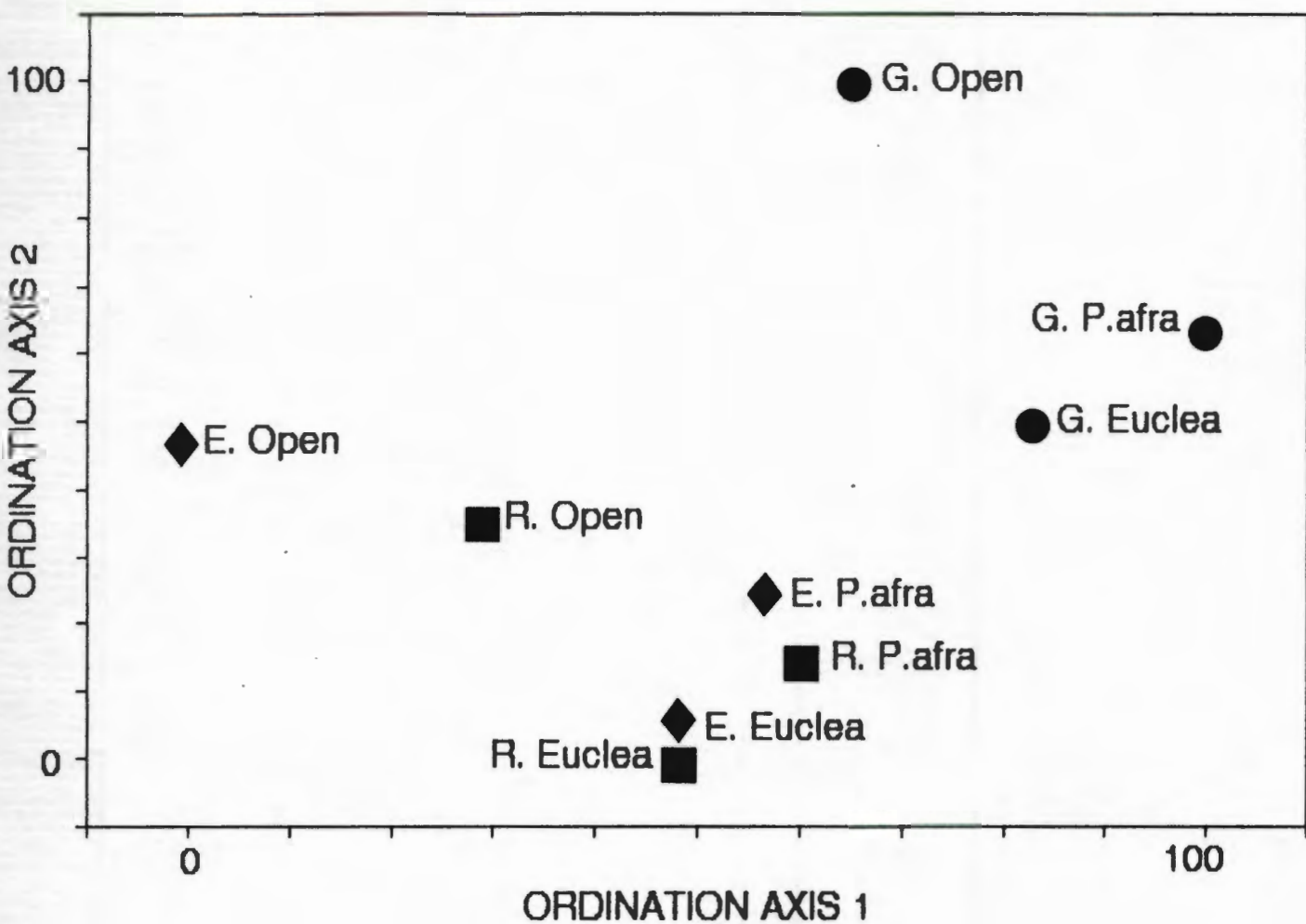


Figure 3 Scatter diagram showing the ordination of sites. Sites are labeled according to treatment; Reserve (R), Elephant (E) and Goat(G); with the corresponding habitats (Open, under *Portulacaria* and *Euclea*).

All four growth form groups collectively followed a general trend of maximum percentage cover, number of species and species m^{-2} , in the Reserve treatment while the Goat treatment resulted in minimum values for these parameters (Figures 4 a], 5 a] and 6 a]). In the Elephant treatment values intermediate to these two extremes were recorded. In other words, the Reserve treatment had the highest cover and species richness which decreased under the Elephant treatment and even more so under the Goat treatment.

Across all treatments *Portulacaria* habitats had the least cover and species richness. On the other hand, Open habitats under the Reserve treatment were remarkably species rich with a relatively high number of total species (19) and a high species density ($3.71 m^{-2}$); further, the 29.3% geophyte and succulent cover recorded for this habitat was the highest cover measured across all treatments and habitats. Under the Elephant treatment Open habitats had lower percentage cover than *Euclea* habitats; in fact, the percentage cover of geophytes and succulents in Open-Elephant sites were only a sixth of that in Reserve-Open sites.

