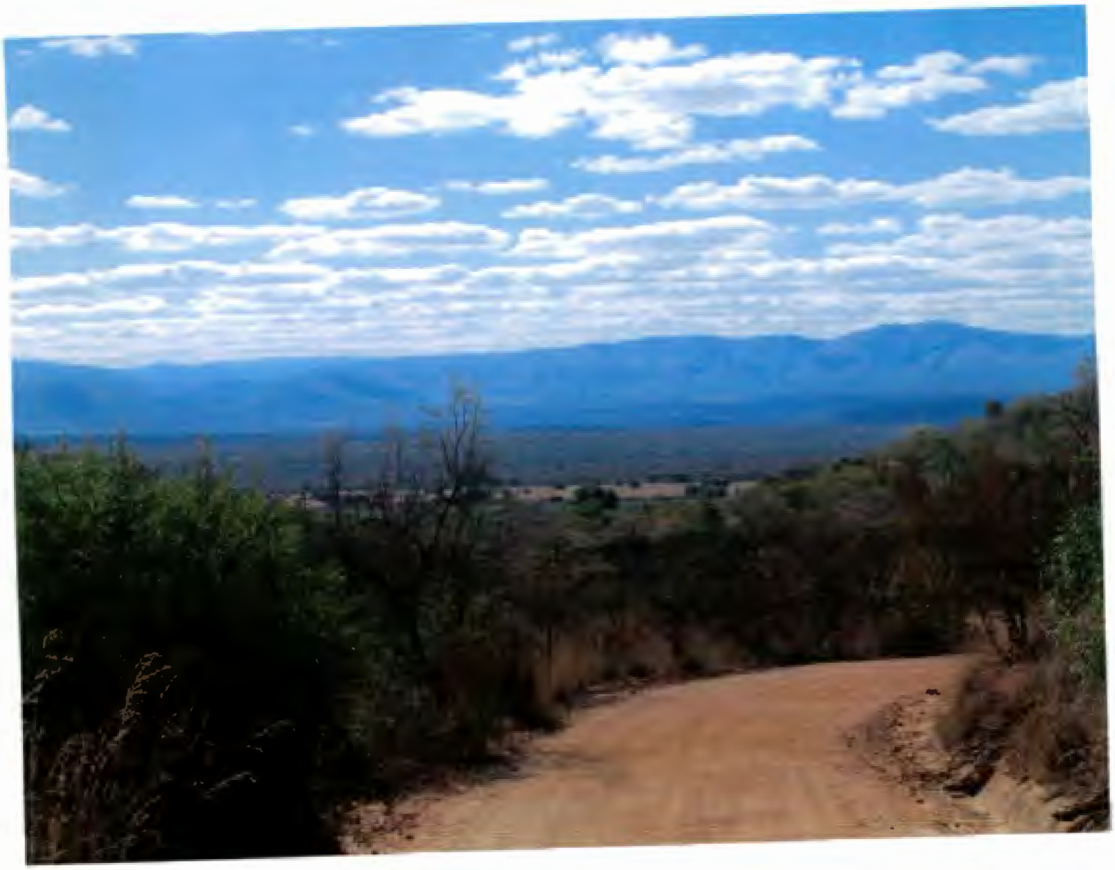
Veld Condition Indexing: relevance to Wildlife Management?



by

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ABSTRACT

Rangelands (veld) form part of an important renewable resource. Measurement and monitoring of veld condition is an important management tool. Management methods need to be centred on the objectives of the livestock farm or game reserve being managed. Veld condition assessments and their use in managing stocking rates are dependent on the range succession model, which sets out the concept of directional successional changes in species composition. Although this rangeland succession model has been widely criticised it is still extensively used for veld management in South Africa. Many variations of veld condition assessment methods have been developed to be used as a tool for making informed management decisions. The Ecological Index Method was the focus of this study.

The general expectation of the relationship between veld condition and animal biomass is that the greatest biomass should be in areas of high veld condition. Soil condition and habitat structure were also explored in terms of their relationship with the veld condition index. Animal biomass was found to decrease slightly with increasing veld condition index scores. There was little to no relationship between VCI and species diversity and evenness. Herbivore species displayed a range of habitat preferences in terms of VCI scores, grass height and tree basal area. This indicated that habitat choices may not have only been influenced by forage quality but also by ability to graze different grass heights, based on jaw morphology, and the risk of predation. The relationship between VCI and veld condition variables was found to be triangular due to the method of calculation causing the VCI to fold back on itself. This complicates interpretation of results. The results of this study suggest that either the interpretation of the index needs to be reconsidered for a game reserve context or a new method needs to be developed.

INTRODUCTION

Rangelands (veld) form part of an important renewable resource, which has the potential to provide both consumable products and non-consumptive services (Batabyal & Godfrey 2002). Livestock management requires that veld condition is assessed to determine whether animal stocking rates are optimal for achieving management goals. Therefore measurement and monitoring of veld condition is an important management tool (du P. Bothma 2002a). Before this can be done it is necessary to be fully aware of the specific management goals of a farm or reserve. Tainton (1999) noted that a common aim of commercial livestock farmers is to optimise production output of a rangeland. Veld condition assessments have been mostly used for this objective however, the objectives of game reserves differ. As explained by van Rooyen (2002a) game reserve objectives fall into three categories: (1) ecotourism, (2) hunting and (3) live animal sales. Depending on the relative importance of each objective, different management approaches may be needed.

Veld condition assessments and their use in managing stocking rates are dependent on the range succession model, which sets out the concept of directional successional changes in species composition (Dyksterhuis 1949). Succession proceeds from a pioneer state towards a climax condition. Grazing acts against the successional pathway to return an area to the pioneer state (Westoby et al. 1989; Du Toit 2000). Measurement of veld condition can indicate whether stocking rates are too high (heading towards pioneer state) or too low (heading to a climax state). Although this rangeland succession model has been widely criticised (Westoby et al. 1989; Vetter 2005) it is still extensively used for veld management in South Africa.

Veld Condition Index

Veld condition has been defined by Trollope et al. (1990) as the health of the veld with regards to its ecological status, the ability to resist soil erosion and the forage production potential. Methods of classifying a reserve's veld condition have been developed as a tool for making informed management decisions. Many variations of veld condition assessment methods have been developed following Dyksterhuis (1949) including: Ecological Index Method (Vorster 1982), Forage Value Composition Technique (Dekker & Oosthuizen 1988), Weighted Key Species Technique (Heard et al. 1986), Degradation Gradient Technique

The index score is calculated by multiplying the proportional contribution of each group by a relative index value. The index values are 10 – decreaser species; 7 – increaser I species; 5 – increaser IIa species, 4 – increaser IIb species and 1 – increaser IIc species.

The predicted relationship between veld condition and animal biomass as well as species numbers, in a game reserve context, was explained by van Hoven (2002). He stated that in general, animal biomass should be greatest in areas of high veld condition. Once grazing pressure exceeds grazing and browsing capacity, biomass increases slightly but this would not be sustainable as herbivore biomass begins to decrease as veld condition deteriorated. The diversity of both animal and plant species, is predicted to decrease as grazing and browsing capacities are exceeded. Continued heavy grazing is ultimately expected to lead to the lowest species abundance, biomass and diversity in areas of low veld condition (Fig. 2).

This study considers the relationship between veld condition index and animal abundance in the context of a game reserve which is managed primarily for ecotourism. Dung frequency is used as a proxy for herbivore abundance and species presence while veld condition index (VCI) is a proxy for veld condition. I expected to find high herbivore abundances and high herbivore diversities, as measured by dung presences, in areas with high VCI scores, as described by van Hoven (2002).

