Response of herbaceous species to a degradation gradient in the western region of Etosha National Park, Namibia

W.P. DU PLESSIS, G.J. BREDENKAMP and W.S.W. TROLLOPE

Du Plessis, W.P., G.J. Bredenkamp and W.S.W. Trollope. 1998a. Response of herbaceous species to a degradation gradient in the western region of Etosha National Park, Namibia. *Koedoe* 41(1): 9–18. Pretoria. ISSN 0075–6458.

The degradation status of 88 sample plots situated in two plant communities in the western region of Etosha National Park was determined. Herbaceous species frequency was correlated by means of an ordination technique with utilisation intensities. Species were categorised in ecological categories (Decreasers and Increasers) according to their abundance along a degradation gradient. This more objective approach is compared with an initial subjective grouping of species. The dangers of blindly following the ordinated results are discussed, and it is concluded that ordination results need to be verified by careful ecological interpretation.

Key words: DECORANA, Decreaser, degradation gradient, Etosha National Park, Increaser.

W. P. du Plessis, Ministry of Environment & Tourism, Etosha Ecological Institute, P.O. Box 13, Okaukuejo, Via Outjo, Namibia; G.J. Bredenkamp, Department of Botany, University of Pretoria, Pretoria, 0002 Republic of South Africa; W.S.W. Trollope, Sub-Department of Pasture Science, Faculty of Agriculture, University of Fort Hare, Alice, Republic of South Africa.

Introduction

The ecological status of species (Increasers and Decreasers) is used in many veld condition assessment techniques. Veld condition refers to the condition of the vegetation in relation to some functional characteristic, for example, maximum forage production potential and resistance to soil erosion (Trollope *et al.* 1989). Decreaser species are dominant in veld with a good condition but decrease in density with poor veld management. Increaser species are dominant in veld which is under or over-utilised (Tainton 1981).

No objective categorisation of species into ecological status groups existed for Etosha National Park (Etosha) prior to this study. The aim of this study was, therefore, to determine objectively the response of key herbaceous species to a degradation gradient in Etosha, and to classify species accordingly into ecological groups (Decreasers and Increasers).

Study area

The study was conducted in Etosha with central coordinates at 19°S, 16°E. The park, with a size of 22 915 km² (Du Plessis 1997) is located in a semi-arid region of northern Namibia (Fig. 1). Three main seasons are recognised, i.e. a wet warm season from January to April, a dry cold season from May to August and a dry warm season from September to December. Rainfall varies from a long-term mean annual rainfall of 445 mm in the east, to 309 mm in the west of the park. Rainfall occurs mainly between January and April, with the highest precipitation recorded during February (Le Roux 1980). Temperatures at Okaukuejo, in the center of the park, range from a mean maximum of 34.8 °C and a mean minimum of 17.7 °C in

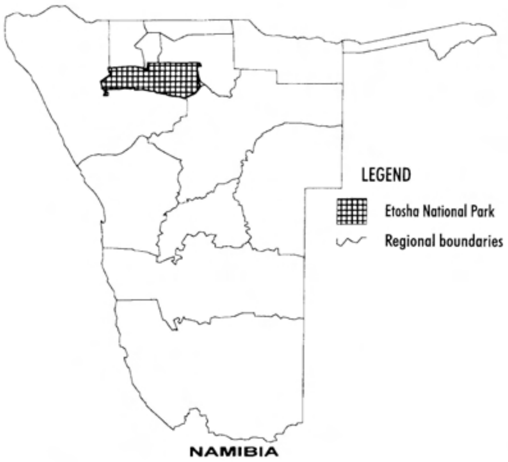

Fig. 1. Location of Etosha National Park in northern Namibia.

November to a mean maximum of 25.0 °C and a mean minimum of 6.0 °C in July (Beyers & Katziambirtas 1987). Frost may occur during the winter months.

Thirty plant communities have been identified in Etosha (Le Roux *et al.* 1988). During this study, nine of these were surveyed during April to May in the years 1989 to 1991 (Fig. 2). This paper reports on the results from two of the nine plant communities assessed. These plant communities were located in the far west (i.e. communities 27 and 28) of the park.