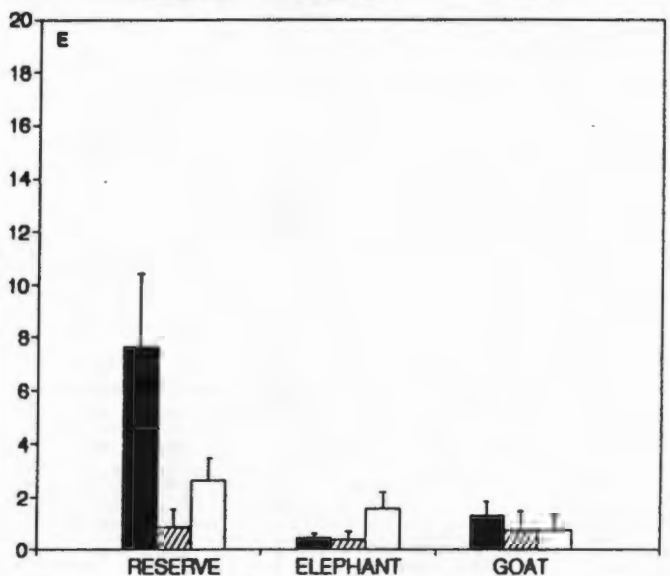
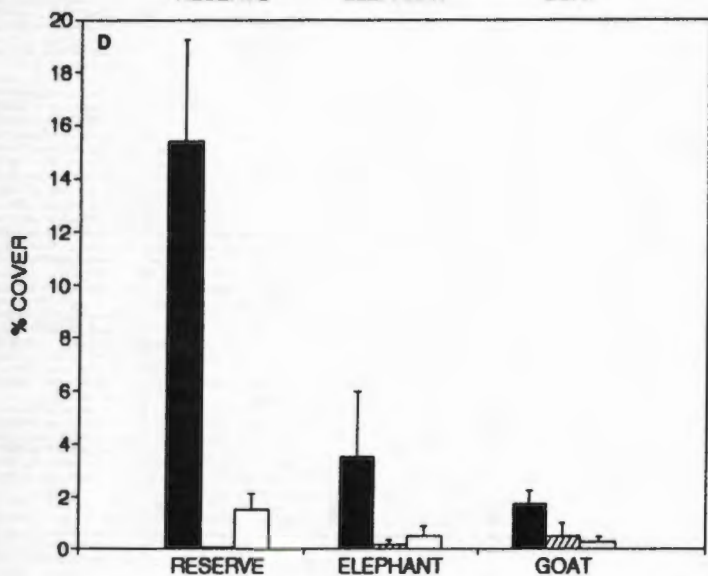
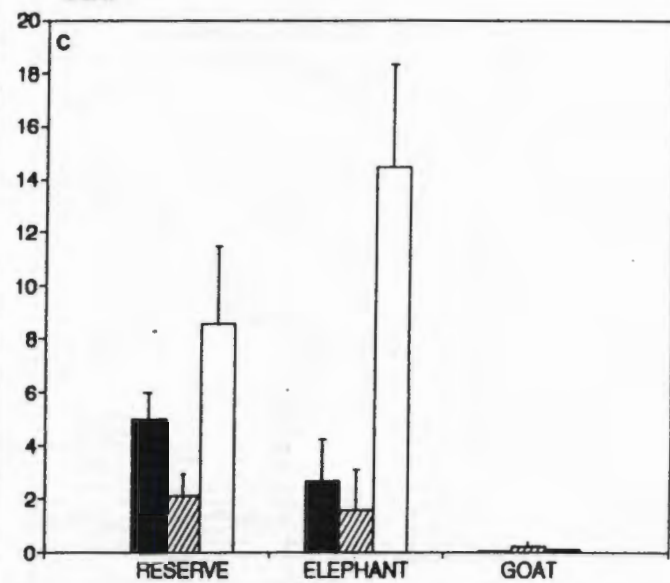
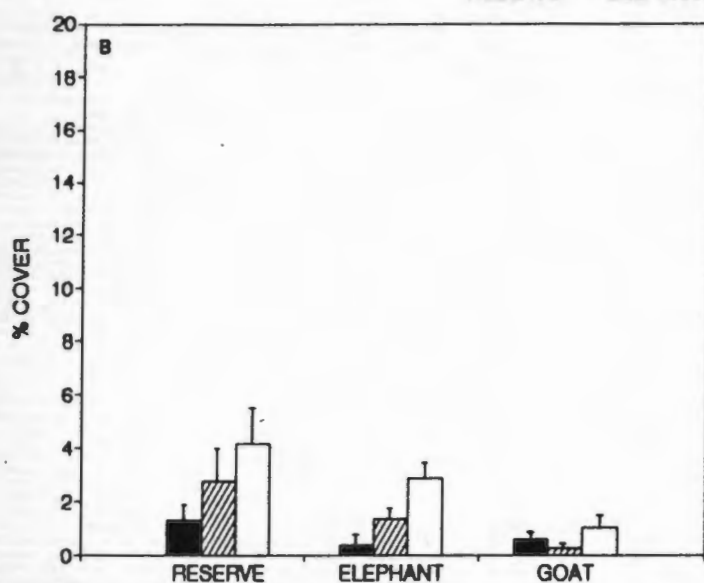
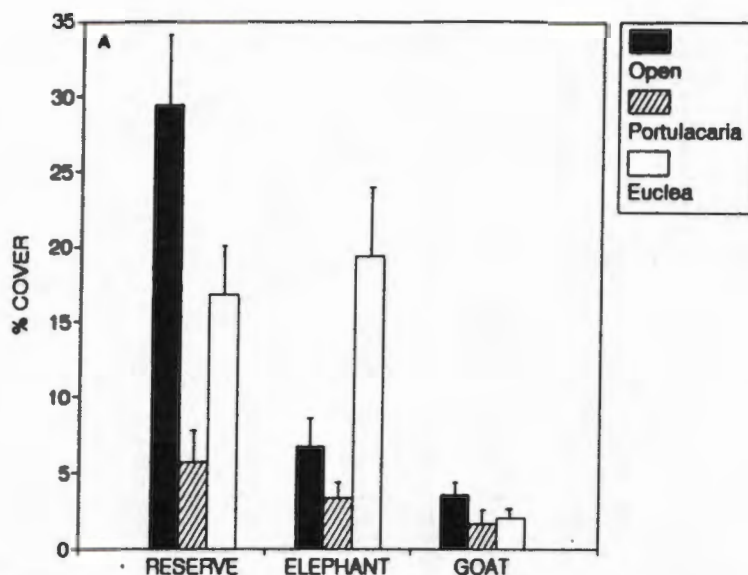


