Kalahari vegetation: veld condition trends and ecological status of species

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Grazing intensity gradients were determined in the duneveld, river terrace and river bed habitats of the Kalahari Gemsbok National Park. Under increased grazing, a species composition characterised mostly by annual forbs and grasses results. In all three habitats the relatively heavily grazed areas were closest to the watering points, although this was less evident in the river terrace and river bed habitats. Monitoring degradation at a watering point over the long term, produced results similar to those observed from a single sampling period. The identification of grazing gradients within homogeneous habitats, is a prerequisite for the classification of plant species into different categories. The allocation of a species to a category is based on the changes in frequency along this grazing gradient and this approach is more acceptable than the classification of species commonly used. The use of terminology such as Decreasers and Increasers is discussed.

Key words: Decreaser, grazing gradients, Increaser, Kalahari, ordination, rainfall, veld condition.

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Introduction

The development of effective grazing management policies requires a sound knowledge of veld condition, grazing capacity and the response of plant species to grazing pressure. The assessment of veld condition in the semi-arid and arid regions of South Africa has received little attention. Fourie *et al.* (1987) determined the veld condition in an extensive stock production system in the Kalahari duneveld, but acknowledged the need for a realistic method of estimating veld condition.

In the semi-arid Kalahari, there is seldom any surface water available for herbivores. The establishment of artificial watering points in the Kalahari Gemsbok National Park (KGNP), potentially discourages animal migration and increases the possibility of overgrazing of the area surrounding the watering point.

Changes in the vegetation can be detected by long term monitoring at or near the watering points. However, the use of a single sampling period, including different (assumed) stages of degradation, in a model for studying changes in vegetation, proved relatively successful (Bosch & Janse Van Rensburg 1987). Veld condition refers to the condition of the vegetation in relation to functional characteristics, normally sustained forage production and resistance to soil erosion (Trollope 1990; Trollope *et al.* 1990). Veld condition has been regularly assessed by commercial pastoralists and has recently been advocated for conservation areas in South Africa (Novellie 1990).

Veld condition assessment (Foran *et al.* 1978; Vorster 1982) involves the determination of a condition score, based on species composition, followed by the classification of species according to their response to grazing. For