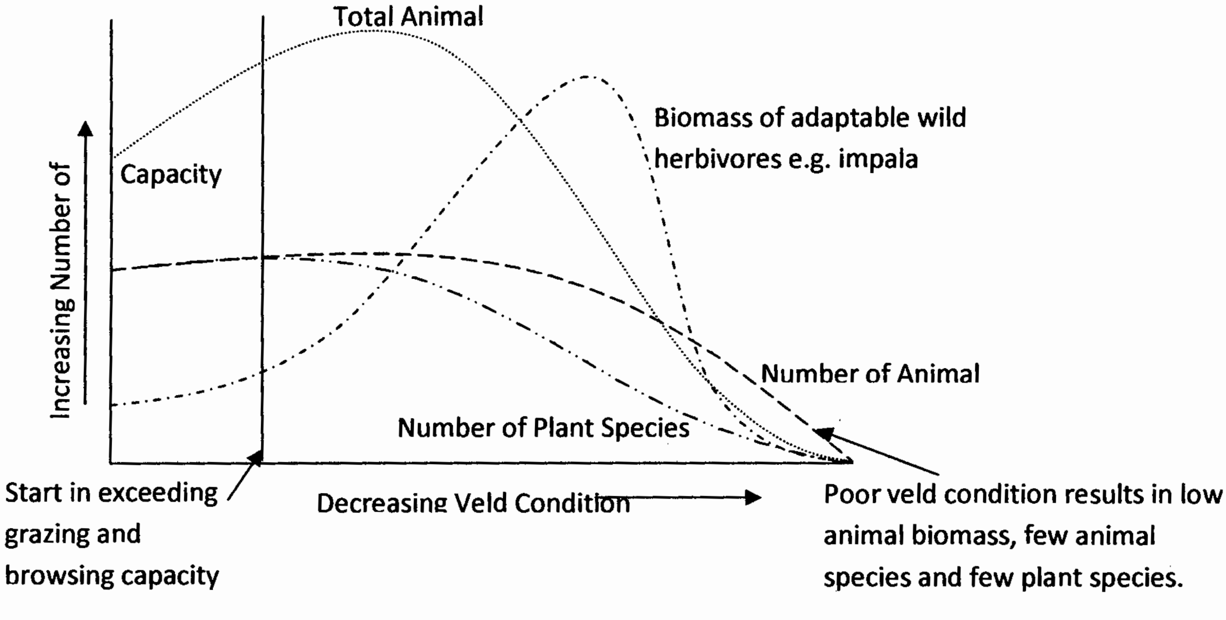


Figure 2: Natural balance between veld condition and pressure from animal use in natural savanna systems (van Hoven 2002).

The relationship between VCI and soil condition was also explored through soil properties such as soil organic matter and bulk density, which are thought to be an indication of veld quality (Vetter 2005). The prediction was that when VCI was high the soil condition would be good, that is high soil organic matter and low bulk density of the soil.

The veld condition index is based on the species composition of the grass sward. Additional ecosystem factors that may affect habitat choice, such as habitat structure, were explored. Animal habitat preferences have been shown to be a reflection of an animal's fear of predation (Ripple & Beschta 2004) or of how mammals have jaw specialisations which dictate the grass sward height they are able to graze (Bell 1971). Ripple & Beschta (2004) explained that herbivores chose grazing areas based on the risk of predation. They chose open sites for grazing on the probability of seeing predators from afar (high visibility) and the probability of escaping if attacked. Bell (1971) noted that short grasses are generally more leafy and therefore are expected to be favoured by all herbivores. However this is more severely restricted, in larger animals, by the food intake rate dictated by their bite depth. Therefore grass height may be a more useful predictor irrespective of the grass sward species composition.

In a wildlife management context one is dealing with multiple species with different habitat and grazing preferences (Trollope et al. 1990; du P. Bothma et al. 2002b), most of which do not resemble those of livestock. Therefore the aim of this study was to determine whether the veld condition index, which was initially developed with livestock farming in mind (Tainton 1999), is relevant to wildlife management. The second aim was to explore other variables that are important for monitoring habitat status for African game animals.

MATERIALS AND METHODS

Study Site - Mabula Game Reserve

Mabula Game Reserve is situated in the Bela-Bela district of the Limpopo Province of South Africa (Longitude: 24°46'S; Latitude: 27°54'E) (Smallwood 2009) (Fig. 3). The Greater Mabula Game Reserve covers 10 000ha in total but is divided by the Renosterhoekspruit provincial road. The Greater Mabula Game Reserve is comprised of Mabula Game Reserve

(8500ha) (Fig. 4) and Madjuma Lion Reserve (1500ha) (Smallwood 2009). Research was conducted on Mabula Game Reserve (MGR) and not on Madjuma Lion Reserve.

MGR falls within the savanna biome and specifically within the Central Sandy Bushveld (SVcb 12) of the Central Bushveld Bioregion (Mucina & Rutherford 2006). MGR's mean annual rainfall is 764mm (1998-2010), mean annual maximum temperature is 26°C and mean annual minimum is 15°C (1998-2010) (Fig. 5). MGR varies in altitude between 1140m and 1432m (Muller 1998). MGR is composed of 12% mountainous terrain, 67% plains and 21% drainage areas (Bredenkamp & Van Rooyen 1990) (Fig. 4). The geology of MGR is dominated by quartzites and granites which weather to infertile sandy soils.

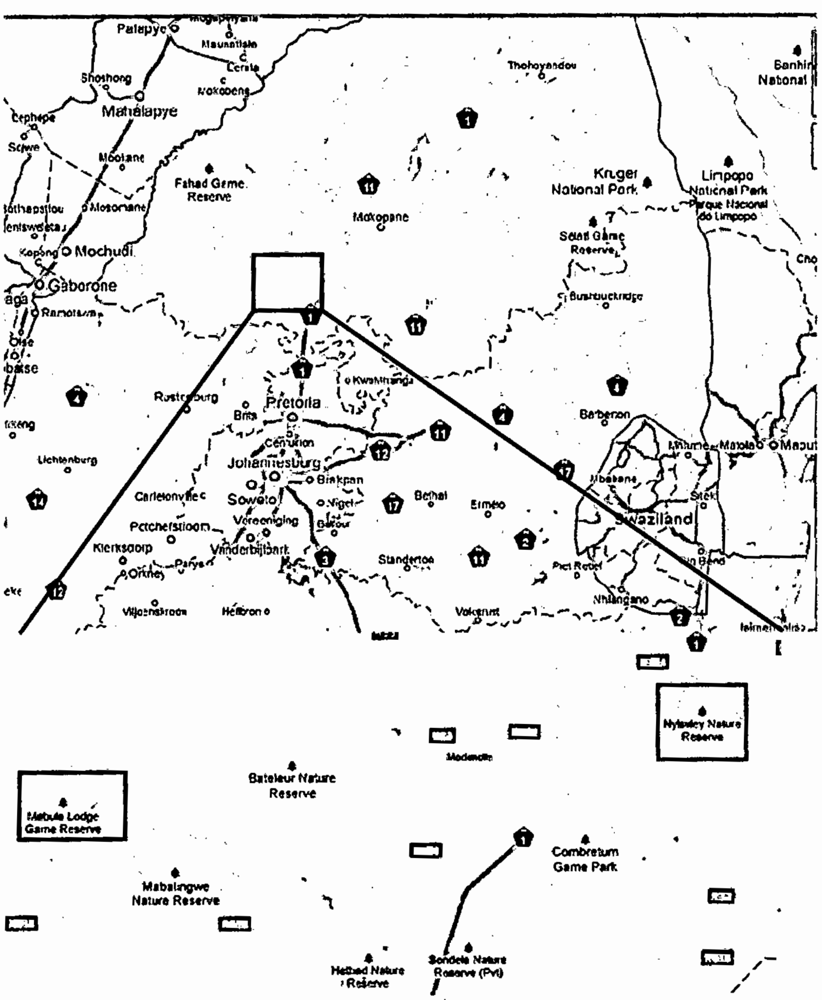


Figure 3: The Greater Mabula Game Reserve's position within Limpopo Province of South Africa. Black square - Mabula Game Reserve; Grey square – Nylsvley Nature Reserve (Modified from Google Maps, 2011).

Figure 4: Topographical map of Mabula Game Reserve with dams and monitoring sites (MGR Database).

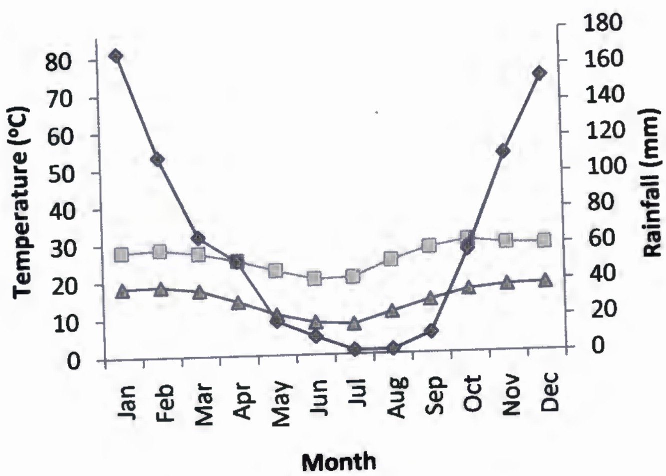


Figure 5: Climate-diagram, for MGR, including average annual rainfall (diamonds) , maximum (squares) and minimum (triangles) temperatures. Rainfall data are collected at four sites across MGR and temperature data are collected at one site on MGR.

Mabula Game Reserve Data Collection

MGR has an extensive data set which includes 14 years (1998-2011) of grass monitoring, 8 years (2004-2011) of disc pasture meter (DPM) data, 20 years (1990-2010) of fire history, 13 years (1998-2010) of daily rainfall and temperature data as well as the geology and topography of the entire farm.