Methods

Field work

Sample plots were systematically selected throughout the two communities. The floristic composition of the herbaceous component was determined in 88 sample plots. Sixteen sample plots were selected in community 27, and 72 in community 28. The percentage frequency of species was determined by identifying the closest species to a thin metal rod placed approximately every two meters. This is an adaptation to the wheel & step-point methods evaluated by Mentis (1981). At each 100 m x 50 m sample plot area, one hundred points placed in two parallel transects 25 m apart, were assessed. The number of points and sample plot dimensions were based on results of Trollope (1990) and Hardy & Walker (1991). The nearest herbaceous species or dwarf shrub to a point within a radius of 400 mm was recorded. The nearest species data (DATA A) included, therefore, annual and perennial species. Non-grass herbaceous species were combined as forbs. A radius of 400 mm was used, as experience has shown that this represents the average maximum distance between rooted herbaceous plants in situations where the veld is in a non-degraded condition.

If no herbaceous species occurred within 400 mm radius of the point, it was recorded as bare ground. Bare ground was treated as if it was a "plant species". This gave an indication of plant density (Mentis 1984), which is also an important additional parameter for recording real changes in veld condition (Danckwerts & Teague 1989).

Sample plots were subjectively located in homogeneous vegetation units within each plant community and represented various visually distinguishable degrees of degradation. For this purpose, gradients were selected from watering points and other areas of high animal concentration to relatively ungrazed veld. Each sample plot was subjectively classified into one of five degradation classes (very highly utilised, highly utilised, moderately utilised, lowly utilised or under utilised).

High grazing intensity and drought are perceived to have the same long-term detrimental effect on species composition and abundance. In this study, the effect of grazing intensity or rainfall on environmental degradation was not clearly distinguishable. Therefore, the term "degradation gradient", incorporating grazing and rainfall effects, was more appropriate to use than the term "grazing gradient".

Various habitat factors were described at each sample plot, which included topograhical unit, soil texture, effective soil depth, lithology, percentage surface stones, average stone size, angle of slope and direction of aspect (Du Plessis 1992).

Data analysis

The sample plots were ordinated by means of detrended correspondence analysis (DECORANA) (Hill 1979). Each community's sample plot data were ordinated separately. Degradation gradients were identified from the position of sample plots in ordination space for each plant community separately. The ordinated position of the most abundant species were plotted on the ordination diagram. Habitat factors were also identified from

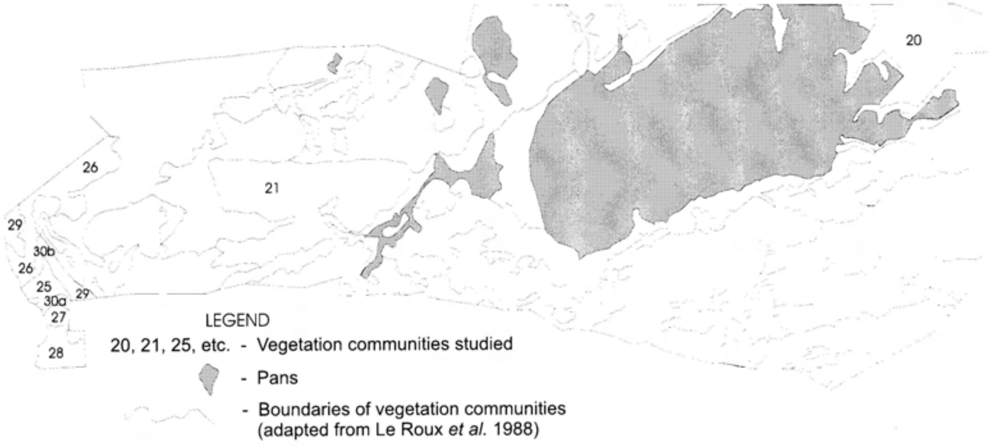

Fig. 2. Nine plant communities surveyed in the Etosha National Park, Namibia. The two plant communities discussed in this paper are numbers 27 and 28.

the position of sample plots in ordination space for each plant community separately.

Species abundance curves were fitted to the degradation gradient identified for each separate community. This was done by means of the polynomial regression technique of the BMDP5R statistical program in the BMDP package (Dixon 1983), to identify objective ecological categories for species. The following degradation categories were distinguished (Trollope 1990).

Category 1: Species dominant in under utilised veld (Increaser 1 species).

Category 2: Species abundant in lightly grazed veld, decreasing with under or over utilisation (Decreasers).

Category 3: Species with low abundance in under-utilised or lightly-grazed veld which tend to increase in abundance when vegetation is moderately grazed (Increaser 2a species).