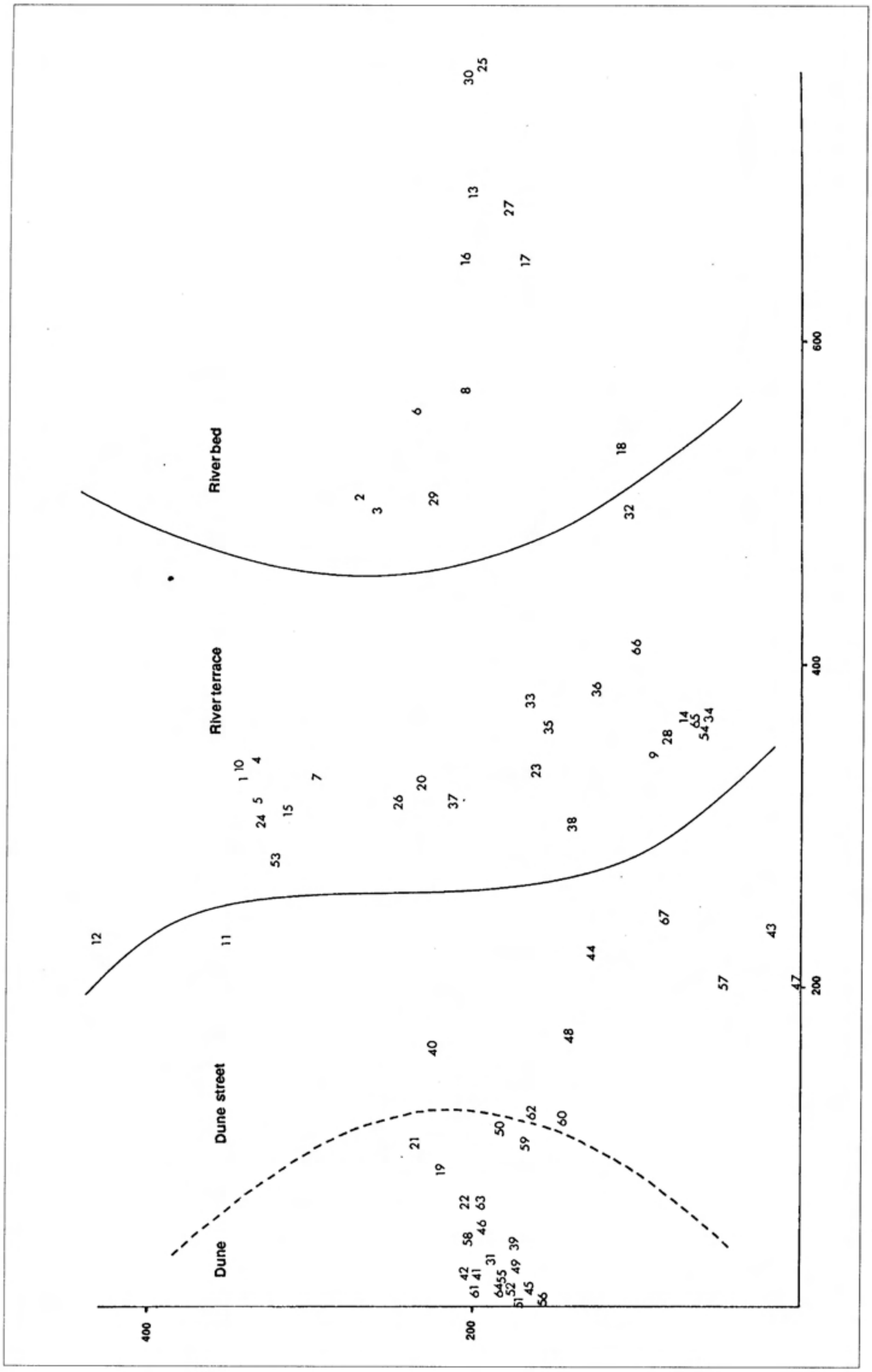

Fig. 1. Scatter diagram of all sample plots, ordinated by means of Detrended Correspondence Analysis (Hill 1979).

example 'Decreasers' (those species dominant in well-managed veld) and 'Increasers' (those species which multiply because of poor management)(Janse van Rensburg & Bosch 1990). The disadvantage of this approacch is the lack of a scientifically based classification of plant species into these categories (Janse van Rensburg & Bosch 1990). Ephemeral forb and grass species are usually classified as undesirable Increasers with a low grazing value (Fourie *et al.* 1987). However, in deserts these are important in the diet of herbivores (Dieckmann 1980). Janse van Rensburg & Bosch (1990) similarly found that a species often responds differently to grazing in different topographical localities, or as a result of ecotypic variation.

The aims of this study in the KGNP were to determine vegetation changes along grazing/environmental gradients and, the objective classification of species into ecological groups, according to their response to grazing and/or environmental gradients.

Study area

The KGNP covers approximately 9 600 km^2 and is situated between 24° 15'S and 26° 30'S, and 20° 00'E and 20° 45'E. The altitude varies from 870 m at Twee Rivieren in the south to 1 080 m at Union's End in the north. The average annual rainfall ranges from 209 mm at Mata-Mata (south-west) to 220 mm at Twee Rivieren (south) and 230 mm at Nossob in the north. Most of the rain falls during summer, from January to April. The mean annual rainfall for the KGNP declined throughout the study period (1978 - 1988) (Van Rooyen *et al.* 1990).

Methods

Changes in vegetation were assessed from data of: long term monitoring of permanent sample plots from 1978 to 1988 (Van Rooyen *et al.* 1990); sample plots monitored in 1958 and 1990; and a single sampling period in 1990. The habitats sampled included the duneveld, river terraces and the river beds of the Auob and Nossob rivers.

Sample plots were subjectively selected to represent various perceived degrees of degradation, within a relatively homogeneous habitat and plant community, taking into consideration the different distances from watering points. Nearest plant recordings were made at 200 points in each sample plot, using the wheel-point method (Tidmarsh & Havenga 1955). Some of the long term data involved 2 000 point surveys (Brynard 1958).

The analysis of the entire data set (presuming high beta-diversity) was done by means of Detrended Correspondence Analysis (DECORANA) (Hill 1979). The Reciprocal Averaging (RA) technique (Gauch 1982) was used to detect possible degradation gradients caused by grazing within the different habitats, because of the low beta-diversity of the stands within the different habitats.

Species abundance curves were fitted to the gradient by means of the polynomial regression technique (IMSL 1987), to identify Decreaser and Increaser species.

Results

Grazing gradients

The DECORANA ordination of all sample plots (Figure 1), enabled three habitats to be distinguished:

- the dune habitat, including the dune street habitat/pan-like depressions, to the left of the diagram;
- the river terrace habitat in the centre of the diagram; and
- the river bed habitat to the right of the diagram.

The separate ordinations of each of these identified habitat classes by RA are presented in Figures 2a, 2b, 3 & 4.