The grass monitoring data has been collected during the mid-growing season, January-February, of each year at 48 sites across the reserve (Fig. 6). The descending point method (Novellie & Strydom 1987) allows for repeatability and direct comparisons of year-on-year data due to the permanent transects marked by steel posts at right angles. Each plot is set out such that four legs (50m each) radiate from a central point. A measuring tape is run between the central post and each leg, and the grass species that is intercepted at 1m intervals is identified. If a grass is not intercepted then the first plant that is within 0.5m behind the initial point is recorded. If no plant is within the 0.5m behind the grass then no grass is recorded. This method produced 200 data points per site per year. During this data collection the above-ground standing biomass was measured with a disc pasture meter (DPM). A reading was taken every 5m resulting in 40 points per site.

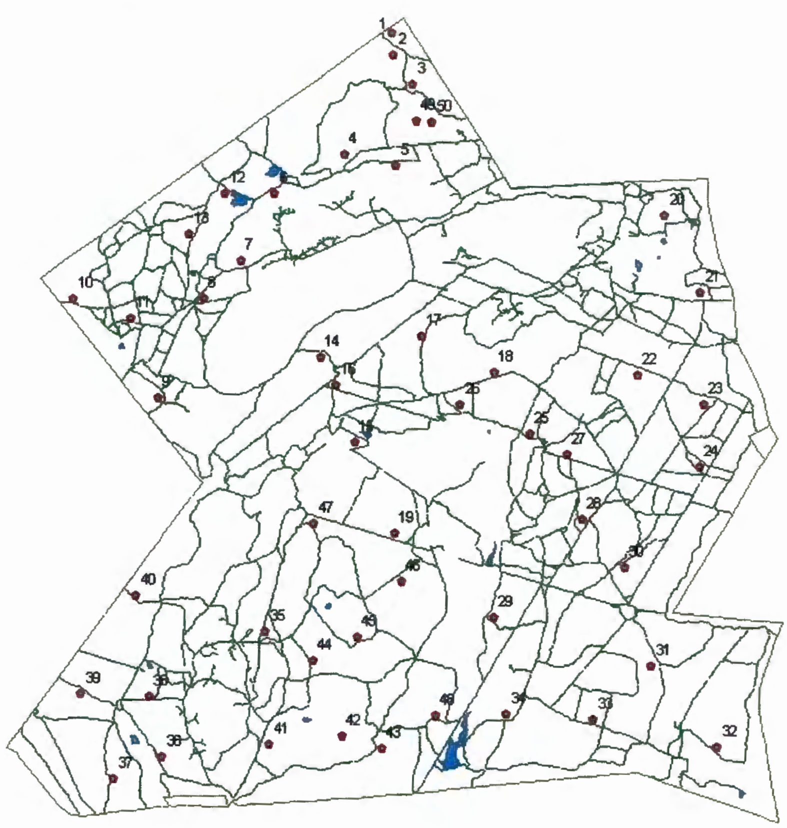


Figure 6: Grass monitoring site distribution on MGR (MGR Database).

The data were analysed by the Ecological Index Method to determine a Veld Condition Index (VCI) of each site. The VCI assessment method is based on the composition of herbaceous plant species (van Rooyen 2002b). The abundance of each species present at a monitoring site is multiplied by the grazing value of that grass species. Grazing value is an indication of production potential and palatability of a grass species (van Rooyen 2002b). The values usually used, which are used by MGR management, are: Decreaser = 10; Increaser I = 7; Increaser IIa = 5; Increaser IIb = 4; Increaser IIc = 1 (van Rooyen 2002b).

The DPM readings were calibrated using the regression equation determined by Dörgeloh (2002) for Nylsvley Nature Reserve which is within 80km of MGR and has similar vegetation (Fig. 3).

$$\hat{y} = 681.8 + 300.4x$$

where ŷ is the above-ground standing biomass ($kg_{drymatter}.ha^{-1}$) and x is the mean disc height (cm).

New Data Collection

In July 2011, all 48 monitoring sites were visited and measurements of soil properties, visibility and herbivore presences were taken. The study methods were chosen on the basis of being easily repeatable and interpretable by reserve managers and staff.

Three soil cores were collected at each site by hammering a metal tube, 11cm into the ground (Volume = 19.4cm^3). Cores were located away from tree canopies, animal paths, ant holes and granite boulders in order to ensure that these factors did not interfere with results. Cores were oven dried and weighed with a high precision balance. The mass and volume of the cores were used to determine the bulk density of the soil. Once bulk density had been determined, the cores were used to determine the soil organic matter content by placing 10-20g of soil into crucibles that were placed in a 600°C kiln for 24 hours. The crucibles and soil were weighed with a high precision balance, after the soil organic matter had been burnt off, and the amount of soil organic matter was determined as a percentage of the initial sample weight.

Sites for measuring soil infiltration rates were selected on the same basis as for the bulk density samples. A small metal cylinder (Area = 34.2cm^2) was hammered into the ground slightly to ensure water could only seep into the area within the cylinder. 100ml of water was poured into the cylinder and the infiltration time recorded. This provided a simulation of approximately 30mm of rainfall.

Tree basal area was measured using a Bitterlich Wedge from the centre-point of the site. Average visibility was estimated from four directions around the centre-point between the paths walked for grass monitoring. Visibility was based on estimating the distance at which only half a piece of white A4 paper was visible. This was done at two heights, 100cm and 165cm, representing head height of small and large animals (Cumming & Cumming 2003, Estes 1992).

A dung transect was set out over 50m and was divided into 2m x 2m blocks. The presence or absence of dung was recorded for each block as well as the species to which the dung belonged. Only dung of grazing species was considered during analysis (Table 1).

Table 1: Grazing preferences of animals considered during analyses (Trollope 1990; du P. Bothma et al. 2002b).

Animal	Species Name	Grazing Type
Buffalo	*Syncerus caffer*	Bulk Grazer
Burchell's Zebra	*Equus burchelli*	Bulk Grazer
Blesbok	*Damaliscus pygargus phillipsi*	Concentrate Grazer
Blue Wildebeest	*Connochaetes taurinus*	Concentrate Grazer
Gemsbok	*Oryx gazelle*	Concentrate Grazer
Impala	*Aepyceros melampus*	Concentrate Grazer
Warthog	*Phacochoerus aethiopicus*	Concentrate Grazer
White Rhino	*Ceratotherium simum*	Concentrate Grazer
Red Hartebeest	*Alcelaphus bucelaphus*	Concentrate Grazer

Data Analysis

The species diversity and species evenness of the plant and animal species were calculated with the Shannon-Wiener Index:

$$H = -\sum_{i=1}^{S} p_i . \ln(p_i)$$

where p_i is the proportion of the *i*th species and S is the number of species at a site. The scores usually ranged between 1.5 (low richness and evenness) and 3.5 (high richness and evenness). Species evenness of the plants and animals was calculated as:

$$E_H = \frac{H}{H_{Max}} = \frac{H}{\ln(S)}$$

where H is the Shannon-Wiener Index and S is the number of species at that site. The values range between 0 and 1 (complete evenness). The Simpson Index was used to determine the species dominance of plants and animals:

$$D = \sum_{i=1}^{S} p_i^2$$

where D is the Simpson Dominance Index and p_i is the proportion of the *i*th species. The index also ranges between 0 and 1, where 1 represents the high dominance of one species and 0 represents low dominance.

To determine whether the different grazer species preferred different veld conditions, the average VCI score of each animal was calculated. The VCI was multiplied by the number of dung presences of each species at that site. This meant that if dung of an animal was not present the VCI of the site would not be included in the weighted average. Weighted VCI scores of each animal were summed and divided by the total number of dung occurrences at all sites. The same method was used to determine the abundance weighted average above-ground standing biomass, visibility, tree basal area, soil organic carbon and bulk density at which each mammal species was found.

$$Abundance\ Weighted\ Average\ X = \frac{\sum_{i=1}^{n} X * (No.dung\ occurrences\ at\ site)}{Total\ No.of\ dung\ occurrences\ at\ all\ sites}$$

where X is the variable being averaged per species and n represents the number of sites (See Table 2 in appendix for worked example).

Statistica was used to perform an ANOVA to determine which animal species had significantly different habitat preferences. Regression analyses were used to determine the strength of relationships between veld condition variables.

RESULTS

Dung frequency, of all herbivores combined, declined slightly with increasing veld condition score ($R^2 = 0.121$, df = 46, $p < 0.05$) (Fig. 7).