Category 4: Species which are more abundant in moderately over utilised veld (Increaser 2b species).

Category 5: Species becoming dominant in severely over utilised veld (Increaser 2c species).

Initial subjectively chosen ecological categories of species were compared with the more objectively derived categorisation, and a final list classifying species into Decreasers and Increasers was compiled using a combination of these results.

Trollope's (1986) definitions of Decreaser and Increaser 1 and 2a–c species were used in this study. The Increaser 1 category was not subdivided into two intensity indicator sub-classes as done by Trollope (1986), because these subdivisions could not be readily distinguished in the veld. Trollope's definitions corresponded with the category description used by Janse van Rensburg & Bosch (1990), although names assigned to the categories by these authors are different. In both of these studies the reference point used was veld in good condition. Van Rooyen *et al.* (1991) defined Decreaser and Increaser species based on a reference point of veld in under-utilised conditions. Both definitions are correct, considering their different reference points. In Etosha, some parts of the veld may not be utilised by animals, but limiting effects of low rainfall rule out an Increaser 1 dominated veld. This is probably why Tainton *et al.* (1980) suggested that dry areas lack Increaser 1 species. A reference point of veld in good or over-utilised condition was consequently preferred in this Etosha study.

Results

Identification of degradation and habitat gradients

Ordination diagrams of species and sample plots for community 27 are included in Fig. 3, and the ordinated positions of species, soil depth and sample plots for community 28 are included in Fig. 4.

The degradation gradient was identified on the first axis of ordination (X-axis) for community 28, and on the second axis (Y-axis) for community 27. Severely degraded samples are spatially distributed to the right of the ordination diagram, and samples where Decreaser and Increaser 1 species dominate, to the left.

Soil depth was the only habitat factor that had an important influence on species abundance in the communities investigated. Soil depth represented the inherent edaphic and topographical differences between communities and between variations within a specific community. The qualitative differences in soil depth, texture and percentage surface stones between the higher lying (upland) and lower lying (lowland) topographical units for community 27 and 28 are given in Table 1 (adopted from Le Roux 1980; Buch 1990).

Comparison of the ecological grouping of species between plant communities

Samples were initially categorised into five degradation classes based on their perceived reaction to varying grazing intensities or rainfall. These five categories could hardly be identified clearly in the data presented in Figs. 3 & 4. Sample plots were therefore grouped in combined degradation classes, for example in Fig. 3 sample plots belonging to Category 1 or 2 were mostly situated to the left of the ordination, and Category 3, 4 or 5 sample plots were situated to the right.

The abundance curves of selected species on the degradation gradients for community 27 and 28, are given in Figs. 5 & 6, respectively. Low coefficient of determination values (R^2 = <0.40) and high residual variance values (V = >100) are the result of low abundance of species in the sample plots, and