Dunes and dune streets

The sample plots representing dunes are clearly separated from the dune streets on the first axis (Figure 2a). The sample plots at the lower left of the scatter diagram indicate relatively undisturbed or under utilised plots on deep sandy dune soils, characterized by typi-

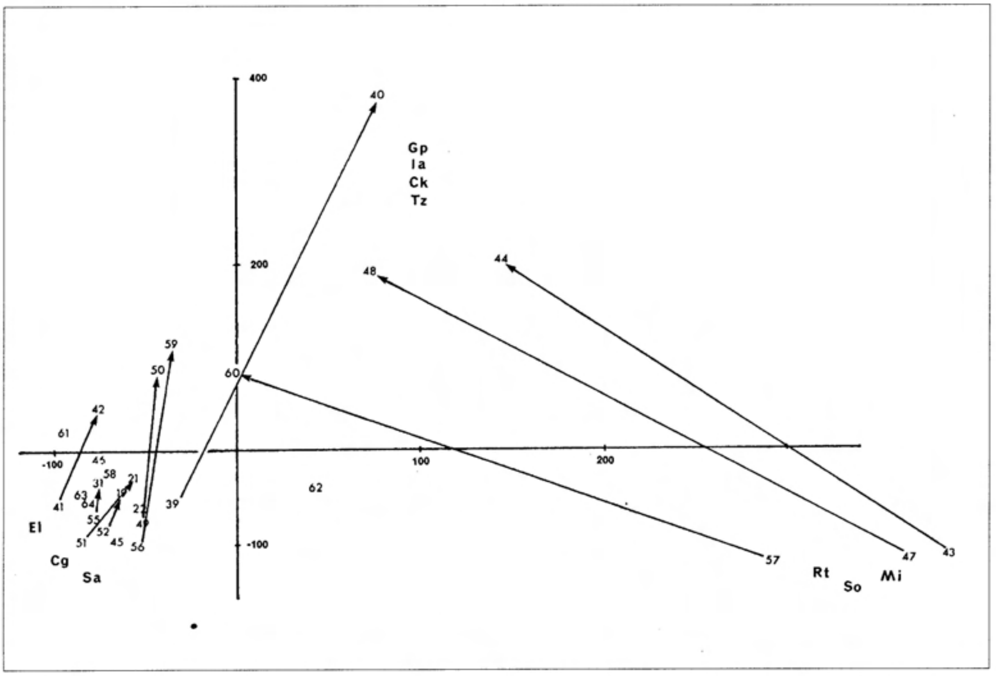

Fig. 2a. Scatter diagram of the dune and dune street habitat indicating trends. Cg = *Centropodia glauca*; Ck = *Cleome kalachariensis*; El = *Eragrostis lehmanniana*; Gp = *Gisekia pharnacioides*; Ia = *Indigofera alternans*; Mi = *Monechma incanum*; Rt = *Rhigozum trichotomum*; Sa = *Stipagrostis amabilis*; So = *Stipagrostis obtusa*; Tz = *Tribulus zeyheri*.

cal dune species such as *Eragrostis lehmanniana*, *Centropodia glauca* and *Stipagrostis amabilis*. The sample plots on the lower right of the scatter diagram also indicate relatively under utilised plots, but on the sandy-loam soils of the dune streets. *Rhigozum trichotomum*, *Monechma incanum*, *M. genistifolium* subsp. *australe*, *Aptosimum albomarginatum* and *Stipagrostis obtusa* are all species typical of the dune streets.

The grazing intensity gradient of the dunes and dune streets (Fig. 2a) was identified on the second axis (Y-axis) of the ordination. No quantitative data on long term grazing pressures are available. The gradient could therefore only be qualitatively described as varying from relatively heavily grazed close to watering points, to under utilised, further away from the watering points. Water was provided within 1,5 km from sample plots 39, 41, 43, 47, 56 and 57 soon after the first survey in 1978.

Data from the surveys of these same plots, repeated during 1988, are indicated on the scatter diagram (Fig. 2a) by plots 40, 42, 44, 48, 59 and 60, respectively. The heavily grazed plots closest to the watering points e.g. 40, 44 and 48, are positioned towards the top of the diagram. The degraded plots of both dunes and dune streets show similarities in floristic composition.

Superimposing the species ordination on the stand ordination clearly shows that under heavy grazing, the resultant species composition is characterised by annual forbs such as *Gisekia pharnacioides*, *Indigofera alternans*, *Cleome kalachariensis*, *Crotalaria sphaero-*