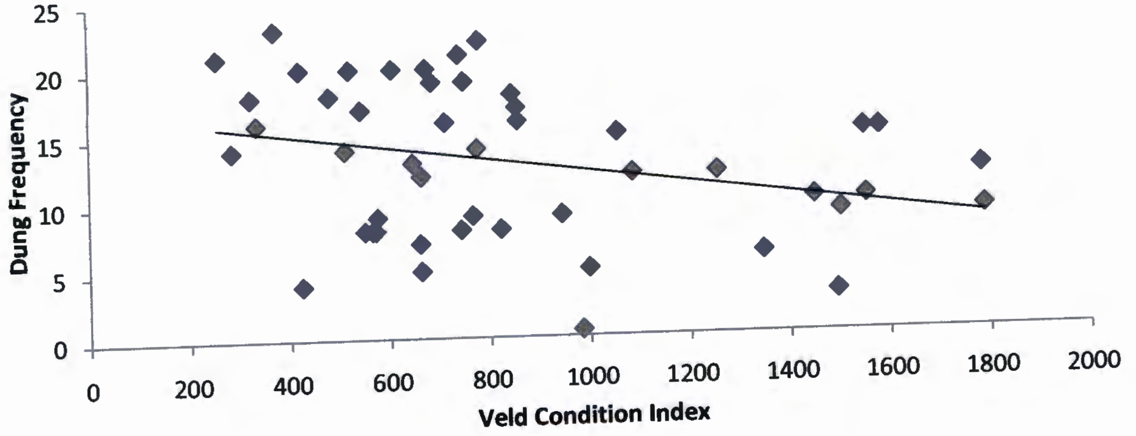


Figure 7: Dung frequency out of a possible 25 presences for each site in relation to the VCI of each site.

The Shannon-Wiener Index and VCI had a slight relationship ($R^2 = 0.1$, df = 46, $p < 0.05$). There was no statistical relationship between evenness, measured by the Simpson Index ($R^2 = 0.05$, df = 46, $p > 0.05$), or the Equitability Index ($R^2 = 0.01$, df = 46, $p > 0.05$) and veld condition score (Fig. 8).

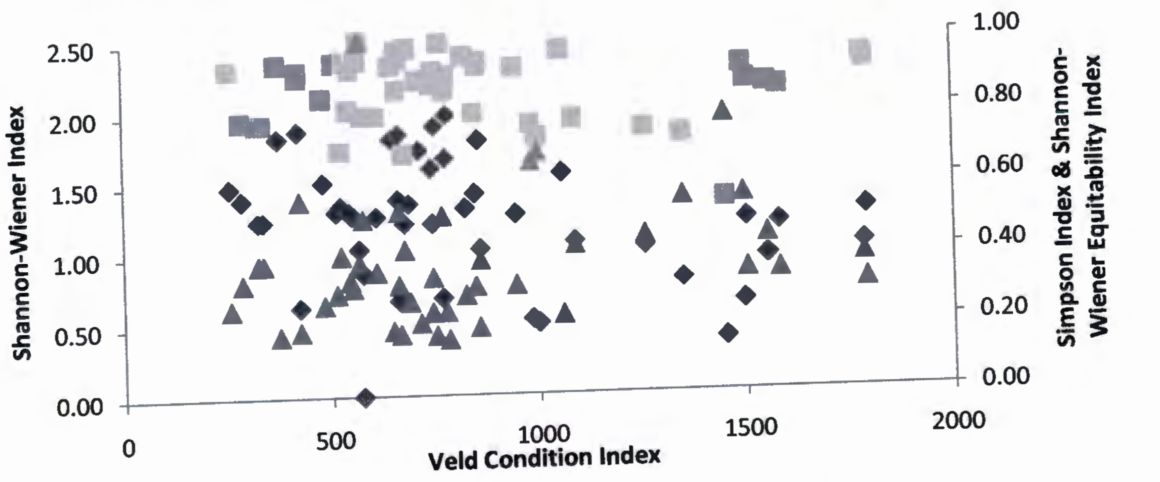


Figure 8: Diversity and evenness indices of dung frequencies. Shannon-Wiener Index = diamonds; Simpson Index = triangles; Shannon-Wiener equitability =squares.

The diversity and evenness of plant species peaked at intermediate VCI scores (between 500 and 1000) for both the Shannon-Wiener Index (R^2 = 0.52, df = 46, $p < 0.01$) and Equitability (R^2 = 0.64, df = 46, $p < 0.01$). The Simpson Index (R^2 = 0.69, df = 46, $p < 0.01$) of dominance displayed the inverse pattern as the Shannon-Wiener indices with high dominance at low and high VCI scores (Fig. 9).

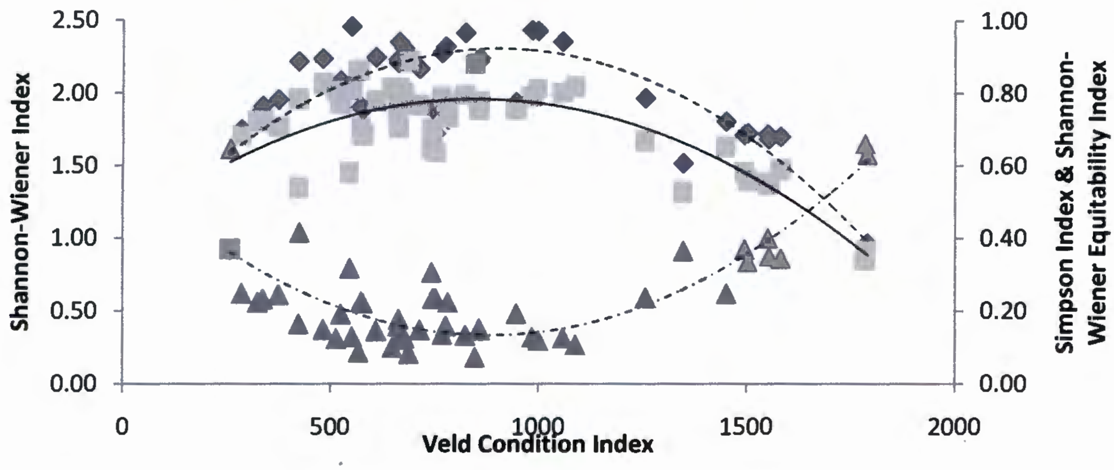


Figure 9: Diversity, evenness and dominance indices of plants in relation to the VCI at each site. All three indices displayed a parabolic relationship with VCI. Shannon-Wiener Index = diamonds, dashed line; Shannon-Wiener equitability = squares, solid line; Simpson Index = triangles, dash dot line.

Habitat Preferences of Herbivores

Dung frequency of each grazing species on MGR is plotted separately along the VCI gradient to determine if VCI could be used to discriminate among different herbivore species (Fig. 10). The majority of high species presences were at low VCI scores with the exception of buffalo and zebra which had relatively more presences at sites with high VCI scores. This indicated that the VCI is inappropriate as a general index for wildlife management but may be useful for specific species such as buffalo and zebra.

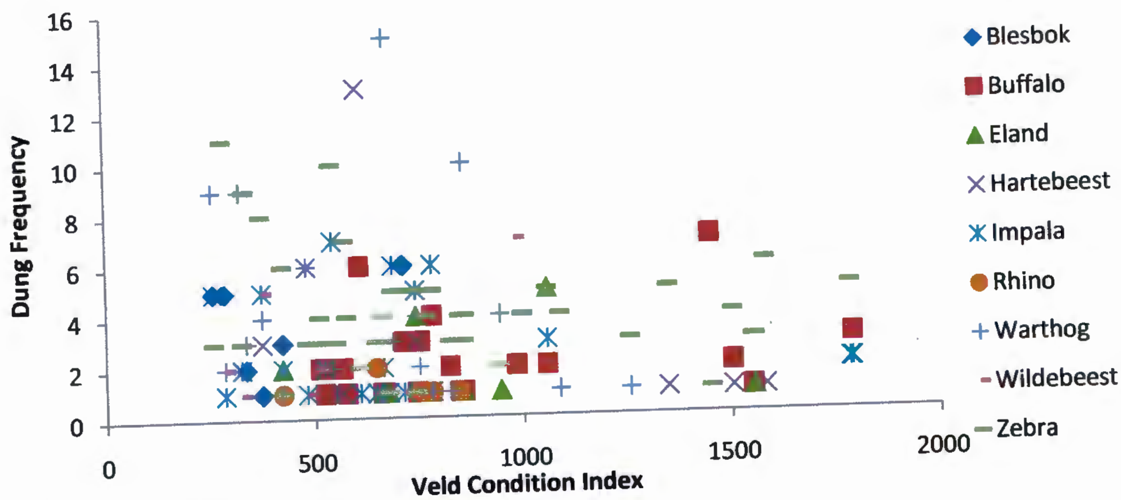


Figure 10: Relationship between dung frequency of each of the grazing species and VCI.

An analysis of variance and a post-hoc test, Tukey HSD, were used to determine whether there was a significant difference in each species' preferred VCI. The results indicated that species had significantly different preferences of grazing areas (ANOVA: $F = 7.66$; $df = 11, 563$; $p < 0.01$) and the post-hoc test indicated which species were significantly different (Tukey HSD: M.S = 0.20, $df = 563$, $p < 0.05$). Blesbok, warthog and wildebeest preferred low VCI scoring sites. Hartebeest, impala and rhino preferred sites with a mid-range score. Zebra, eland and buffalo preferred sites with higher VCI scores (Fig. 11).