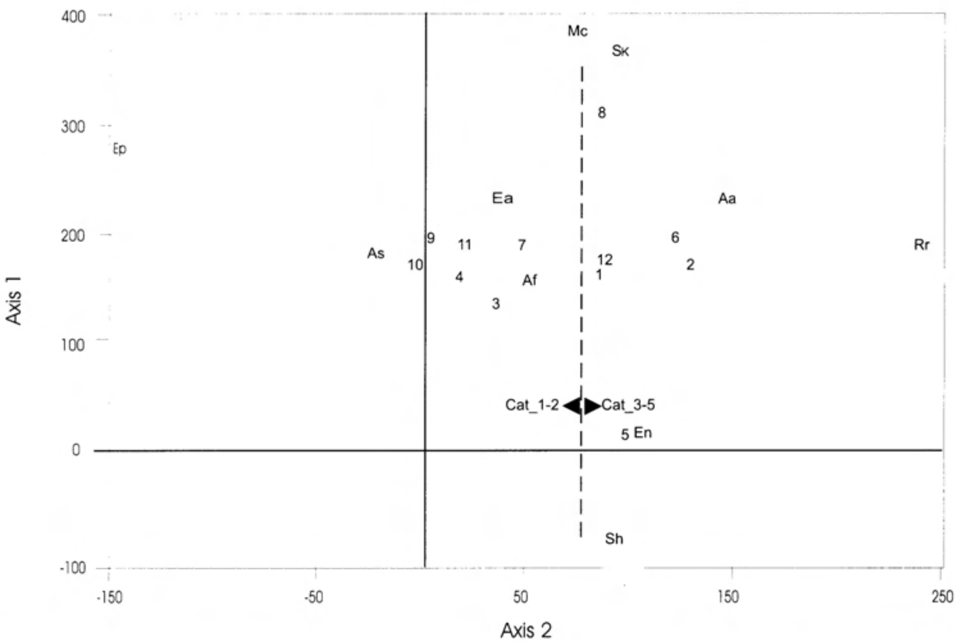

Fig. 3. Spatial distribution of sample plots (numbers) and species (letters) for community 27A (DATA A) on the first and second axis (X & Y-axes) of ordination (see Table 2a for an explanation of the species abbreviations used). Dashed lines indicate the division between the sample plots of different ecological categories. Category 1-5: 1=Increaser 1; 2=Decreaser; 3=Increaser 2a; 4=Increaser 2b; 5=Increaser 2c.

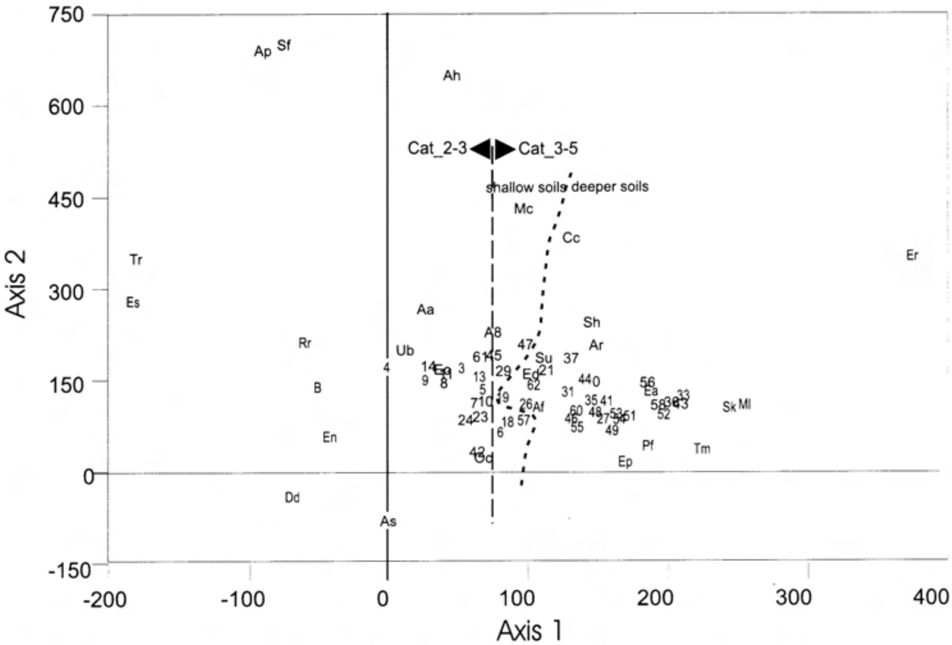

Fig. 4. Spatial distribution of sample plots (numbers) and species (letters) for community 28A (DATA A) on the first and second axis (X & Y-axes) of ordination (see Table 2a for an explanation of the species abbreviations used). Dashed lines indicate the division between the sample plots of different ecological categories. Category 1-5: 1=Increaser 1; 2=Decreaser; 3=Increaser 2a; 4=Increaser 2b; 5=Increaser 2c. Small dashed lines indicate divisions between relatively deeper soils (mostly lower lying topographical units) and shallower soils (mostly higher lying topographical units).

may not accurately reflect ecological categorisation for those species.

Table 2a shows the classification of the most abundant species in the ecological groups for the two plant communities. Table 2a gives a list of the ecological categorisation of species based on the more objectively derived groupings, which has been compiled using the peak position of the species abundance curves (Figs. 5 & 6). This table also gives the final ecological categorisation of species, where the subjective categorisation was, where sensible, adapted according to the objectively derived classification and should be considered as the final list. Table

Table 1

Description of soil depth, soil texture and percentage surface stone cover for the higher and lower lying topographical units of communities 27 and 28

Plant community number	Higher lying topographical units	Lower lying topographical units
27	Shallow lithosols with a high percentage of stones	Deep sands in dry river beds and on their banks, with low percentage of stones
28	Shallow to deep loamy sands with respectively a high or low percentage of stones	Deep loamy sands with few or no stones

