Technique to study the impact of large herbivores on woody vegetation within piospheres

J. BRITS, M.W. VAN ROOYEN and N. VAN ROOYEN

Brits, J., M.W. van Rooyen and N. van Rooyen. 2000. Technique to study the impact of large herbivores on woody vegetation within piospheres. *Koedoe* 43(2): 47–56. Pretoria. ISSN 075-6458.

A continuously sampled transect away from a watering point provides good results in situations where geology and soil type remain constant, but is unsuitable to apply where regular changes in soil type occur. A comparison was made between a continuously sampled transect and sampling taken at intervals along the transect. An analysis of variance indicated no significant differences in any of the variables obtained by means of the two sampling methods. The advantage of interval sampling is that, within each zone, areas with the same soil type can be selected in order to avoid environmental heterogeneity. A comparison between transects made in different directions from the watering point yielded no significant differences in any of the structural variables of the woody vegetation at the same distance from the watering point. Therefore, combining transects from different directions to attain a representative sample away from the watering point was an acceptable practice. It is recommended that the original data be smoothed and the logistic function used to model the impact of large herbivores on the structure of the woody vegetation around watering points.

Key words: artificial watering points, browsing pressure, Kruger National Park, large herbivores, piosphere, woody vegetation

J. Brits, Centre for Wildlife Management, University of Pretoria, Pretoria, 0002 Republic of South Africa (Present address: Wilderness Trails, Kruger National Park, South African National Parks, Private Bag X402, Skukuza, 1350, Republic of South Africa); *M.W. van Rooyen and N. van Rooyen, Department of Botany, University of Pretoria, Pretoria 0002, Republic of South Africa.*

Introduction

It is generally believed that the best design to study impacts is an areas-by-times factorial experiment (Green 1979) which entails data collection before and after the impact has occurred, both near and away from the point of impact. This type of design has both temporal and spatial controls. However, the study of impacts often only begins once the disturbance has already occurred and in these cases the impacts have to be inferred from spatial patterns alone.

In the Kruger National Park a water-for-game programme was implemented in five phases between 1929 and 1990 (Brynard 1969; Pienaar 1985; Thrash 1993). At present, there are 283 artificial watering points where drinking water is supplied in troughs, 42 concrete dams and 51 earthen dams, giving a density of artificial watering points of about one per 5 000 ha. In recent years, this artificial water provision scheme has been sharply criticised for being inducive to overutilisation and consequently degradation of the habitat. In the light of these allegations an assessment of the impact of large herbivores on the vegetation in the Kruger National Park was necessitated.

Lange (1969) used the word piosphere to describe the area of rangeland which surrounds a permanent watering point. His definition of a piosphere is "an ecological system of interactions between a watering point, its surrounding vegetation and the grazing animal". According to Graetz & Ludwig (1978), a piosphere develops as a result of the interaction of the maintenance and social behaviour patterns of herbivores with the vegetated landscape in which the watering point has been established.

A lack of baseline data before the erection of watering points made direct comparisons before and after the impact impossible. Therefore, the approach that had to be followed was one of inferring the impact from present spatial patterns alone. However, spatial patterns in the vegetation may reflect changes in environmental factors such as geology, soil type, soil depth and topography (Gertenbach 1987; Venter 1990) and are not necessarily correlated with herbivore impact. To avoid confounding the effects of herbivores with other environmental factors, the environment that is sampled has to be kept as homogeneous as possible. This could be successfully done to study the herbaceous stratum, where the effects of large herbivores are concentrated in a relatively small area surrounding the watering point (Thrash 1993, 1998). In the case of the woody vegetation, the impact of large herbivores may extend for several kilometres around the watering point, making it virtually impossible to keep all the environmental factors, across the area sampled, homogeneous. No technique has yet been described which satisfactorily deals with this source of variation, and consequently a new technique had to be devised.

The method mostly used to study piosphere effects is a continuous transect away from the watering point. When such a transect stretches over several kilometres differences in geology and soil types are usually encountered. One way to overcome this problem is to divide the transect into sections, and to sample only one particular soil type within each of these sections. The question then arises whether such a sub-sample within each section can be considered as representative of the entire section. When the watering point is located in an extremely heterogeneous environment, it may not always be possible to find a particular soil type within each section on the same directional line. The particular soil type may, however, be present at the same distance from the watering point, but in another direction. However, vegetation structure could differ on the same soil type, depending on the direction from the watering hole. It was therefore necessary to test whether structural variables, at the same distance intervals, differed significantly in direction.