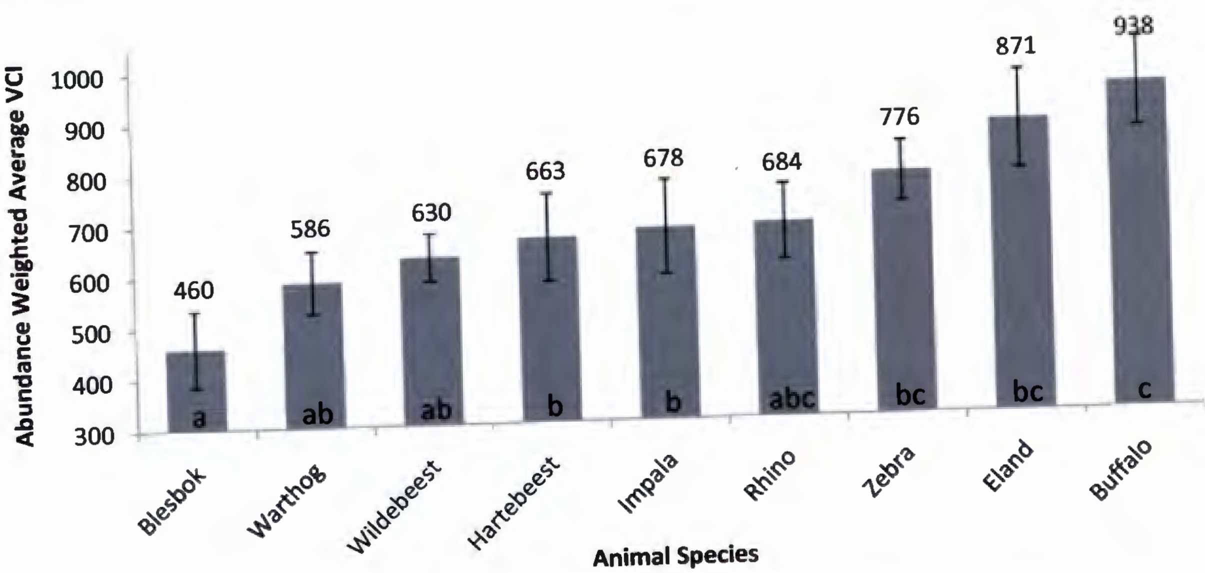


Figure 11: abundance weighted average VCI for each species. Bars represent standard error of results. Letters represent significant differences between mean VCI score for each species ($p < 0.05$) according to ANOVA and Tukey HSD.

Influence of Vegetation Structure and Composition on Habitat Preference

The abundance weighted average above-ground standing grass biomass (hereafter referred to as biomass) for each species and VCI were plotted to determine whether grazers on MGR had different preferences for short grass versus tall grass (Fig. 12). The pattern indicated that zebra and buffalo preferred tall grass, high VCI sites while eland preferred high VCI but lower grass height. Warthog and hartebeest displayed a preference for mid-range grass height and low VCI while the wildebeest, rhino and impala, with similar VCI scores, appeared to prefer shorter grass. Blesbok had a striking preference for very low VCI and short grass.

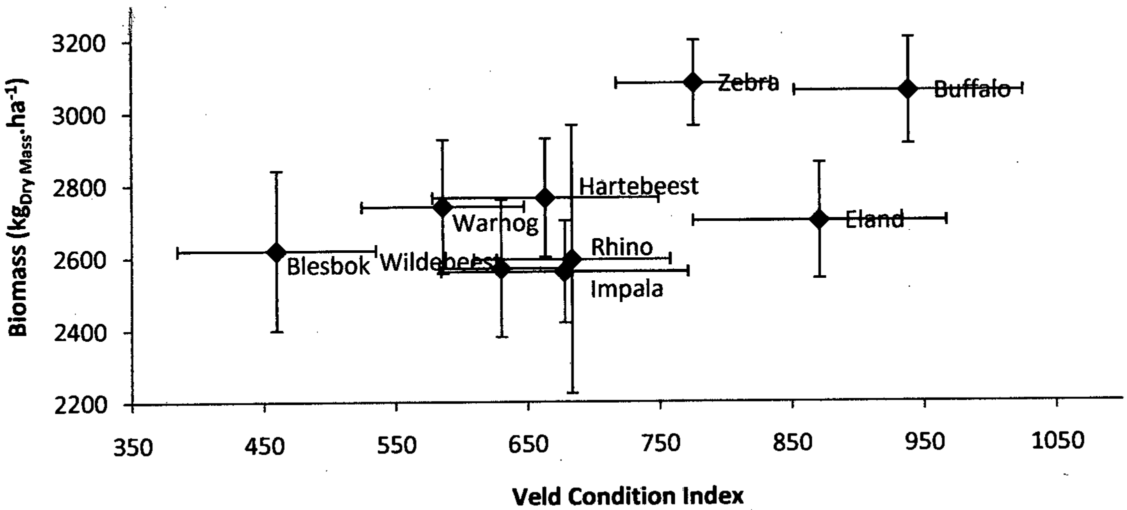


Figure 12: relationship between dung abundance weighted VCI score and dung abundance weighted above-ground standing biomass ($kg_{dry\ mass}.ha^{-1}$). Error bars indicated for both variables.

Visibility at 1m and 1.65m were found to correlate strongly ($R^2 = 0.70$, df = 46, p <0.01) (Fig. 13), therefore results of 1m visibility were considered a good representation of both heights.

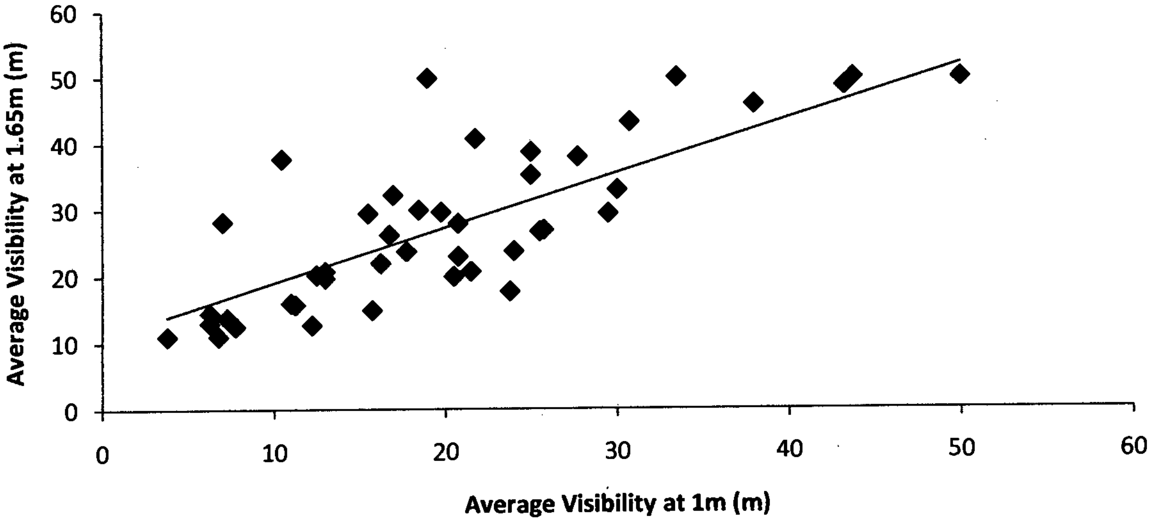


Figure 13: Correlation between visibility at 1m and 1.65m.

Grazing species habitat preferences' relation to visibility, grass biomass and tree basal area is shown in Figs. 14 & 15. Animals, such as blesbok, which preferred low biomass sites favoured high visibility areas which also tended to have low tree basal area. For large animals, such as buffalo, good visibility was not a requirement. This indicated that site selection by animals was also influenced by visibility which in turn was influenced by both biomass ($R^2 = 0.18$, df = 46, $p < 0.01$) and tree basal area ($R^2 = 0.21$, df = 46, $p < 0.01$) (Fig. 16).

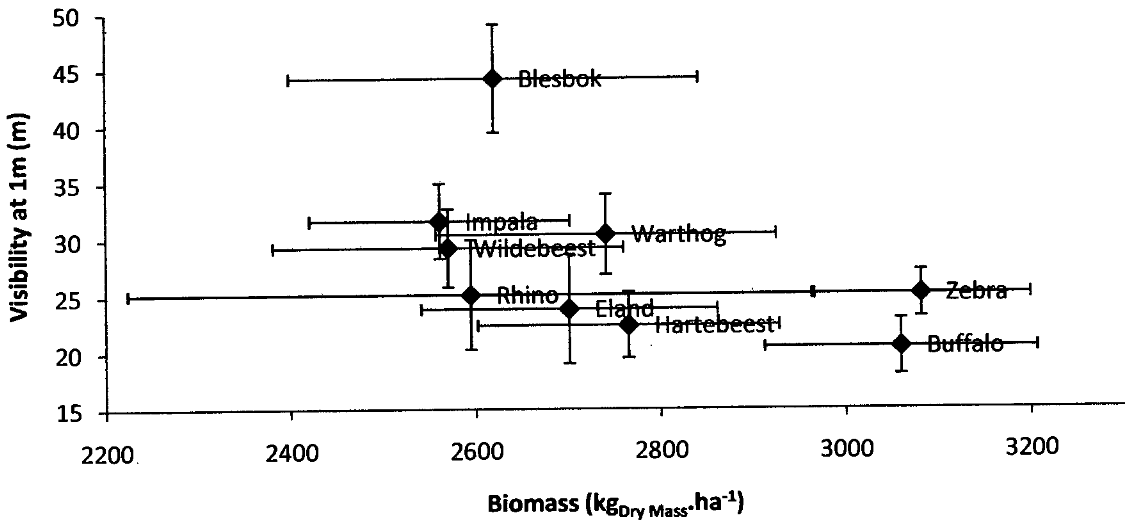


Figure 14: Preferred visibility and preferred biomass of grazing species.