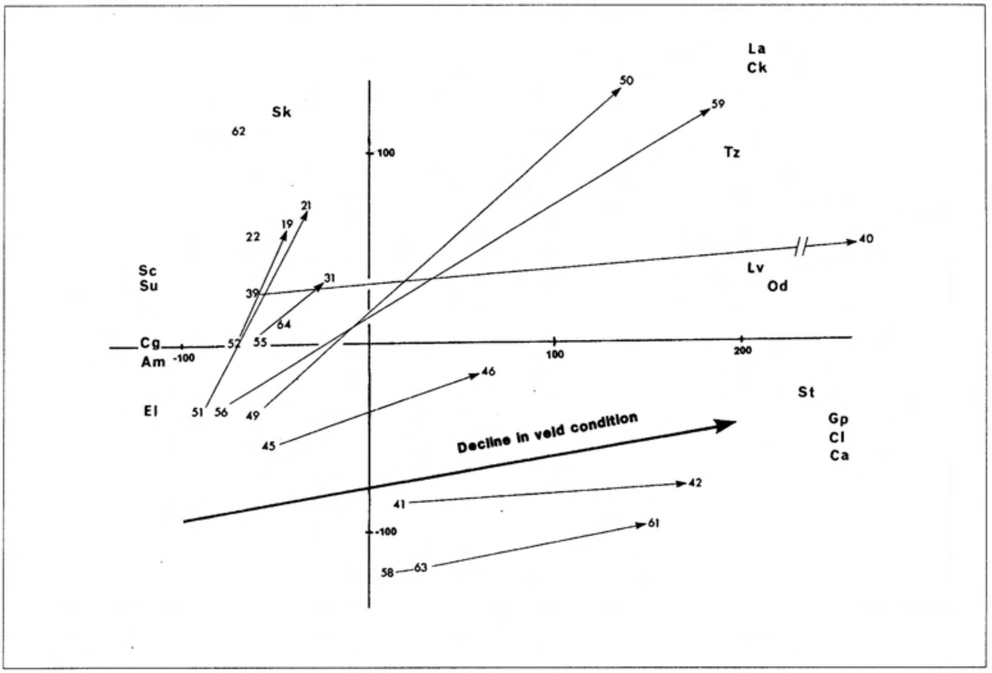

Fig. 2b. Scatter diagram of the dune habitat indicating trends. Am = *Aristida meridionalis*; Ca = *Cucumis africanus*; Cg = *Centropodia glauca*; Ck = *Cleome kalachariensis*; Cl = *Citrullus lanatus*; El = *Eragrostis lehmanniana*; Gp = *Gisekia pharnacioides*; La = *Limeum aethiopicum*; Lv = *Limeum viscosum*; Od = *Oxygonum dregeanum*; Sc = *Stipagrostis ciliata*; St = *Sesamum triphyllum*; Su = *Stipagrostis uniplumis*; Tz = *Tribulus zeyheri*.

carpa and *Tribulus zeyheri*.

The degradational trends at sampling plots further than 1,5 km from watering points are less conspicuous, indicating under utilization and probably the effects of drought e.g. between plots 51 and 21, 55 and 31, and 52 and 19 (Fig. 2a).

The sample plots of the dunes were separated from those of the dune streets, and the dune plots ordinated by means of RA (Fig. 2b). The grazing intensity gradient of the dunes was identified on the first axis of the ordination. When the surveys at sample plots 39, 41, 45, 49, 56 and 58 were repeated in 1988, the changes in floristic composition resulting from grazing and the possible influence of drought, showed a trend to the right of the scatter diagram (Fig. 2b). The position of sample plot 40 (originally 39), was off scale, far to the right of the diagram Fig. 2b).

The species ordination, superimposed on the stand ordination (Fig. 2b), indicated that *Centropodia glauca*, *Eragrostis lehmanniana*, *Aristida stipitata*, *A. meridionalis*, *Stipagrostis ciliata*, and *S. uniplumis* were associated with veld in good condition. An increase in grazing and trampling resulted in an increase in annual species such as *Cleome kalachariensis*, *Limeum aethiopicum*, *L. viscosum*, *Tribulus zeyheri*, *Sesamum triphyllum*, *Oxygonum dregeanum*, *Chamaesyce inaequilatera*, *Citrullus lanatus*, *Cucumis africanus* and *Gisekia pharnacioides*.

River terrace

The pristine river terrace vegetation was entirely dominated by *Stipagrostis obtusa*. This species decreased noticably when the veld condition deteriorated.

The grazing intensity gradient of the river terrace habitat (Fig. 3) was identified on the first axis (X-axis) of the ordination. The heavily grazed and trampled plots, mostly closest to watering points, were positioned to the right of the scatter diagram, while the less utilised plots were positioned to the left. There would seem to be a grazing gradient associated with distance from watering points in this habitat. The diagram (Fig. 3) shows sample plots from 2,8 to 4,3 km away from the nearest water (4, 7, 15), positioned amongst relatively heavily utilised plots around watering points. However, sample plots 35, 36 and 66, located at a watering point, were positioned to the top left of the scatter diagram. Thęse three sample plots represented a separate plant community at Koedoebos, with some similarity to river bed vegetation. Sample plot 10 represented an atypical stand on the edge of a pan, in the area transitional to duneveld.

The vegetation of sample plot 33, which became plot 34 in 1988, showed an improvement in veld condition since 1978, while that of sample plot 54 (later plot 23), showed signs of degradation over the 30 year period since 1958 (Fig. 3).