The aim of this study was to provide answers to these questions by comparing (a) a continuously sampled transect to sampling taken at intervals along the transect; and (b) transects done in different compass directions. The effect of smoothing the data prior to fitting either the logistic or polynomial curves to the data is evaluated. A new technique is suggested to study the impacts of large herbivores on the woody vegetation around watering points.

Methods

The four largest land systems in the Kruger National Park are the Satara, Letaba, Skukuza and Phalaborwa land systems (Venter 1990). The impact of large herbivores on the vegetation had to be evaluated in each of these land systems. The Satara and Letaba land systems lie on basaltic rock, while the Skukuza and Phalaborwa land systems are underlain by granitic rock.

On the eastern basalt plains of the Satara and Letaba land systems both soil type and depth are fairly homogeneous along a transect away from the watering point. The undulating terrain on granitic rock of the Skukuza and Phalaborwa land systems results in continual changes in soil type (Coetzee 1983). The deep sandy soils of the crests grade into the well leached soils of the midslope and then to the duplex soils on the footslope areas (Venter 1990).

The survey method used in this study was essentially the BECVOL (Biomass Estimates for Canopy VOLume) transect method described by Smit (1989). A woody individual was recorded when its main stem was rooted inside the transect but not when only part of the canopy covered the transect. Each woody individual was identified and the following dimensions measured:

- A Tree height;
- B Height of maximum canopy diameter;
- C Height of the lowest leaves;
- D Maximum canopy diameter; and
- E Diameter of the foliage at C.

Measurements D and E were taken in two directions perpendicular to one another to obtain a better estimate of canopy volume. The structural variables that were calculated with the BECVOL computer programme (Smit 1989) were total density (all woody individuals), tree density (woody individuals > 2 m), shrub density (woody individuals ≤ 2 m) and ETTE (Evaporation Tree Equivalents). The latter estimate (ETTE) is defined as the leaf volume equivalent of a 1.5 m tall single stemmed tree and since it is a function of both tree height and canopy diameter it is regarded as an accurate estimate of biomass (Smit 1989).

Procedure on basaltic soils

A trial transect was laid out in the Satara Land System. To position the transect, the area around the watering point was assessed using stereoscopic aerial photographs. The transect was placed in the landscape where the least possible changes in soil type were likely to occur and within the same burning block, to keep the effect of fire constant (Trollope *et al.* 1998).

In the first instance a 4 m wide continuous transect (consisting of consecutive plots of 4 m x 100 m), starting at the watering point and following a directional line away from the watering point, using a Global Positioning System (GPS), was sampled (Fig. 1). Secondly, 10 m x 50 m transects at 100 m intervals were sampled perpendicular to and on the same directional line and soil type used for the previous technique (Fig. 1).

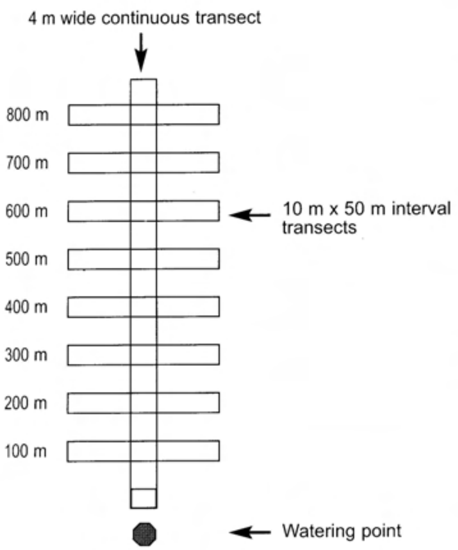

Fig. 1. Placement of the continuous and interval transects around watering points (not to scale).

For the continuous sampling technique the transect ended at 3 000 m because of the presence of a dolerite dyke making further homogeneous sampling impossible. With the interval sampling the dyke could be avoided and the transect ended when the sphere of influence of the nearest neighbouring watering point was reached at 4 000 m.

For the continuous transect, the mean for each variable (total, shrub, tree and ETTE density) was calculated in each consecutive 100 m interval away from the watering point. This was compared to the mean of that variable in the 10 m x 50 m transect at the corresponding distance. The two data sets were compared by means of multifactor analysis of variance using the Statgraphics computer package. Only the first 3 000 m were used in the analysis.