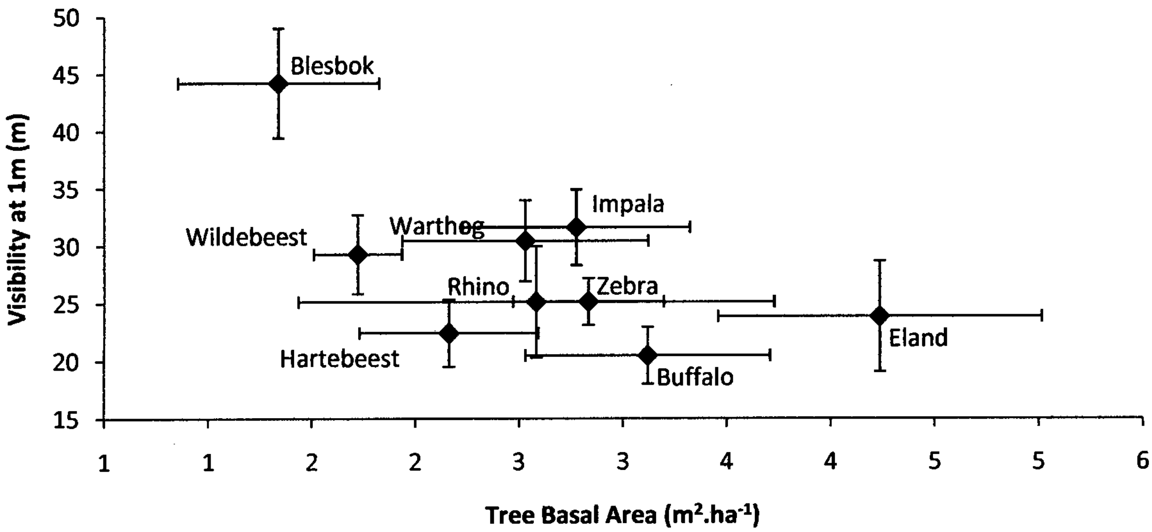


Figure 15: Abundance weighted average visibility and tree basal area of sites visited by animals.

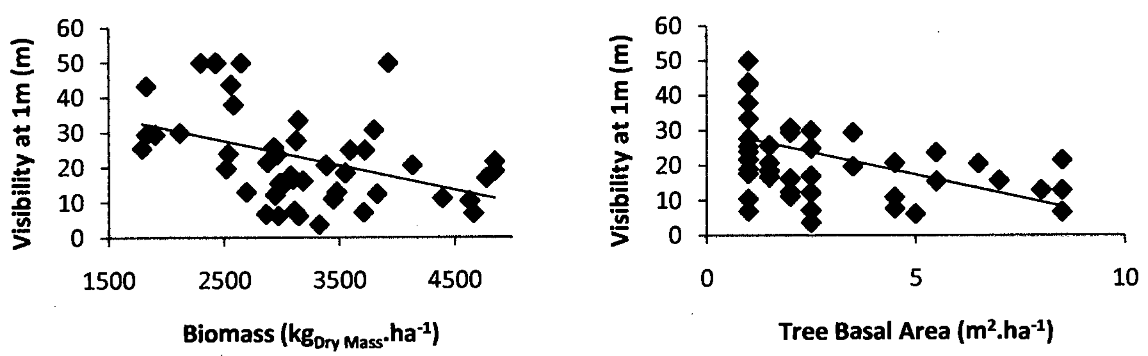


Figure 16: Visibility decreases with an increase in both grass biomass and tree basal area.

Soil organic matter ranged from 1.5% to 4.9% with a mean of 2.4%. Average infiltration time was 346 seconds with a range from 96 seconds to 725 seconds. The bulk density had a minimum of 4g.cm^{-3} and maximum of 7g.cm^{-3} with a mean of 5g.cm^{-3}. The patterns indicated that the lowest compaction was generally in wooded areas and highest compaction was in open areas and plains. Fast infiltration times occurred in the sandy areas of MGR while the slower infiltration times occurred in areas with high clay content.

Relationship between VCI, veld and soil condition variables

The relationship between VCI and most veld condition variables is not linear but rather forms a triangular relationship (Figs. 17).

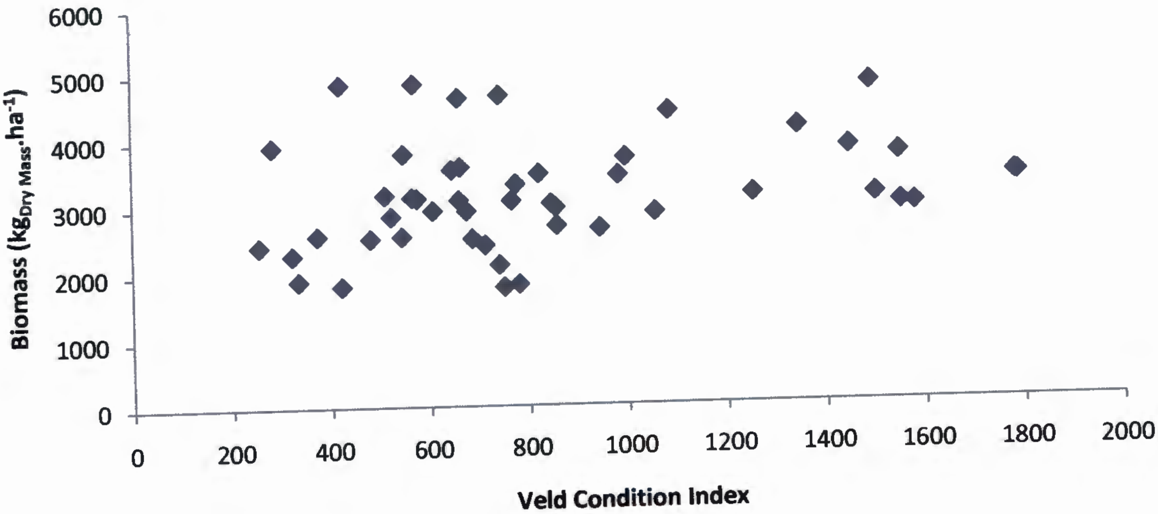


Figure 17: non-linear relationship between above-ground standing biomass and veld condition index (Regression: $F = 3.06$, $df = 46$, $p = 0.09$).

Other variables, which are indicators of veld condition, displayed the same non-linear relationship with VCI. These variables included soil organic carbon (Fig. 18a) and soil bulk density (Fig. 18b). The triangular relationship did not appear to apply to the average infiltration time (Fig. 18c).