Table 2a

A comparison of objective and final ecological categorization (partly subjective) of species for all samples of DATA A in community 27 and 28. Abbreviation=species abbreviations used in Figs.3 & 4; 1=Increaser 1; 2=Decreaser; 3=Increaser 2a; 4=Increaser 2b; 5=Increaser 2c

Abbreviation	Species	Plant communities ("A"=DATA A) Objectively derived species ecological category groups (1-5)		Final ecological categorisation (partly subjective)
		27A	28A	
As	*Anthephora schinzii*	1-2	2-3	4
Aa	*Aristida adscensionis*	4	2-3	5
Ar	*Aristida rhiniochloa*	–	3-5	5
Ec	*Enneapogon cenchroides*	-	2-3	4
Ea	*Eragrostis annulata*	-	3-5	5
En	*Eragrostis nindensis*	4	2-3	2
Ep	*Eragrostis porosa*	-	3-5	5
Af	Forb annual	1-2	3-5	5
Rr	*Melinis repens*	4	2-3	3
Pf	*Pogonarthtria fleckii*	-	3-5	3
Sk	*Schmidtia kalihariensis*	4	3-5	5
Sh	*Stipagrostis hirtigluma*	4	3-5	5
Su	*Stipagrostis uniplumis*	-	2-3	2
Tr	*Triraphis ramosissima*	1-2	2-3	1
Ub	*Urochloa brachyura*	-	2-3	4
B	Bare ground	-	2-3	5

Table 2b

Subjectively chosen ecological categories of the less abundant species in the study area. These species are more common elsewhere in Etosha.
1=Increaser 1; 2=Decreaser; 3=Increaser 2a; 4=Increaser 2b; 5=Increaser 2c; +=dwarf shrub

Species	Subjective ecological categorisation	Species	Subjective ecological categorisation
Anthephora pubescens	2	*Leucosphaera bainesii*	5+
Aristida effusa	5	*Michrocloa caffra*	2
Aristida hordeacea	5	*Monechma genistifolium*	5+
Aristida meriodinalis	3	*Monolytrum luederitzianum*	5
Aristida scabrivalvis	5	*Oropetium capense*	5
Bothriochloa radicans	3	*Petalidium engleranum*	5+
Brachiaria poaeoides	3	*Pseudobrachyaria deflexa*	3
Cenchrus ciliaris	3	*Rynchelytrum bellispicatum*	2
Danthoniopsis dinteri	3	*Schmidtia pappophoroides*	1
Enneapogon desvauxii	5	*Setaria finita*	3
Enneapogon scoparius	2	*Setaria verticilata*	4
Eragrostis echinochloidea	5	*Stipagrostis namaquensis*	1
Eragrostis rigidior	2	*Stipachostis hochstetterriana*	2
Eragrostis superba	3	*Tragus pedunculatus*	5
Eragrostis trichophora	5	*Tragus racemosus*	5
Fingerhuthia africana	2	*Tricholaena monachne*	3

2b includes those species encountered in the study area with a very low abundance and importance and whose ecological categorisation could, therefore, not be objectively determined. These species may have higher abundance and importance in other plant communities in Etosha.

Table 3 gives the eigenvalues of DECORANA for the communities investigated. Only axis 1 and 2 values were used in the final interpretation of the data, because of their higher representation of variation in the data (axis 3 values were, therefore, disregarded).

Discussion

Comparison of the ecological grouping of species between plant communities

As previously indicated, Table 2a provides a list of the final (partly subjective) and objective ecological categorisation of species. Most species listed in Table 2a were classified objectively into similar ecological categories as is shown by the final list (partly subjective) at the end of this table. Some discrepancies in species' classification were observed.

Anthephora schinzii was categorised subjectively as an Increaser 2b species, which is confirmed by the data in community 28, but not in community 27A (Table 2a). In community 27 it is objectively categorised as a Category 1 (Increaser 1) or Category 2 (Decreaser) species. This is incorrect. The explanation for this is that if a species such as *A. schinzii* is abundant in a soil type with a very low ecological potential as in community 27, it behaves as the climax species there. Under more favorable conditions, other species become more abundant. Even though *A. schinzii* is, therefore, probably a climax annual species in community 27, it is not by definition, as the results suggest, a Category 1 or 2 species. This is because the current environmental factors (shallow