The species ordination (Fig. 3) superimposed on the stand ordination, indicated that *Stipagrostis obtusa*, *S. ciliata* and *Dimorphotheca polyptera* were associated with veld in good condition. Increased trampling in this habitat caused destabilisation of the sand which caused increases in *Schmidtia kalihariensis*, *Eragrostis porosa* and *Acrotome inflata*.

River bed

The grazing intensity gradient of the river bed habitat (Fig. 4) was identified on the first axis (X-axis) of the ordination. The heavily grazed and trampled plots, were distributed to the left of the scatter diagram, while the under utilised

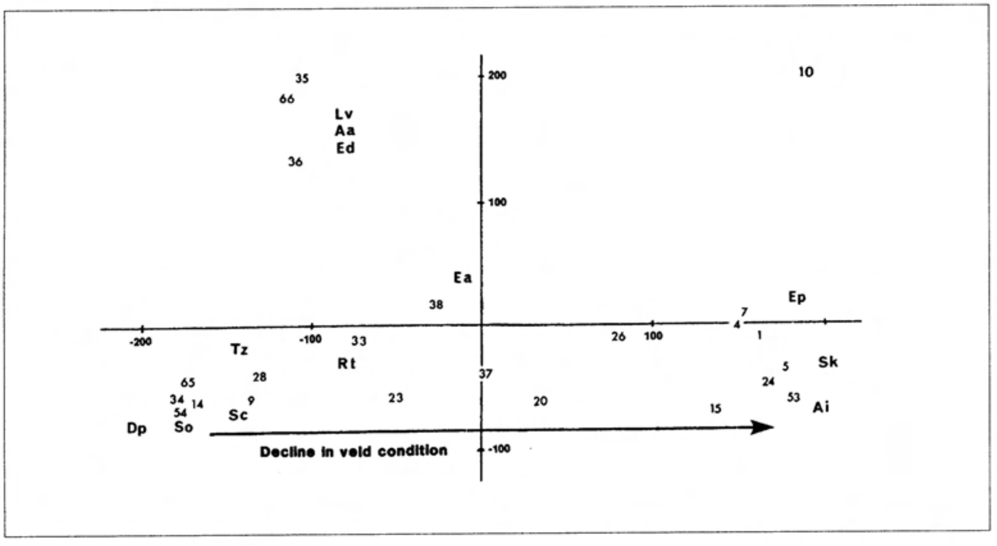

Fig. 3. Scatter diagram of the river terrace habitat indicating trends. Aa = *Aptosimum albomarginatum*; Ai = *Acrotome inflata*; Dp = *Dimorphotheca polyptera*; Ea = *Eragrostis annulata*; Ed = *Enneapogon desvauxii*; Ep = *Eragrostis porosa*; Lv = *Limeum viscosum*; Rt = *Rhigozum trichotomum*; Sc = *Stipagrostis ciliata*; Sk = *Schmidtia kalihariensis*; So = *Stipagrostis obtusa*; Tz = *Tribulus zeyheri*.