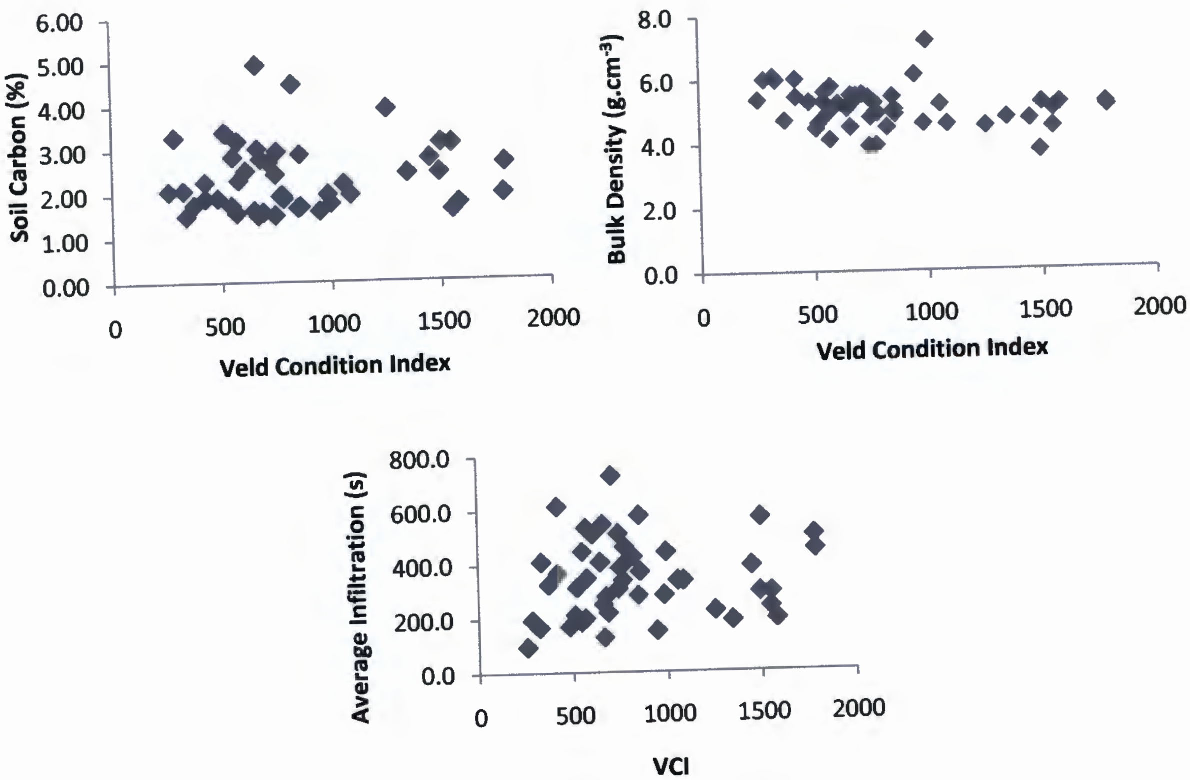


Figure 18: non-linear relationship between veld condition index and veld condition variables: (a) soil organic carbon, (b) bulk soil density and (c) average infiltration time.

Discussion

Veld condition indexing was developed for livestock farming with cattle as the main herbivore (Tainton 1999). The VCI system has been transferred to game reserves as a method of monitoring veld condition with the same grouping of grass species (van Rooyen 2002b). The expectation is that a high VCI score would be an indication of veld in 'good condition', indicating that the forage requirements of the wildlife are being met. Thus the relationship between VCI and herbivore density (measured as dung frequency) should be positive. These sites would also be expected to have a high diversity and evenness of herbivore species.

However, the results indicated that in a, multiple herbivore species, game reserve context the VCI did not have a positive relationship with dung presences (Fig. 7). Neither the abundance, nor the dung frequency of herbivores varied with VCI. The poor performance of

VCI in predicting the abundance or diversity of grazers indicates that it is an inappropriate measure of veld condition in a wildlife management context. VCI does not take into consideration that most game species do not resemble cattle in their forage and habitat preferences, nor do all game species have similar preferences. Furthermore differences in habitat preferences of game species have been shown to be influenced by body size (Bell 1971), predation risk (Ripple & Beschta 2004) and forage and water availability (Dörgeloh 2001).

Habitat Preferences of Grazing Herbivores

VCI preferences differed between grazing species. Blesbok (VCI = 460), warthog (VCI = 586) and wildebeest (VCI = 630) preferred areas with low VCI scores. If a reserve manager were to determine that the veld condition across most of a reserve was 'poor', management would be altered to 'improve' veld condition. By promoting grass species which would increase the veld condition score, one would cause a decrease in available habitat for species such as blesbok, warthog and wildebeest. While species such as buffalo (VCI = 938), eland (VCI = 871) and zebra (VCI = 776) would have more than sufficient preferred grazing area available to them. This was supported by van Hoven (2002) who noted that wild herbivores appear to cope better with 'poor' veld conditions than domestic animals.

This survey was conducted in the early dry season. The habitat preferences reported are characteristic of the species on MGR. Habitat preference is unlikely to change with season however in the late dry season habitat preferences may shift slightly due to grazing requirements not being met in some areas.

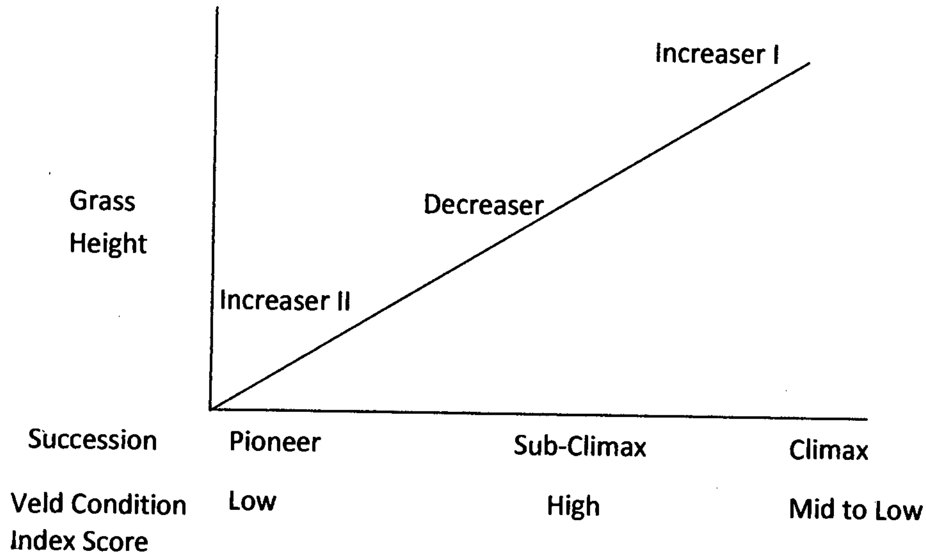
Vegetation Structure and Habitat Preferences

African mammals have been categorised as tall grass or short grass feeders (du P. Bothma 2002b, Novellie 1990) and this study supported this assertion (Fig. 12). The choice of high or low biomass may be indicative of animals choosing areas based on the forage height (Bell 1971, Laca et al. 1992, Edwards et al. 1995) or visibility during foraging (Ripple & Beschta 2004). Bell (1971) found that niche partitioning of grazing was based on body size in relation to grass height, while Laca et al. (1992) and Edwards et al. (1995) found that it was based on herbivore bite size. The grass biomass preferences of animal species on MGR were similar in that larger animals preferred taller grass while smaller animals preferred shorter grass (Fig. 12). Habitat preferences were influenced by variables related to predator avoidance, visibility (Fig. 14) and tree basal area (Fig. 15). Animals which chose high visibility areas, regardless of VCI, were generally smaller while larger animals tended to choose areas with higher VCI scores and lower visibility. Rhino did not display very specific habitat choices, with large standard errors around mean grass biomass and tree basal area. This is consistent with the idea that larger herbivores are less concerned with predation risks (Ripple & Beschta 2004).

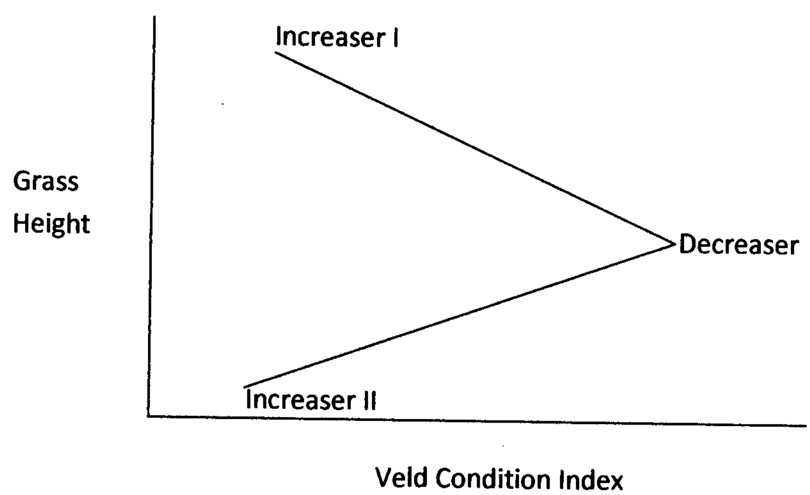
Veld Condition Index and Veld Condition Variables

Snyman (1999) suggested that the relationship between veld condition and dry matter production ($kg.ha^{-1}$) would be a positive linear relationship, which is influenced strongly by rainfall (See also Du Toit 2000; Hardy et al. 1999). However, the results of this study revealed that VCI was not linearly related to biomass as expected from Snyman's (1999) suggestion. The VCI is calculated in such a way that linear relationships with biomass, productivity and soil variables are very unlikely. This is because of the scoring system with pioneer and climax species having lower scores than mid-successional decreasers (Du Toit 2000; Hardy et al. 1999) (Figs. 19 & 20). Pioneer species are traditionally shorter grasses which are classified as increaser II species. Decreaser species are generally sub-climax species while increaser I species are usually climax species which are taller than decreasers (Fig. 19). Hardy et al. (1999) explained that areas in poor condition are typically in the pioneer state while areas in good or excellent condition are typically dominated by climax or sub-climax species.

This weighting system, along with the disjunct series of weighting values (Du Toit 2000) cause the relationship to fold back on itself forming a triangular relationship (Fig. 20).