Both the logistic curve and a third order polynomial curve were fitted to the data using non-linear regression analysis (Statgraphics 1993 computer package). An additional term (z) was included in the logistic equation to correct for situations where the lower asymptote of the curve was not zero ($y = z + a / \{1 + e^{b - cx}\}$). A similar procedure was followed for the polynomial equation where a constant (C_0) was added ($y = C_0 + C_1x + C_2x^2 + C_3x^3$).

In direct gradient analysis some form of smoothing is often desirable (Gauch 1982). Friedel (1988) used a 10 m window at 5 m intervals successfully to smooth woody vegetation data around a watering point. In this study a five point moving average (Statgraphics 1993) was calculated from all the data whereafter the logistic and polynomial curves were fitted to the smoothed data.

Procedure on granitic soils

The two landforms that cover the largest part of the landscape in the Skukuza Land System are the crest (47 %) and footslope (37 %) areas (Venter 1990). The midslope and valley bottom constitute only a small proportion of the landscape and were not sampled.

Because of the undulating terrain and soil changes, it became apparent that the application of the continuous sampling technique would not be suitable. The interval sampling technique could be applied to some extent. The problem being, that on a particular directional line away from the watering point, the same soil type could not be found at every 100 m interval. If sampling was done in all directions this problem could be largely overcome, because a particular soil type could always be found within every 100-m interval. This necessitated combining transects from different directions to compile an imaginary representative sample away from the watering point.