Figure 4 Percentage cover of geophyte and succulent species in each of the three different treatments, namely: Reserve (low browsing intensity), Elephant and goat. a) % cover of all geophyte and succulent species; b) % cover of geophytes; c) % cover of Crassulaceae; d) % cover of Mesembryanthemaceae and e) % cover of "other" succulent species. Response within each treatment has been divided into the three habitat types identified: Open, Portulacaria and Euclea. Note that the y axis scale in a) is different to that in the other graphs.

Table 3 Two-way analyses of variance comparing the percentage cover of the different growth-forms in terms of treatment (Reserve, Elephant and goat) and habitat (Open, *Portulacaria* and *Euclea*). Percentage cover values were arcsin transformed prior to analysis of variance. n = 5

	df.	F-value	P.
a) <u>All groups:</u>			
Treatment	2	16.853	0.0000
Habitat	2	8.995	0.0000
Interaction	4	6.583	0.0004
b) <u>Geophytes:</u>			
Treatment	2	6.569	0.0008
Habitat	2	5.473	0.0037
Interactions	4	0.853	0.5013
c) <u>Crassula:</u>			
Treatment	2	6.575	0.0037
Habitat	2	7.280	0.0022
Interactions	4	2.862	0.0371
d) <u>Mesembryanthemaceae:</u>			
Treatment	2	7.464	0.0019
Habitat	2	14.422	0.0000
Interactions	4	6.208	0.0007
e) <u>Other succulents:</u>			
Treatment	2	12.594	0.0001
Habitat	2	7.112	0.0025
Interactions	4	6.552	0.0005