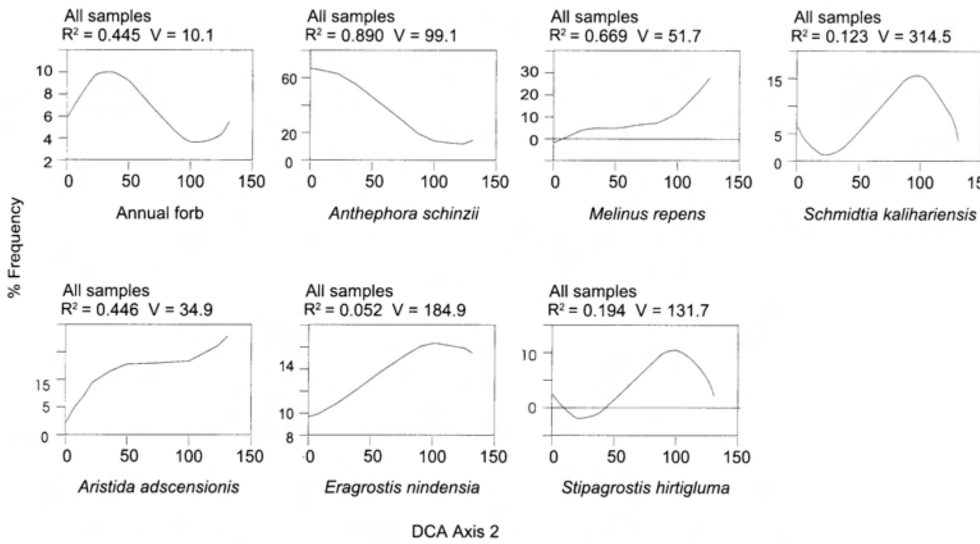

Fig. 5. The frequency (abundance) of species on the degradation gradient (axis 2 = Y-axis) for community 27A (DATA A), derived from polynomial regression analysis. R^2 = coefficient of determination; V = residual variance.

lithosols, poor soil texture, high grazing pressure) prevailing in community 27 cause this community to have a maximum potential of allowing only a Category 3–5 species to be dominant. Annual forbs in community 27 (Fig. 5) (Table 2a) have also been incorrectly grouped with the Increaser 1 or Decreaser class, because of the same reason as explained above.

Eragrostis nindensis, a perennial Decreaser species, has been grouped with the Increaser 2a–c class in community 27 (Fig. 5) (Table 2a), but is classified as a Decreaser species in the final classification (Table 2a). The reason for this discrepancy can be attributed to its low abundance and high residual variance, which resulted in very low R^2-values (Fig. 5), and which caused an incorrect classification. *E. nindensis* is much more abundant in a fenced-off quarantine camp with a very low grazing pressure which is situated in community 27. This then indicates that *E. nindensis* most likely did previously occur