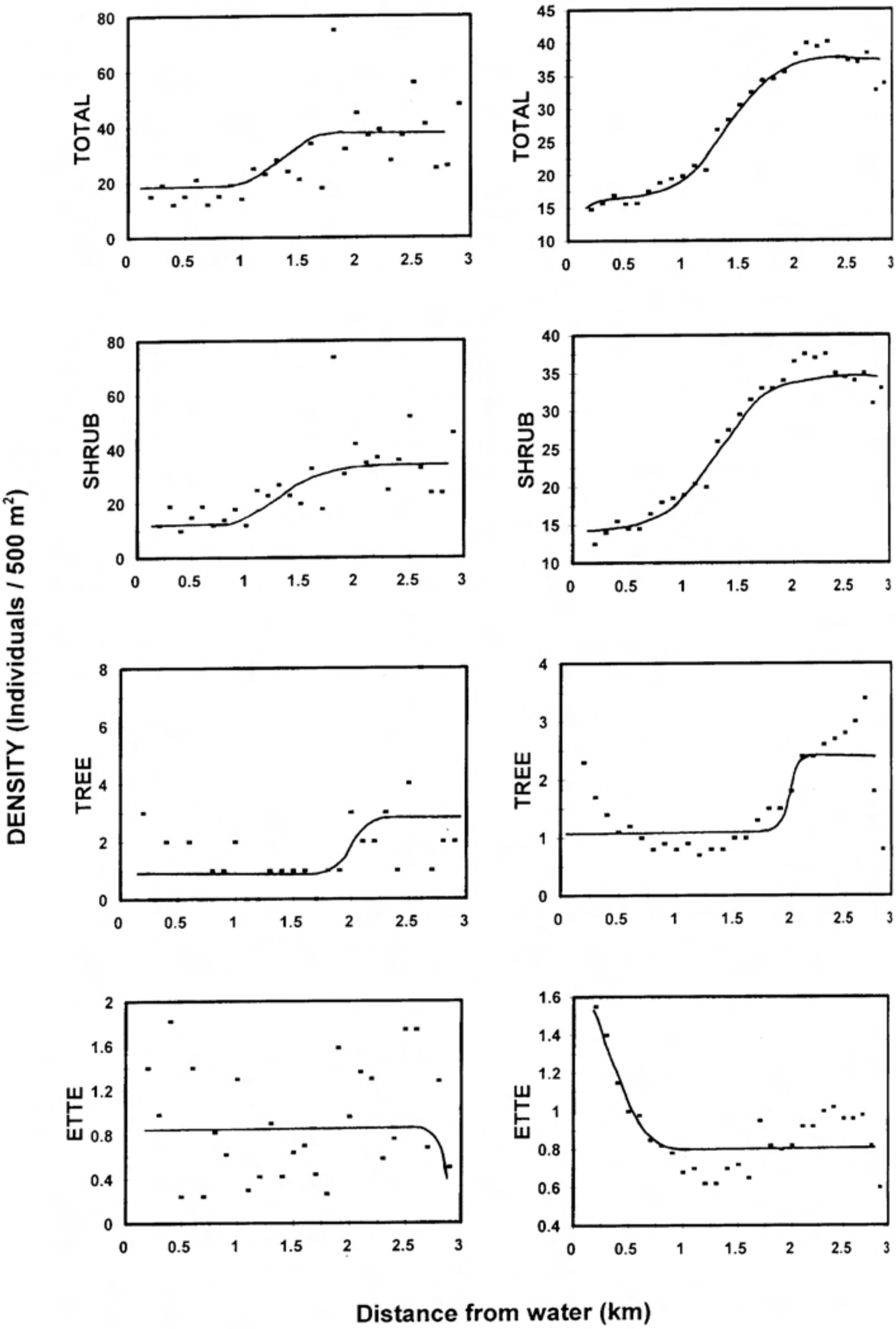

Fig. 2. Structural variables as a logistic function of distance from water, using the continuous sampling technique on basaltic soils. The original data are on the left and the smoothed data on the right. ETTE = Evapo-ration Tree Equivalents.

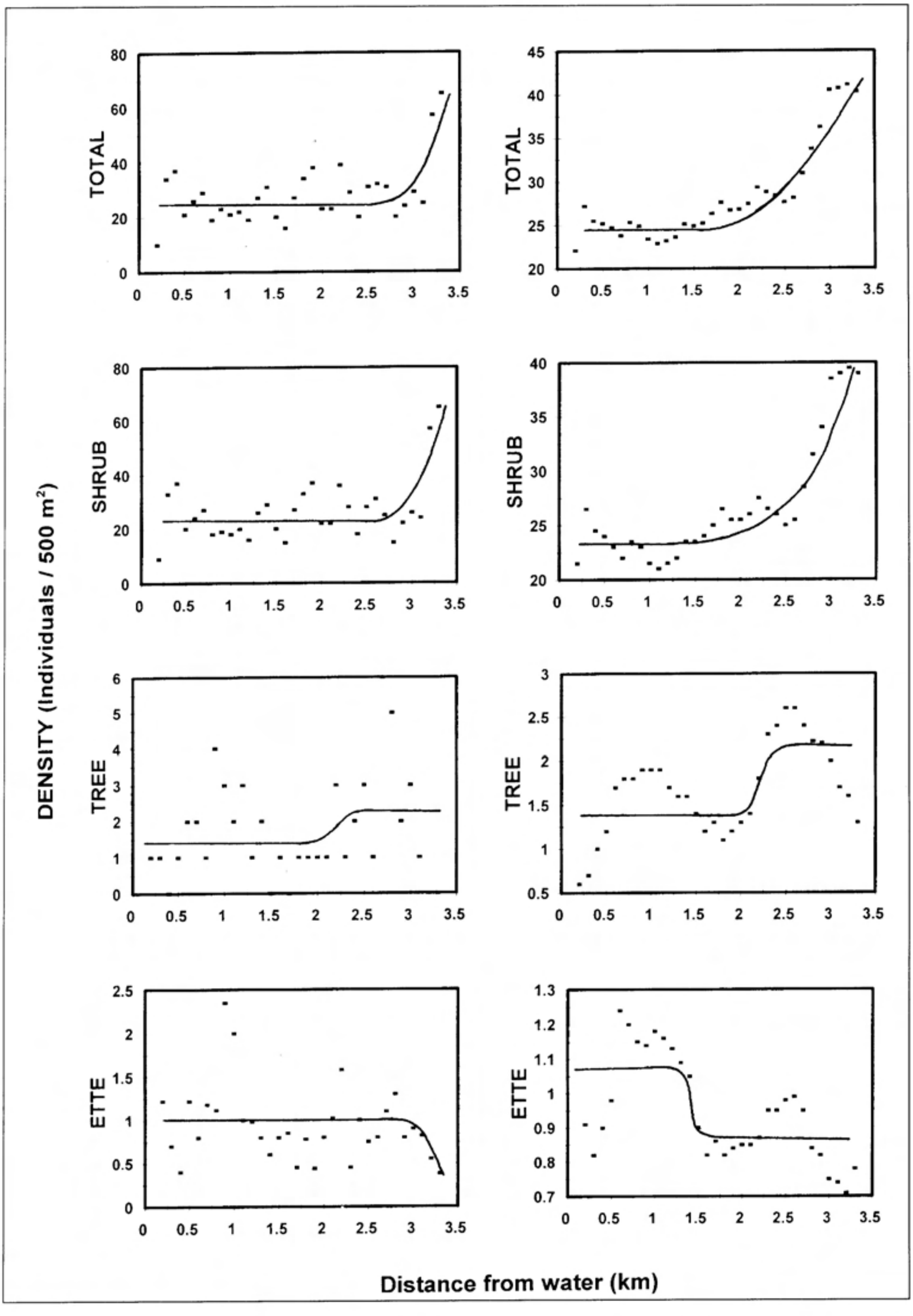

Fig. 3 Structural variables as a logistic function of distance from water, using interval sampling on basaltic soils. The original data are on the left and the smoothed data on the right. ETTE = Evaporation Tree Equivalents.