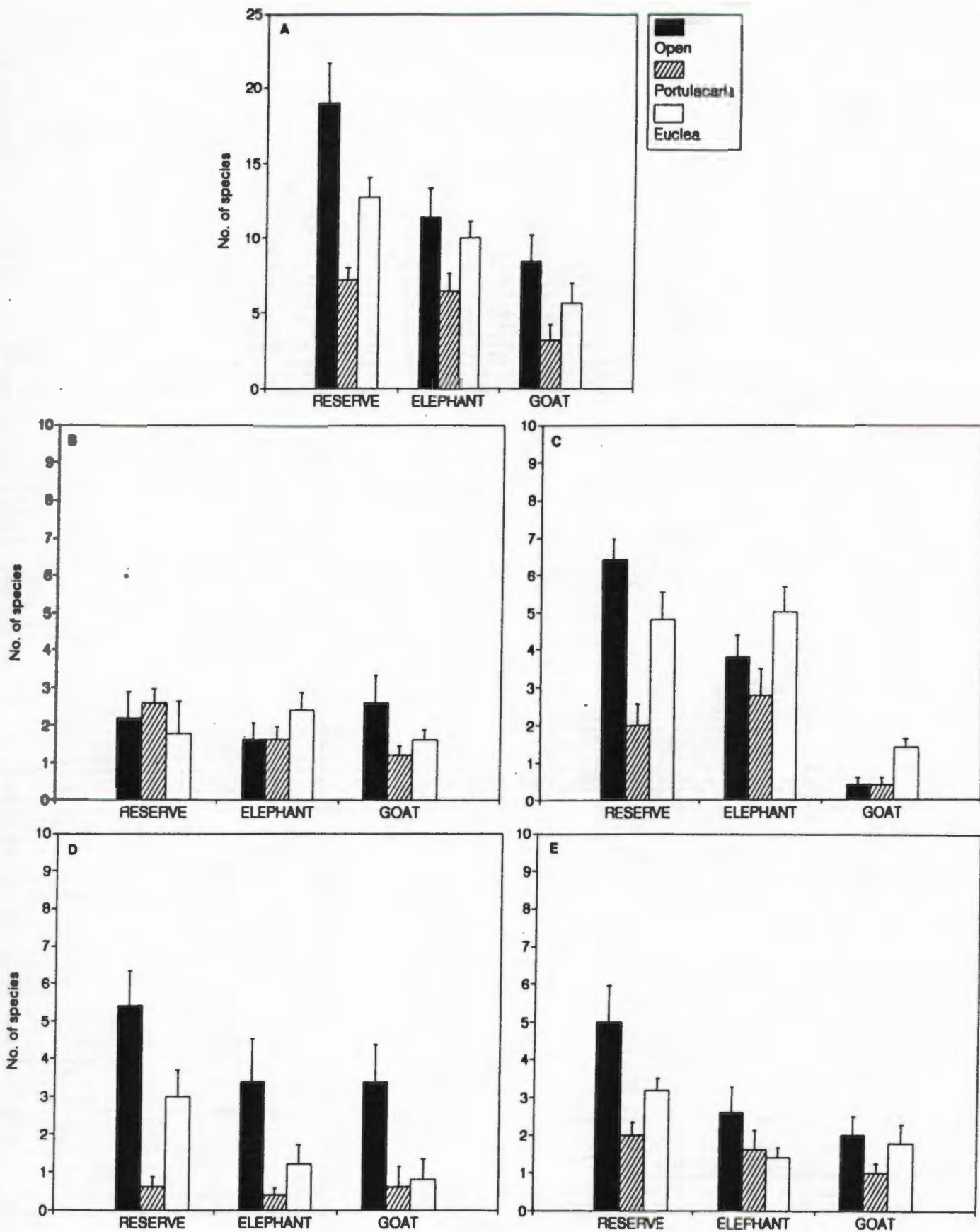


Figure 5 Number of geophyte and succulent species in each of the three different treatments, namely: Reserve (low browsing intensity), Elephant and goat. a) no. spp of all geophyte and succulent species; b) no. spp of geophytes; c) no. spp of Crassulaceae; d) no. spp of Mesembryanthemaceae and e) no. spp of "other" succulents. Response within each treatment has been divided into the three habitat types identified: Open, Portulacaria and Euclea. Note that the y axis scale in a) is different to that in the other graphs.

Table 4 Two-way analyses of variance comparing the number of species of the different growth-forms in terms of treatment (Reserve, Elephant and goat) and habitat (Open, *Portulacaria* and *Euclea*). n = 5

	df.	F-value	P.
a) <u>All groups:</u>			
Treatment	2	13.127	0.0000
Habitat	2	13.378	0.0001
Interaction	4	1.308	0.2856
b) <u>Geophytes:</u>			
Treatment	2	0.481	0.6223
Habitat	2	0.295	0.7466
Interactions	4	1.411	0.2501
c) <u>Crassulias:</u>			
Treatment	2	24.873	0.0000
Habitat	2	7.690	0.0000
Interactions	4	3.028	0.0299
d) <u>Mesembryanthemaceae:</u>			
Treatment	2	2.499	0.0001
Habitat	2	13.039	0.0964
Interactions	4	0.567	0.6883
e) <u>Other succulents:</u>			
Treatment	2	6.962	0.0007
Habitat	2	5.257	0.0028
Interactions	4	1.027	0.4064