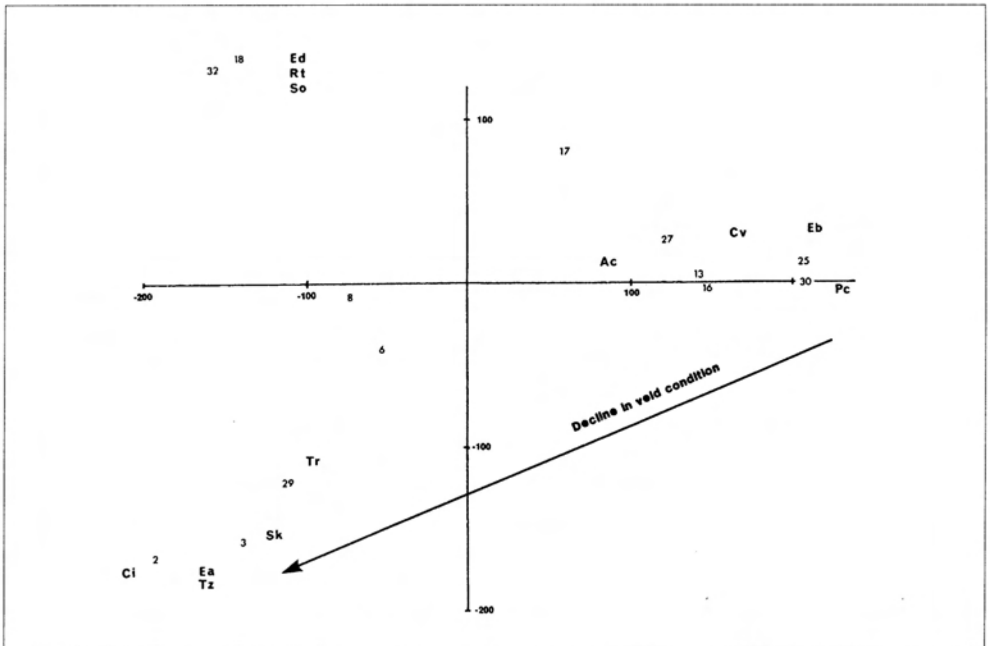

Fig. 4. Scatter diagram of the river bed habitat indicating trends. Ac = *Aristida congesta*; Ci = *Chamaesyce inaequilatera*; Cv = *Chloris virgata*; Ea = *Eragrostis annulata*; Eb = *Eragrostis bicolor*; Ed = *Enneapogon desvauxii*; Pc = *Panicum coloratum*; Rt = *Rhigozum trichotomum*; Sk = *Schmidtia kalihariensis*; So = *Stipagrostis obtusa*; Tr = *Tragus racemosa*; Tz = *Tribulus zeyheri*.

plots were positioned to the right. There seemed to be a grazing gradient associated with distance from watering points in this habitat, as the sample plots positioned to the left of the scatter diagram were generally closer to the watering points than those to the right of the scatter diagram (Fig. 4). A moisture gradient could also result in a similar gradient.

Superimposing the species ordination on the stand ordination clearly showed that under heavy grazing the resultant species composition was characterised by annual grasses and forbs, e.g. *Eragrostis annulata*, *Chamaesyce inaequilatera*, *Tribulus zeyheri*, *Tragus racemosa* and *Amaranthus thunbergii* (Fig. 4). Perennial grass species such as *Panicum coloratum*, *Eragrostis bicolor*, *E. rotifer*, *Chloris virgata* and *Echinochloa colona* were associated with veld in a better condition.

Ecological classification of species

The classification of species into different ecological categories used in this paper, differs from that used by Bosch & Janse van Rensburg (1987) and Janse van Rensburg & Bosch (1990). The reference point for the present classification was taken as under utilised veld and species were grouped according to their response to increased grazing pressure (Fig. 5). For example, according to Janse van Rensburg & Bosch (1990), species in Category 1 are called Increaser 1 species. However, these species decrease along the grazing gradient (from left to right in Fig. 5) and should preferably be described as Decreasers.

The species were classified into the following five categories, according to their frequency curves on the grazing intensity gradients

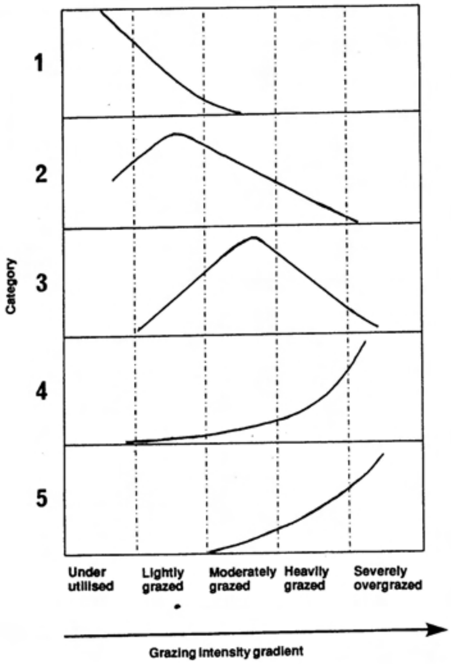

Fig. 5. Schematic presentation of the five categories defined along a grazing intensity gradient.

within each of the three habitats (Figs. 5 & 6 and Table 1):

Category 1: Those species characteristic of under utilised veld which decline in frequency along the grazing gradient. These are usually absent from veld that is moderately to over-grazed (Decreaser species). Examples are *Stipagrostis ciliata*, *S. uniplumis*, and *Aristida meridionalis* in the dune habitat, *S. obtusa* in the river terrace and *Panicum coloratum* and *Chloris virgata* in the river bed habitats.

Category 2: Those species rare or low in frequency in under utilised veld, but which increase when the veld is lightly grazed. Moderate to heavy grazing decreases their numbers (Intermediate 1 species). Examples are: *Centropodia glauca* and *Eragrostis lehmanniana* in the dune habitat, and *Eragrostis bicolor*, *Rhigozum trichotomum* and *Cullen obtusifolia* in the river terrace habitats. *Enneapogon desvauxii* in the river terrace habitat also falls into this category.

Category 3: Those species which rarely occur in lightly grazed veld, but which increase in frequency when the veld is moderately or selectively grazed (Intermediate 2 species). These include: *Stipagrostis amabilis* and *Indigofera alternans* in the duneveld, *Eragrostis porosa* in the river terrace area, and *Aristida congesta* and *Tragus racemosa* in the river bed habitats.