<u>Figure 19:</u> Relationship between veld condition index groups and succession pathway (Du Toit 2000; Tainton & Hardy 1999).



<u>Figure 20:</u> resulting triangular relationship from method of calculating veld condition index.

This system may be appropriate for cattle since they prefer decreaser species. For wildlife species, however, this weighting system greatly complicates interpretations of VCI by turning a linear successional relationship into a triangular relationship where correlations with other veld condition measurements are unlikely. Grass height (biomass), for example, would be greatest in sites dominated by increaser I species but those sites would have mid to low VCI scores similar to those of sites dominated by short grass increaser II species. Decreaser dominated sites would have mid grass heights but high VCI scores. Thus VCI produces a triangular relationship with grass height (Fig. 21) and this confounds the interpretation of the index.

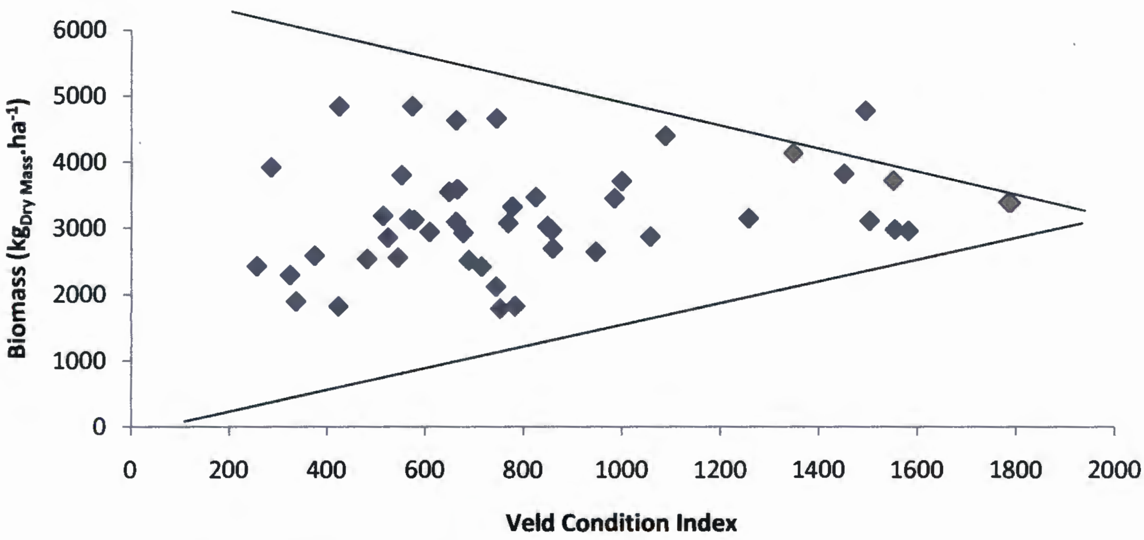


Figure 21: non-linear relationship between above-ground standing biomass and veld condition index. Lines indicate triangular relationship.

Soil properties such as soil organic matter and bulk density also have a triangular relationship with VCI (Fig. 18). High biomass at increaser I dominated sites (low grazing pressure) would promote the return of carbon to the soil through grasses dying and decomposing in the area. Less biomass would be available in areas dominated by decreaser and increaser II species leading to lower soil organic matter content. Low VCI sites had the highest bulk density which supports the suggestion that animals prefer areas that would be considered to be in 'poor' condition as animals would be trampling these areas more than areas with higher VCI scores.

Towards More Appropriate Veld Condition Scores

The results of this study show that VCI, in its current form, is inappropriate as a veld condition assessment tool for wildlife management practices. The use of the range succession model for veld management has been heavily criticised because of inappropriate assumptions about veld succession patterns (Westoby et al. 1989). Criticism has also stemmed from inappropriate assumptions about management objectives in some livestock systems (see Vetter 2005 for a recent review). The use of VCI for wildlife management however, fails for different reasons. The veld succession model may be quite effective for wildlife management systems but, unlike cattle, different African mammal species are specialised for early, mid and late successional stages. Therefore, it is essential for veld monitoring methods to detect these different successional stages. The current method, imported directly from livestock farming, confounds early and late successional stages so managers cannot differentiate between systems that are moving towards a heavily cropped grazing lawn, typically with high grazer densities and a tall grass system with few grazers. Potential alternatives to using VCI would require altering the interpretation of the current system. Perhaps the development of a numbering system that reflects the linearity of successional trends should be the first priority. However, there is also the option of developing an entirely new system.

By changing the interpretation from aiming to increase the overall score of a reserve, a manager could also aim to have a good representation of a wide range of scores (Novellie 1990) thereby creating a mosaic of habitats. This would require accounting for the proportions of different herbivores, and their varying habitat requirements, on the reserve. Therefore research is required to determine what range of veld conditions are preferred by different grazing species throughout the year. Additionally, it would be ideal to include monitoring of variables linked to predator avoidance, such as visibility and woody tree cover, as this had a definite influence on the habitat choices made by some herbivore species.

An example of a potentially new system would be the use of habitat structure (e.g. grass height and tree basal area) rather than vegetation species composition. This method may be informative as well as a less work-intensive monitoring method. The importance of grazing height and perceived predation risk, on habitat preferences, would then be taken into account with this method. Disc pasture meter measurements could be used as a proxy for grass height and tree basal area, or visibility distance, would provide an estimation of woody thickening which may alter the predation risk. Further research would be required to ensure the relationship between habitat structure and habitat preference is better understood.

However, as noted by Trollope (1990) regardless of having the appropriate techniques or not it is necessary for the condition of different habitats to be assessed, whether subjectively or objectively. The requirement for monitoring is because fenced areas are no longer in their 'natural state' therefore management interventions are necessary

(Buitenwerf et al. 2011). This study has shown that basic development work is still required to transfer methods developed in classic rangeland science to the more complex ecological characteristic of wildlife management systems.

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APPENDIX

Worked Example of Abundance Weighted Average Calculation:

$$Abundance\ Weighted\ Average\ VCI\ for\ Buffalo = \frac{\sum_{i=1}^{48} VCI * (No. dung\ occurrences\ at\ site)}{Total\ No. of\ dung\ occurrences\ at\ all\ sites}$$

$$Abundance\ Weighted\ Average\ VCI\ for\ Buffalo = \frac{43168}{46}$$

$$\underline{Abundance\ Weighted\ Average\ VCI = 938}$$

Table ??: Data used to determine the abundance weighted VCI for Buffalo.

Site	VCI	Buffalo Dung Occurrences	VCI*Dung Occurrences	Site	VCI	Buffalo Dung Occurrences	VCI*Dung Occurrences
1	745	1	745	25	551	2	1102
2	1257	0	0	26	1451	7	10157
3	857	1	857	27	1554	0	0
4	1088	0	0	28	1503	2	3006
5	257	0	0	29	1348	0	0
6	688	0	0	30	824	2	1648
7	946	0	0	31	513	2	1026
8	324	0	0	32	782	4	3128
9	677	0	0	33	768	0	0
10	567	2	1134	34	423	0	0
11	482	0	0	35	848	1	848
12	859	0	0	36	777	0	0
13	609	6	3654	37	662	1	662
14	1495	0	0	38	743	0	0
15	577	1	577	39	752	3	2256
16	663	0	0	40	524	1	524
17	1551	1	1551	41	374	0	0
18	573	0	0	42	336	0	0
19	285	0	0	43	999	0	0
20	424	0	0	44	648	0	0
21	1785	0	0	45	665	1	665
22	1790	3	5370	46	545	0	0
23	1582	0	0	47	1058	2	2116
24	714	3	2142	48	984	0	0

Table ??: Species that fall into each of the veld condition index groups.

Decreaser Species	Increaser I Species	Increaser IIa Species	Increaser IIb Species	Increaser IIc Species
Anthephora pubescens	*Alloteropsis semialata*	*Bewsia biflora*	*Aristida meridionalis*	*Aristida adscensionis*
Brachiaria nigropedata	*Andropogon chinensis*	*Diheteropogon amplectens*	*Bothriochloa insculpta*	*Aristida bipartite*
Brachiaria serrata	*Andropogon eucomus*	*Eragrostis capensis*	*Bothriochloa radicans*	*Aristida canescens*
Cenchrus ciliarus	*Andropogon huillensis*	*Eragrostis lehmanniana*	*Chloris gayana*	*Aristida congesta barbicollis*
Digitaria eriantha	*Andropogon schirensis*	*Eragrostis pseudosclerantha*	*Chloris virgata*	*Aristida congesta congesta*
Eustachys paspaloides	*Bothriochloa bladhii*	*Schizachyrium jeffreysii*	*Dactyloctenium aegyptium*	*Aristida diffusa*
Fingerhuthia africana	*Brachiaria brizantha*	*Sporobolus stapfianus*	*Digitaria monodactyla*	*Aristida junciformis*