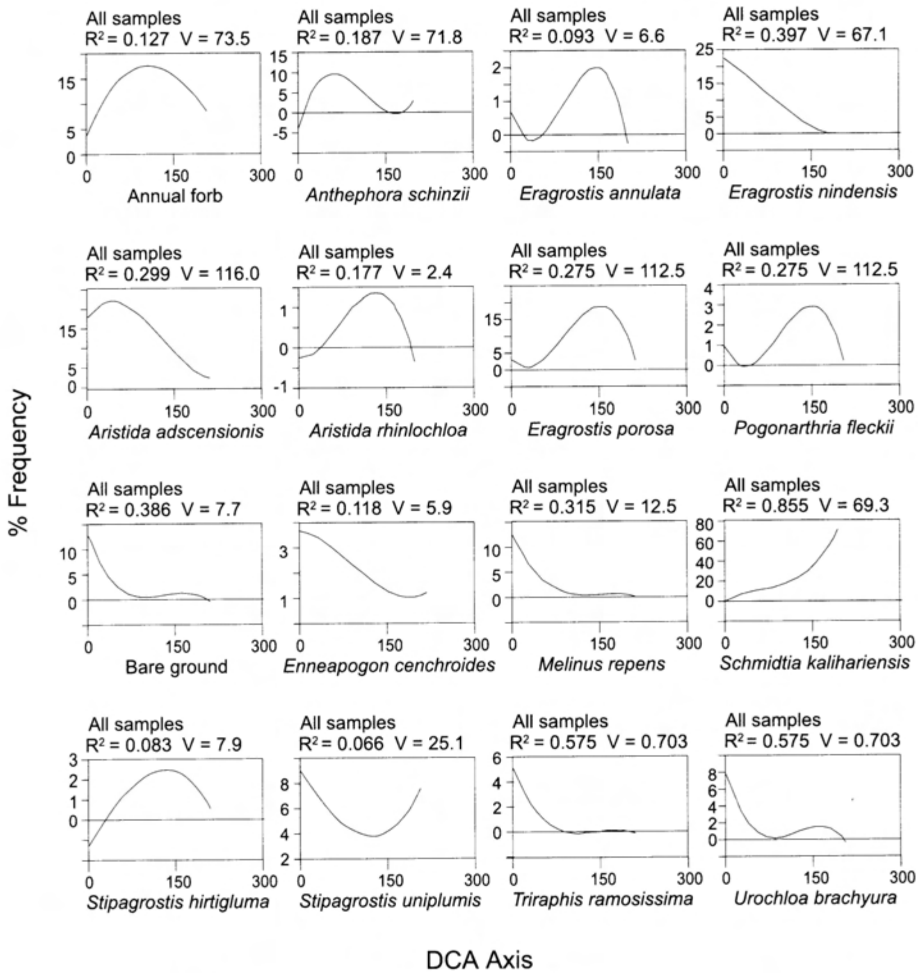

Fig. 6. The frequency (abundance) of species on the degradation gradient (axis 1 = X-axis) for community 28A (DATA A), derived from polynomial regression analysis. R^2=coefficient of determination; V=residual variance.

Table 3
Eigen values for DCA axis 1 and 2 of the communities investigated

Community number	DCA axis number	Eigenvalue
27A	1	0.442
	2	0.222
28A	1	0.287
	2	0.157

abundantly (before the area was degraded) in community 27.

Bare ground was considered as a "species" and its high abundance is a good indication of over-utilisation and highly degraded vegetation. It was mostly correctly classified (using the objective classification) as belonging to the Increaser 2a–c group, except in community 28A, where it was classified as an Increaser 1 or Decreaser species (Table 2a). This discrepancy resulted from the high abundance of *E. nindensis* (Decreaser species) in community 28. Therefore, in some instances a specific sample site has been classified as a Decreaser stand because of the relatively high abundance of *E. nindensis*. At the same time, some of these sample plots also had a relatively high abundance of bare ground and a low abundance of other species, mainly because of the rocky nature of the soil which occur in some topographical variations in this plant community. Because of this interconnected relationship of bare ground (an Increaser 2c "species") with *E. nindensis* (a Decreaser species), bare ground was incorrectly grouped as an Increaser 1 or Decreaser species. This discrepancy is another clear indication that ordination results need to be verified by careful ecological interpretation.

However, species may possibly differ in their reactions to grazing intensity (degradation) in more mesic environments. Janse van Rensburg & Bosch (1990) found that one species can have different average abundance (different ecological groupings) in different topographical units and between edaphic variations within the same unit. They ascribed this variation in a species ecological grouping in and between plant communities to the fact that it reacts differently to the same grazing intensities in and between these communities.

Conclusions

It can be concluded that in general, for Etosha, it is incorrect to classify an individual species (which occurs in different plant communities) into different ecological groups because of perceived reaction to differences in grazing intensities. When the above "objective" ordination and polynomial regression techniques are used, inconsistent species categorisation may occur which cannot be attributed to grazing intensity alone. This is probably also true for other similar arid and semi-arid environments, due to the important influences which different environmental factors may have on the spatial distribution of species in ordination space, and are reflected in low abundance values, low R^2-values and high residual variances. Venter *et al.* (1989) also found that differences in the topographical positions of plots (therefore differences in soil factors), rather than the differences in land-use impact on species richness, production and soil erosion, explained the greater amount of variability in his ordinated data. Ordination may also just mask an initial high degree of subjectivity and artificial manipulation in data gathering and data restructuring (Barnes *et al.* 1984).

Furthermore, the related reactions of different competing herbaceous species to the same environmental factors must also be considered. In savanna ecosystems the abiotic environment often dominates and masks interactions between the biotic elements (Noble 1986).

Therefore, the generalised grouping of species into ecological categories, based on an objective approach, but not excluding careful ecological interpretation of the observed reaction of species to environmental factors, gave meaningful results during this study.

Acknowledgements

The ministry of Environment and Tourism of Namibia is thanked for supporting this research at the Etosha National Park.