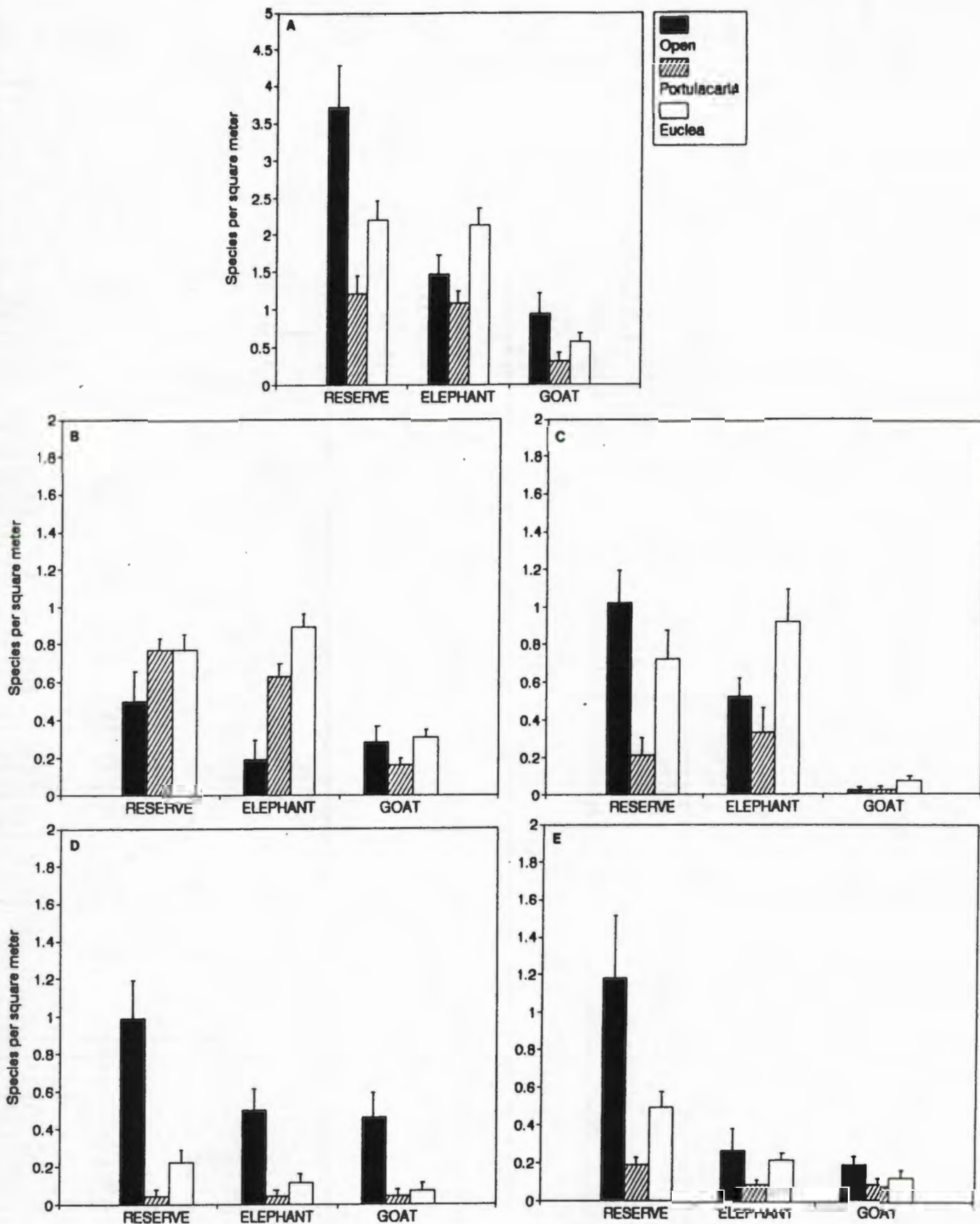


Figure 6 Number of species per square meter of geophyte and succulent species in each of the three different treatments, namely: Reserve (low browsing intensity), Elephant and goat. a) spp. m^{-2} of all geophyte and succulent species; b) spp. m^{-2} of geophytes; c) spp. m^{-2} of Crassulaceae; d) spp. m^{-2} of Mesembryanthemaceae and e) spp. m^{-2} of "other" succulents. Response within each treatment has been divided into the three habitat types identified: Open, Portulacaria and Euclea. Note that the y axis scale in a) is different to that in the other graphs.

Table 4 Two-way analyses of variance comparing the species per square meter of the different growth-forms in terms of treatment (Reserve, Elephant and goat) and habitat (Open, *Portulacaria* and *Euclea*). n = 5

	df.	F-value	P.
a) <u>All groups:</u>			
Treatment	2	19.996	0.0000
Habitat	2	9.098	0.0000
Interaction	4	3.815	0.0110
b) <u>Geophytes:</u>			
Treatment	2	12.990	0.0001
Habitat	2	8.117	0.0013
Interactions	4	3.291	0.0217
c) <u>Crassula:</u>			
Treatment	2	18.478	0.0000
Habitat	2	7.019	0.0027
Interactions	4	3.474	0.0169
d) <u>Mesembryanthemaceae:</u>			
Treatment	2	2.742	0.0779
Habitat	2	19.285	0.0000
Interactions	4	1.402	0.2530
e) <u>Other succulents:</u>			
Treatment	2	7.549	0.0018
Habitat	2	4.745	0.0148
Interactions	4	2.269	0.0808

Treatment And Habitat Effect On Geophytes

Not all the growth forms responded in the same way to the different treatments. The geophytes as a whole was the only group which did not show great differences between treatments and in terms of the number of geophyte species in each treatment no differences between treatments were apparent (Figure 5 b)]. Although geophytes did have a lower percentage cover and number of species m^{-2} in the Goat treatments (Figures 4 b] & 6 b]), as compared to the Reserve and Elephant treatments, differences were not as pronounced as for the other life form groups.

Treatment And Habitat Effects On Crassulaceae

Of the three succulent groups the Crassulaceae were especially vulnerable to goat utilization, having less than 0.11% (average for all habitats) cover in the Goat treatment (Figure 4 c)). Similarly, the number of Crassulaceae species and number of species m^{-2} in the Goat treatment were very low (Figures 5 c) and 6 c)). Of particular interest is the observation that the Crassulaceae did not show pronounced differences in cover, number of species and species m^{-2} between the Reserve and Elephant treatments (see Tables 3 - 5 for significance levels). In other words, even though Crassulaceae appear to be extremely vulnerable to Goat browsing, elephant herbivory seems to have a relatively small impact on Crassulaceae species. In both the Reserve

and Elephant treatments, *Euclea* habitats had the highest percentage cover (not no. of spp and spp m^{-2}) of Crassulaceae species; this is in contrast to the general trend (across all treatments and for all growth forms) of highest cover (and diversity) in Open habitats.

Treatment And Habitat Effects On Mesembryanthemaceae

Although Mesembryanthemaceae percentage cover was significantly (Table 3) lower in the Goat treatment (Figure 4 d), the Elephant and Goat treatments were not that different in terms of number of species and species m^{-2} (Figures 5 d) and 6 d); see Tables 4 & 5 for significance levels). Mesembryanthemaceae seemed to favour Open habitats and across all treatments this habitat had the highest cover, number of species and species m^{-2} ; *Portulacaria* habitats were the least preferred. Mesembryanthemaceae were not as vulnerable to goat herbivory as Crassulaceae and seemed to respond to elephant and goat herbivory in a similar way, except for a slightly lower Mesembryanthemaceae percentage cover in the Goat treatment. The Reserve treatments had highest cover, no. spp and spp m^{-2} .

Treatment And Habitat Effects On "Other" succulents

Both Elephant and Goat treatments had very low cover of the "other" succulents, as compared to the Reserve treatment. Also, the Elephant and Goat treatments had about the same no. of spp and spp m^{-2} . As with both the

Crassulaceae and Mesembryanthemaceae species, the Reserve treatment had the highest percentage cover, no. spp and spp m^{-2} . Furthermore, across all treatments the Open habitats had the highest no. of spp as well as spp m^{-2} of "other" succulent species. Reserve treatment Open habitats had the highest cover of "other" succulents whereas in both the Elephant and Goat treatments cover was uniformly low across all habitats. Thus, the "other" succulents fared the best in the Reserve treatment and worst under Elephant and Goat treatments.

Discussion

In terms of percentage cover, number of species as well as species m^{-2} , the Goat treatment had a severe impact on geophyte and succulent community structure as compared to the Reserve and Elephant treatments. The Elephant treatment sites fared better than the Goat sites, but that elephant herbivory is having a major impact on the vegetation is clear from the reduced cover and species richness relative to Reserve sites. Only in the Reserve sites and Elephant-Euclea site did the percentage cover of geophytes and succulents reach appreciable amounts, in all other sites cover was lower than five percent.