Category 4: Those species which are rare in lightly to moderately grazed veld, but which increase when the veld is fairly heavily grazed (Increaser species). Examples are *Schmidtia kalihariensis* and *Eragrostis annulata* in the river terrace and *Enneapogon desvauxii* in the river bed habitats.

Category 5: Species which are absent in lightly grazed veld but which become dominant in veld that is severely overgrazed (Encroacher species). They are *Chamaesyce inaequilatera* in the duneveld and *Eragrostis annulata* in the river bed habitats.

Changes in frequency of the different species along the grazing gradients, within the three habitats, are shown in Fig. 6.

Discussion

Rainfall in the southern Kalahari has a marked influence on the presence or dominance of annual species (Van Rooyen *et al.* 1990) and is also the main determinant of forage production (Fourie *et al.* 1987). There was a general decline in total herbaceous cover during the past decade, due to the below average rainfall. An increase in forb species diversity was however also recorded over this period (Van Rooyen *et al.* 1990). The data clearly showed that the species composition

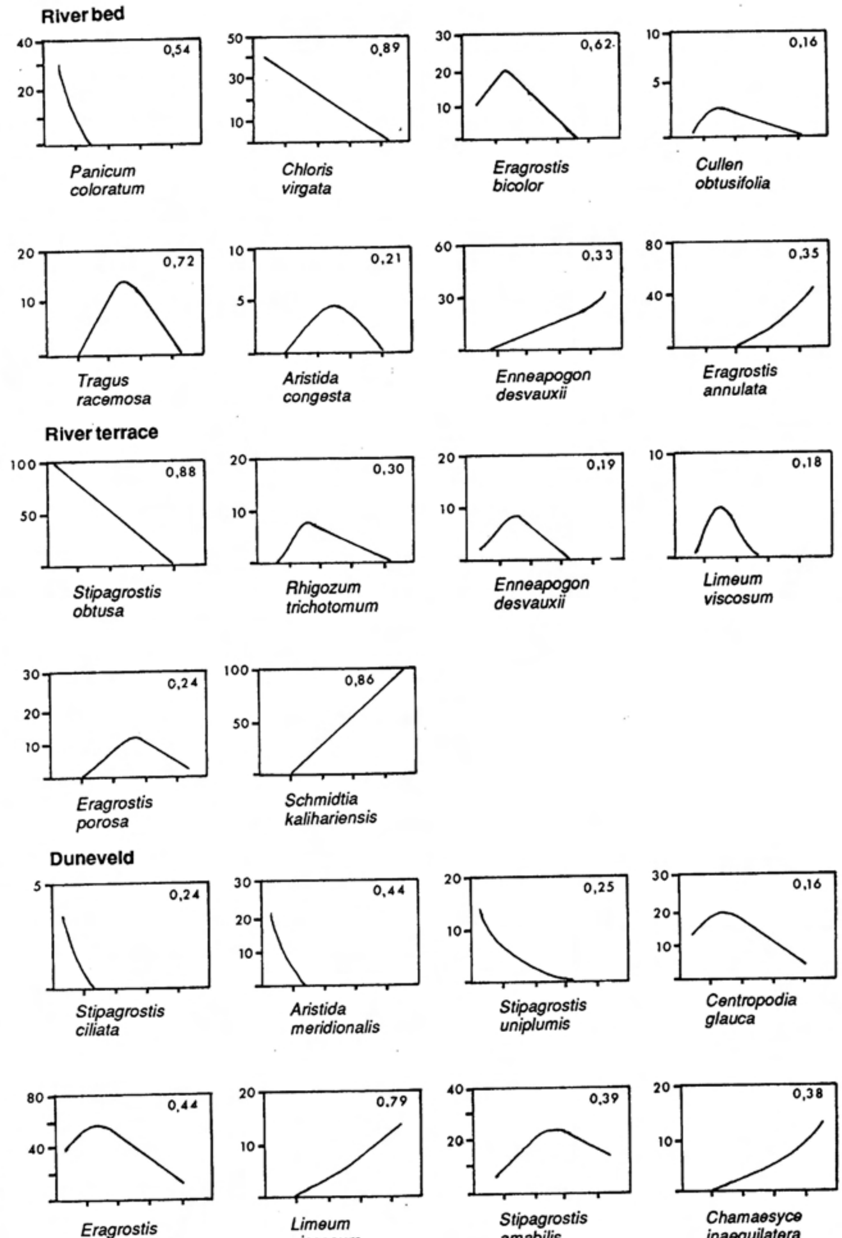

Fig. 6. Changes in the frequency of different species on the grazing gradient in the dune, river terrace and river bed habitats. The Y-axis indicates percentage frequency of the species within a habitat and the X-axis the grazing gradient (see Fig. 5), ranging from under utilised to severely over grazed. The r^2 values are indicated in the right hand corner of the Figs. 5 & 6.