References

BARNES, D.L., N.F.S. RETHMAN, B.H. BEUKES & G.D. KOTZE. 1984. Veld composition in relation to grazing capacity. *Journal of the Grassland Society of South Africa* 1: 16–19.

BEYERS, J.J. & E.E. KATSIAMBIRTAS. 1987. *Climate of South West Africa/Namibia*. SWA/Namibia Meteorological Survey, Department of Transport. (Series no. 1).

BUCH, M.W. 1990. Soil, soil erosion and vegetation in the Etosha National Park, northern Namibia. Institute for Geography, Univ. of Regensburg, Federal Republic of Germany. (Internal report).

DANKWERTS, J.E. & W.R. TEAGUE. 1989. *Veld management in the eastern Cape*. Pretoria: Pasture research Section, Dept. of Agriculture and Water Supply, Eastern Cape Region.

DIXON, W.J. 1983. *BMDP Statistical Soft Ware*. Berkeley, California: University of California Press.

DU PLESSIS, W.P. 1992. Chapter 4: Formulation of forage and fuel factors for herbaceous plant species in the Etosha National Park. Pp. 82–115. *In:* DU PLESSIS, W.P. 1992. Development of techniques for the assessment of veld condition in the Etosha National Park, Namibia. M.Sc thesis, Univ. of Pretoria, Pretoria.

DU PLESSIS, W.P. 1997. Refinements to the burning strategy in the Etosha National Park, Namibia. *Koedoe* 40(1): 63–76.

HARDY, M.B. & R.S. WALKER. 1991. Determining sample size for assessing species composition in grassland. *Journal of the Grassland Society of South Africa* 8(2): 70–73.

HILL, M.O. 1979. *DECORANA – A Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ecology and Systematics*. New York: Cornell University.

JANSE VAN RENSBURG, F. P. & O.J.H. BOSCH. 1990. Influence of habitat differences on the ecological grouping of grass species on a grazing gradient. *Journal of the Grassland Society of South Africa* 7(1): 11–15.

LE ROUX, C.J.G. 1980. Vegetation classification and related studies in the Etosha National Park. D.Sc. Agricultural thesis, University of Pretoria, Pretoria.

LE ROUX, C.J.G., J.O. GRUNOW, J.W. MORRIS, G.J. BREDENKAMP & J.C. SCHEEPERS. 1988. A classification of the vegetation of the Etosha National Park. *South African Journal of Botany* 54(1): 1–10.

MENTIS, M.T. 1981. Evaluation of the wheel-point and step-point methods of veld condition assessment. *Proceedings of the Grassland Society of South Africa* 16: 89–94.

MENTIS, M.T. 1984. *Monitoring in South African grasslands*. Pretoria: Council for Scientific and Industrial Research, National Scientific Programmes Unit (South African National Science Programs report no. 91).

NOBLE, I. R. 1986. The dynamics of range ecosystems. Pp. 16–31. *In:* JOSS, P.J. (ed.), P.W. LYNCH & O.B. WILLIAMS. *Rangelands – A resource under siege*. Canberra: Australian Academy of Sciences.

TAINTON, N.M., P.J. EDWARDS & M.T. MENTIS. 1980. A revised method for assessing veld condition. *Proceedings of the Grassland Society of South Africa* 15: 37–42.

TAINTON, N.M. (ed), 1981. *Veld and pasture management in South Africa*. Pietermaritzburg: University of Natal Press.

TROLLOPE, W.S.W. 1986. *Land use surveys: assessment of veld condition in Ciskei*. Alice: University of Fort Hare.

TROLLOPE, W.S.W., A.L.F. POTGIETER & N. ZAMBATIS. 1989. Assessing veld condition in the Kruger National Park using key grass species. *Koedoe* 32(1): 67–93.

TROLLOPE, W.S.W. 1990. Development of a technique for assessing veld condition in the Kruger National Park using key grass species. *Journal of the Grassland Society of South Africa* 7: 46–51.

VAN ROOYEN, N., G.J. BREDENKAMP & G.K. THERON. 1991. Kalahari vegetation: veld condition trends and ecological status of species. *Koedoe* 34(1): 61–72.

VENTER, J., B. LIGGITT, N.M. TAINTON & G.P.J. CLARKE. 1989. The influence of different landuse practices on soil erosion, herbage production and on species richness and diversity. *Journal of the Grassland Society of South Africa* 6(2): 89–98.