Carrying capacity and stocking regimes are usually determined by considering only those species most important

as potential fodder, in the present study it has been shown that all succulent species (not only agriculturally important species) show dramatic declines under intense goat browsing. These declines are particularly alarming considering the high level of endemism observed among the succulent families in the valley bushveld.

Although the proportion of endemic species from the Sundays River valley bushveld is low relative to other rich centres of endemism in southern Africa; 9.2% for valley bushveld as a whole, with 2.6% threatened species (Everard, 1987); it is an important centre of endemism for a number of succulent families including Mesembryanthemaceae, Crassulaceae and Euphorbiaceae (Hoffman & Cowling, 1991). The present study is consistent with these observations: Mesembryanthemaceae, Crassulaceae and Euphorbiaceae all had a high proportion of endemic species.

The Chi-square analyses show that all treatments were affecting the proportion of endemics in a similar way. However, in terms of number of endemic species, analyses of variance reveal that both the browsing treatments (Elephant and Goat) had significantly less endemic species as compared to the Reserve treatment. Cowling and Holmes (1991) also found that severe overgrazing reduces the number of endemic species.

From the ordination it is clear that treatment and habitat are affecting plant (geophyte and succulent) community structure. The Goat treatment seemed to have the

greatest effect on community structure whereas the Reserve and Elephant treatments appear to affect community structure in a similar way. The Open habitats in each treatment were very different from the *Portulacaria* and *Euclea* habitats, which were similar to each other; this is hardly surprising since both the former habitats create understory micro-environments appropriate to a different suite of species than in Open habitats.

The general paucity of species in the *Portulacaria* habitats may be explained by the growth form of this tree. *Portulacaria* grows a "skirt" of branches (Stuart-Hill, 1991) which substantially reduces light levels under the bush, thus preventing most plants from establishing. The only species found consistently in this habitat was the geophyte *Sansevieria aethiopica*. This notion is supported by the higher percentage cover and species richness recorded in the *Euclea* habitats as compared to *Portulacaria* habitats; *Euclea undulata* does not grow a "skirt", but rather has a crown some distance from the ground, this allows greater light penetration into this habitat as compared to *Portulacaria* habitats.

Although the Open habitats were the most diverse, particularly in the Reserve, these habitats may be especially vulnerable to over-utilization since both herbivory as well as trampling probably occurs. This may apply specifically to the Elephant Open sites which in terms

of cover and species m^{-2} were among the poorer habitats sampled.

Of the four growth-form groups investigated geophytes showed the least difference between treatments. Geophytes are ephemeral and by definition spend a large proportion of their life underground; this may afford them some degree of protection from herbivory, i.e. an "unapparent" plant in Feeny's (1976) terminology. Furthermore, the low cover in the Elephant- and Goat-Open habitats may even favour geophytes up to a point, i.e. no plants to grow over them during their dormancy. Finally, geophytes are probably not a preferred food given the alternative foods. Although Archibald (1955) suggested that *S. aethiopica* was important in elephant diet in Addo Elephant National Park, Penzhorn et al (1974) found that this species was a minor elephant food source and propose that it is only a favoured elephant food in dry environments as a source of water. It is important to note that *Sansevieria aethiopica* is extremely common (the bulk of geophyte percentage cover recorded was *S. aethiopica*) and as Archibald (1955) noted: next to *P. afra*, *S. aethiopica* is the most ubiquitous species in the Addo vegetation. Penzhorn (1974) also found *P. afra* and *S. aethiopica* in all his plots. Further, *S. aethiopica* was found almost exclusively in the understory of the *Portulacaria* and *Euclea* habitats sampled. The high percentage cover of geophytes in understory habitats (i.e. *Portulacaria* and *Euclea*) is mostly attributable to *S. aethiopica*.

Crassulaceae species were especially vulnerable to goat browsing where-as elephant herbivory seem to have small effects relative to the Reserve treatment. Crassulaceae are extremely palatable (van Jaarsveld, pers. comm.) and are thus browsed by both elephants and goats. The great difference in Crassulaceae cover and richness between Elephant and Goat treatments is probably due to differences in elephant and goat mouth and thus bite sizes. That is, Crassulaceae are able to resprout from fragments (van Jaarsveld, pers. comm.) and messy feeding by elephants may scatter fragments which can then re-establish; goats with their much more delicate mouths probably selectively eat all fragments preventing re-establishment. Thus, breakage by elephants may promote vegetative reproduction as compared to goat browsing. The high Crassulaceae percentage cover recorded in the *Euclea* habitats is mostly attributable four ubiquitous Crassulaceae species, namely *Crassula perforata*, *C. spathula*, *C. cultrata* and *C. muscosa*, which were mainly found in understory habitats.

The Mesembryanthemaceae species recorded were not as vulnerable to goat browsing as Crassulaceae and this may be due to the lower palatability of the former, as compared to the latter, succulent group (van Jaarsveld, pers. comm.). But, although Mesembryanthemaceae species responded to elephant and goat herbivory in a similar way this group of succulents reached maximum percentage cover and diversity/richness in the Reserve sites. The majority (50%)

of the endemic species recorded were Mesembryanthemaceae. Almost all (90%) of these species occurred in the Reserve treatment whereas only half occurred in the Goat treatment and thus, given that this region is a centre of endemism for Mesembryanthemaceae, it is imperative that unbrowsed areas are protected. The protection of areas in this centre of endemism for Mesembryanthemaceae must be seen as a priority since this is a large and important family extending across most of the sub-continent.