Table 1
The ecological status (categories 1 - 5) of individual species in the dune veld, river terrace and river bed habitats of the Kalahari Gemsbok National Park

Species	Dune veld	River terrace	River bed
Aristida meridionalis	1		
Stipagrostis uniplumis	1		
Stipagrostis ciliata	1		
Stipagrostis obtusa		1	
Chloris virgata			1
Panicum coloratum			1
Centropodia glauca	2		
Eragrostis lehmanniana	2		
Rhigozum trichotomum		2	
Enneapogon desvauxii		2	4
Eragrostis bicolor			2
Cullen obtusifolia			2
Stipagrostis amabilis	3		
Indigofera alternans	3		
Eragrostis porosa		3	
Aristida congesta			3
Tragus racemosa			3
Schmidtia kalihariensis		4	
Chamaesyce inaequilatera	5		
Eragrostis annulata		4	5

resulting under increased grazing, was characterised by mainly annual forbs and grasses. In all three habitats surveyed to estimate veld condition, the most heavily grazed plots were generally those closest to the watering points, suggesting that grazing gradients may well exist in each habitat.

The degradational trends at watering points, observed by monitoring long term changes since the establishment of these watering points, over a period of decreasing rainfall and increasing grazing pressure, were similar to those observed from data of a single sampling period. This suggests that subjective, but carefully selected sample plots of a single sampling period, may indicate the same gradients or trends in veld condition, obtained through long term monitoring. The main advantage of long term experiments is that the climatic and grazing histories of the areas sampled are known, although the grazing history of a plot in a large conservation area is difficult to quantify. Bosch & Janse van Rensburg (1987) also found that studying vegetation changes through single sampling periods was relatively successfull.

The identification of grazing gradients within homogeneous habitats is, however, a prerequisite for the classification of plant species into different categories. The allocation of a species to a category is based on the changes in frequency along this grazing gradient and this approach is more acceptable than the classification of species commonly used. The categories defined here agree to a certain extent with definitions used by other authors (see Bosch & Janse van Rensburg 1987).

The definitions of Trollope *et al.* (1990) could not easily be applied to the species frequency curves, especially not for Increaser species. Such narrow subjective categories are difficult to distinguish and cannot be used in large conservation areas, where quantitative information concerning grazing histories is usually lacking.

Although the definition of Trollope *et al.* (1990) of a Decreaser species is vague, it could be applied to Category 1 species. This definition also differs from that of Bosch & Janse van Rensburg (1987) and Janse van Rensburg & Bosch (1990). The latter's definition probably applies to sourveld conditions in higher rainfall areas, where these species might decrease with under utilisation. The Increaser 1 species of Bosch & Janse van Rensburg (1987) and Janse van Rensburg & Bosch (1990) are considered as Decreasers by the present authors.

Categories 2 & 3 species increase initially with increased grazing, reach a peak at light to moderately or selectively grazed situations, and decrease under heavy to severe over grazing. Considering the total grazing gradient these species are therefore neither Increasers nor Decreasers. The terms Increaser and Decreaser are therefore inappropriate.

The only true Increasers fall under Categories 4 and 5 and may be classified as Increaser and Invader species, respectively.

Some of the species curves depicted in Fig. 6, have low r^2 values, indicating that other factors e.g. rainfall, have a greater influence on their frequency than grazing. However, the general trends are still relatively useful in describing grazing conditions.

Most of the species were diagnostic for a specific habitat, and could be classified into a specific category, but there were also species that differed in their classification between habitats (Table 1). There was some agreement between the present classification of species and that of Fourie & Visagie (1985) and Fourie *et al.* (1987). *Panicum coloratum* and *Stipagrostis* spp. with the exception of *S. amabilis*, which was regarded as an Category 3 species, were classified as Decreasers in the present study. *Eragrostis lehmanniana* was classified by all authors as an Increaser species, while *Centropodia glauca* was regarded as a Decreaser by Fourie *et al.* (1987), but an Category 2 species in the present study. *Aristida meridionalis* and *Chloris virgata* were classified as Increasers by Fourie & Visagie (1985), but were found to be Decreasers in the present study. The latter might be due to this species's sensitivity to drought, as was also found by Fourie *et al.* (1987). Although Fourie *et al.* (1987) did not find any clear evidence of an increase by *Rhigozum trichotomum* over a 16 year period, they classified it as an Increaser IIc species, together with Invaders. In the present study, it was classified as an Category 2 species in the river terrace habitat. Fourie *et al.* (1987) classified all annual grass species as Increaser IIc or Invader species, although this was not always valid. In the present study, *Chloris virgata*, *Schmidtia kalihariensis*, *Eragrostis porosa*, *Aristida congesta, Tragus racemosa* and *Eragrostis annulata* were classified under Categories 1, 2 & 4, 3, 3, 5 and 5, respectively (Table 1).

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