Most of the "other" succulent species investigated belonged to the families Euphorbiaceae, Asteraceae and Lilliaceae. The disappearance of *Aloe africana* from the elephant browsed areas in the AENP has been remarked upon by several workers (eg. Penzhorn et al, 1974; Stuart-Hill, 1991) and is consistent with the present study's findings, i.e. no *A. africana* were found in the Elephant treatment and it seems as if elephants are particularly fond of these plants. Three out of the seven Euphorbiaceae species recorded were endemics; not one of these species were recorded in the Goat treatment and only one endemic Euphorbiaceae species was recorded in the Elephant treatment. Euphorbiaceae are generally toxic and at the very least unpalatable, their demise from from the plant communities under the Goat treatment is a sad reflection of the general devastation of these farm environments.

The general richness of the Reserves in succulent species, as compared to the other treatments, argues

strongly for the continued protection of the vegetation in these areas since they have in effect become islands surrounded by a "sea" of elephant destruction which in turn is surrounded by a "sea" of goat devastation. Further, it may be argued that since almost all of the Sundays River valley thicket is being utilized to some degree (less than two percent of this vegetation type is currently protected; Lubke et al, 1986) and given this vegetation type's inability to recover from intense disturbance (eg. Hoffman & Everard, 1987; La Cock, 1988; Stuart-Hill, 1991 and others) it is not only essential to protect more of this vegetation, but sound conservation is needed as part of the farming strategy.

Existing usage of this vegetation will have to change if sustained agriculture is to be achieved. In other words, steps such as decreasing stocking rates, as suggested by eg. Grewar (1991) and Stuart-Hill (1991) need to be taken. But, it is not as simple as merely removing some animals since farmers are faced with a dilemma of having to decrease stocking rate (in order to be left with any vegetation to utilize) at a time when, if anything, economics dictate an increase in stocking rates. Thus, alternative uses for the land need to be found. These alternatives may include game ranching for hunting or tourism. Much the existing valley bushveld still supports relatively high densities of kudu and bushbuck (Stuart-Hill, 1991). That even potentially destructive animals such as elephants do not affect the

valley bushveld as severely as overgrazing by goats is suggested by both the present study and Stuart-Hill's (1991).

However, the Addo Elephant National Park (AENP) seems to be overstocked with elephants and this has been suggested by several studies (eg. Archibald, 1955; Penzhorn et al, 1974; Novellie et al, 1991); the park is currently stocked at about 2 elephant km^{-2} (Barratt & Hall-Martin, 1991), this is a heavy stocking rate as compared to other parks in Africa with a similar rainfall (c. 500 mm). For example, in the Kruger National Park elephant stocking rates higher than 0.3 km^{-2} leads to habitat deterioration (Van Wyk & Fairall, 1969); in Ruwenzori National Park elephant densities of 1.1 km^{-2} was thought to exceed the carrying capacity as reflected in the habitat destruction the elephants wreaked there (Penzhorn et al 1974); there are many more examples of tree cover destruction throughout Africa with the continued concentration of these beleaguered animals in small conservation areas.

Overstocking of the AENP presents the managers with a dilemma since to stock at the recommended 0.4 elephants km^{-2} (Penzhorn et al, 1974; Novellie, 1991) would allow only about 30 animals in the AENP. In the future, conservation areas will have to increasingly rely on tourists for revenue and 30 animals in the AENP will allow for very few sightings; something tourists are already complaining about at the present stocking rate of almost 170 elephants (Novellie,

1991). This is something to keep in mind when suggesting alternative uses (than goat browsing only) for this vegetation, since merely switching to game ranching (to obtain tourist revenue) is not always economically feasible. Further, there are many other problems with game ranching such as difficulty in obtaining accurate population censuses, rotational grazing is impossible, capital outlay (eg. fences) is enormous and most importantly, meat market values of kudu and springbok are well below that of the already low prices offered for dorper sheep and angora goats; only ostriches are really lucrative at three times the price of other stock (domestic or game).

Tourism and meat production are not the only revenues possible from game ranching, hunting is an alternative which allows for greater revenues. The higher revenues generated this way is a consequence of a foreign elite of hunters prepared to pay exorbitant prices for one of the "big five"; elephants as one this mythical grouping of animals is potentially worth a lot of money as trophy, a single elephant can go for as much as \$50 000 or about R130 000 (pers. obs.). But, the potential foreign hunter clientele, though expected to grow in the coming years, is limited in South Africa; 737 hunters in 1988 (Bothma & Ebedes, 1990). In other words, catering for this market demands unique opportunities (such as hunting one of the "big five") which small landowners are unable to do. In recent years the

amalgamation of small farms into larger conservancies has been an attempt to counter this problem.

There is increasing pressure for the utilization of available land in South Africa to fall within acceptable ecological limits. As a result, present stock ranches which remain productive solely because they follow a destructive management policy, can change into unproductive units if they were to be used within ecological limits. Combined game and stock ranching can possibly improve this matter and may even make currently uneconomical ranching units productive again (Bothma & Ebedes, 1990). In the process sound veld management could improve the overall veld condition and state of conservation although in ecosystems such as the valley bushveld which does not seem to re-establish after decimation this problem becomes acute. This fact is especially scary in a time with increasing demands for land use as our population burgeons; future veld management options are being severely limited by current shortsighted over-utilization of this valuable resource.

From a conservation point of view maximum diversity needs to be maintained and thus all species, from elephant to rare succulent species, need to be protected. Conservation is not just the protection of isolated environments in a "sea" of destruction, for use by a select few who can pay, but rather its aims are much broader. Ideally all land should be conserved so as to preserve genetic diversity as well as to ensure sustainable

utilization of species and ecosystems (Botha & Huntley, 1989).

CONCLUSION

The valley bushveld is being extensively utilized for goat production. This vegetation type seems to be particularly unsuited for this type of exploitation since economically feasible goat densities destroy a plant community which seems to be unable to re-establish once decimated. The valley bushveld is a centre of endemism for important southern African succulent families and as such needs to be protected to a greater extent than it currently is. From both a conservation and an agricultural point of view the demise of palatable Crassulaceae species; as well as the decline in percentage cover, number of species and species m^{-2} of succulents in general; in goat browsed areas is alarming.

A serious attempt to find alternative, more ecologically sound, usages for this vegetation type is urgently needed. Switching to game ranching is often suggested as just such a solution, but in reality this is a complex and risky venture and it may be better to look for alternatives in the combination of different existing practices, i.e. diversifying into both stock and game ranching as some farmers are doing (Grewar, 1991). Research aimed specifically at finding these possible alternative

uses is needed, not only in the eastern Cape, but throughout southern Africa since the above described dilemma is faced by farmers all over this country. The land and vegetation upon which farming depends needs sound ecological management, not only for an esoteric "to keep the balance of nature" but rather so that continued utilization of the valley bushveld is still possible in the future.

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APPENDIX

List of geophytes and succulents recorded in the survey. Nomenclature after the Bolus Herbarium. (Endemic species are marked with an asterisk).

SPECIES LIST

GEOPHYTES

AMARYLLIDACEAE

Ammocharis coronica (Ker-Gawl) Herb.

HYPOXIDACEAE

Hypoxis argentea Harv. ex Bak.

IRIDACEAE

Gladiolus permeabilis Delaroché

OXALIDACEAE

Oxalis stellata Eckl. & Zeyh.

LILLIACEAE

* *Albuca aurea* Jacq.

Albuca sp

Chlorophytum crispum (Thunb.) Bak

Eriospermum thyrsoideum Bak.

Haemanthus coccineus L.

Ledebouria ovalifolia (Schrader) Jessop

Ledebouria spp

Ornithogalum thyrsoides Jacq.

Ornithogalum tenuifolium Delaroché

Sansevieria hyacinthoides (L.) Druce

Sansevieria aethiopica Thunb.

CRASSULACEAE

* *Cotyledon velutina* Hook.f.

Crassula alba Forssk.

Crassula atropurpurea (Haw.) Dietr.

Crassula capitella Thunb.

Crassula cordata Thunb.

Crassula cultrata L.

* *Crassula latibractea* Toelken

* *Crassula mesembryanthioides* (Haw.) Dietr.

Crassula muscosa (Lam.)

Crassula nudicaulis Eckl. & Zeyh.

Crassula orbicularis L.

Crassula ovata (Miller) Druce

Crassula pepliodes Harv.

Crassula perforata Thunb.

Crassula spathulata Thunb.

Crassula tetragona L. ssp *acutifolia* (Lam.) Toelken

* *Crassula tetragona* L. ssp *robusta* (Toelken) Toelken

Kalanchoe rotundifolia Haw.

MESEMBRYANTHEMACEAE

Bergeranthus sp

* *Delosperma ecklonis* (Salm-Dyck) Schwantes

Delosperma pruinosa (Thunb.) J. Ingram

Delosperma sp

- * *Delosperma uniflorum* L. Bol.
- Drosanthemum floribundum* (Haw.) Schwantes
- Drosanthemum hispidum* (L.) Schwantes
- Drosanthemum lique* (N.E Br.) Schwantes
- Drosanthemum parvifolium* (Haw.) Schwantes
- * *Glottiphyllum longum* (Haw.) N.E. Br.
- * *Faucaria felina* (Weston) Schwant & Jacobsen
- Lampranthus coccineus* (Haw.) N.E. Br.
- Lampranthus dependens* (L. Bolus) L. Bolus
- * *Lampranthus productus* (Haw.) N.E. Br.
- * *Mestoklema albanicum* N.E. Br. ex Glen
- Mestoklema copiosum* N.E. Br. ex Glen
- * *Platythyra haeckeliana* (Berger) N.E. Br.
- * *Ruschia knysnana* (L. Bol.) L. Bol.
- Ruschia bijliae* L. Bol.
- Sphalmanthus acuminatus*
- * *Sphalmanthus primulinus* (L. Bol.) L. Bol.
- Sphalmanthus radicans* (L. Bol.) L. Bol.
- * *Trichodiadema marlothi* L. Bolus

"OTHER" SUCCULENTS

APOCYNACEAE

Pachypodium bispinosum (L.f.) A. DC.

ASTERACEAE

Kleinia radicans DC.

Othonna carnosa Less.

Senecio gramineus Harv.

- * *Senecio pyramidatus* DC.

EUPHORBIACEAE

Euphorbia burmannii E. Mey. ex Boiss.

Euphorbia caterviflora N.E. Br.

- * *Euphorbia clava* Jacq.

- * *Euphorbia fimbriata* Scop.

Euphorbia inaequilatera Sond.

- * *Euphorbia ledienii* Berger

Euphorbia mauritanica L.

LILLIACEAE

- * *Aloe africana* Mill.

Bulbine frutescens (L.) Willd.

Bulbine latifolia (L.F.) Roem & Schult

Gasteria bicolor Haw.

PORTULACACEAE

Portulacaria afra Jacq.