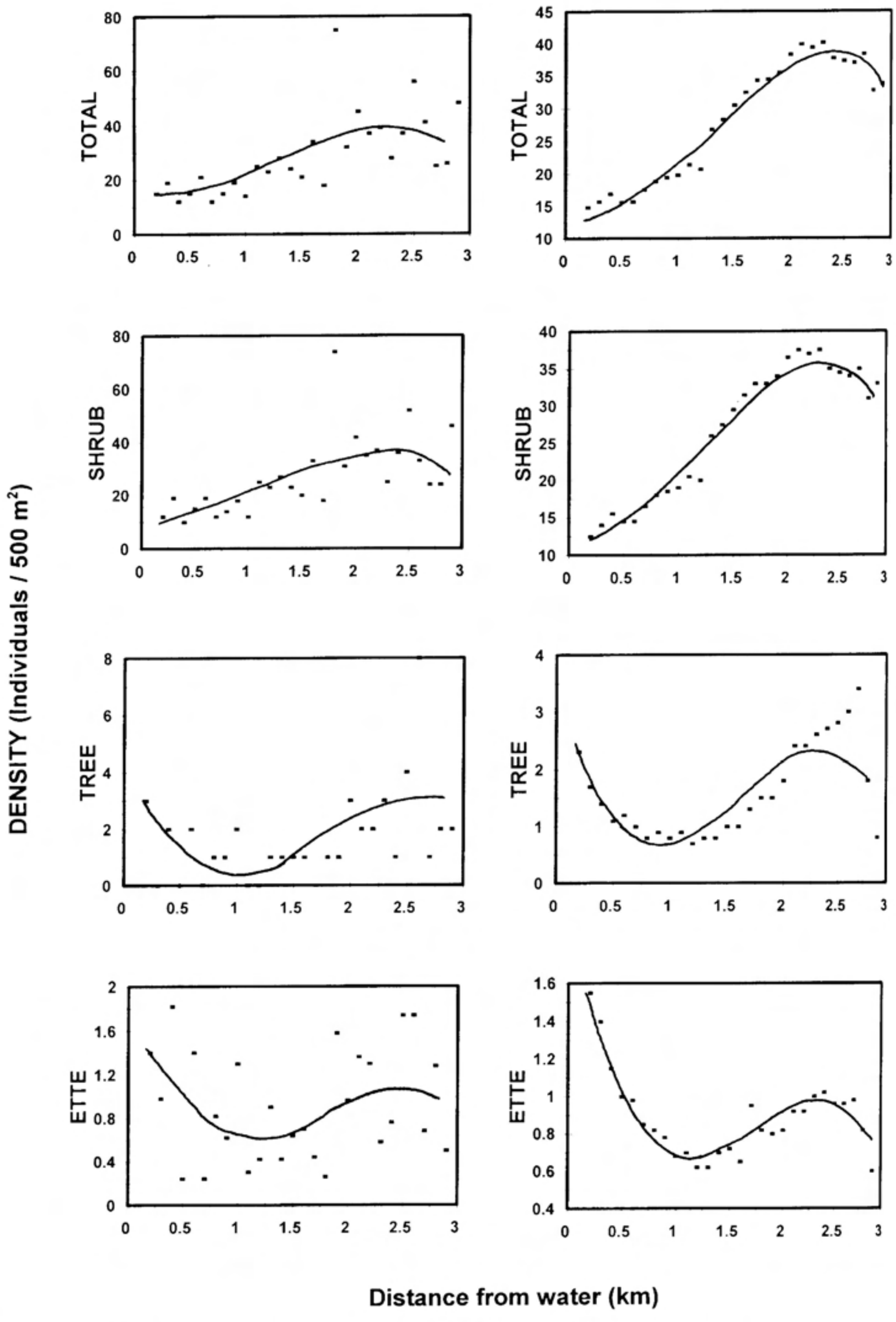

Fig. 4 Structural variables as a polynomial function of distance from water, using the continuous sampling technique on basaltic soils. The original data are on the left and the smoothed data on the right. ETTE = Evaporation Tree Equivalents.

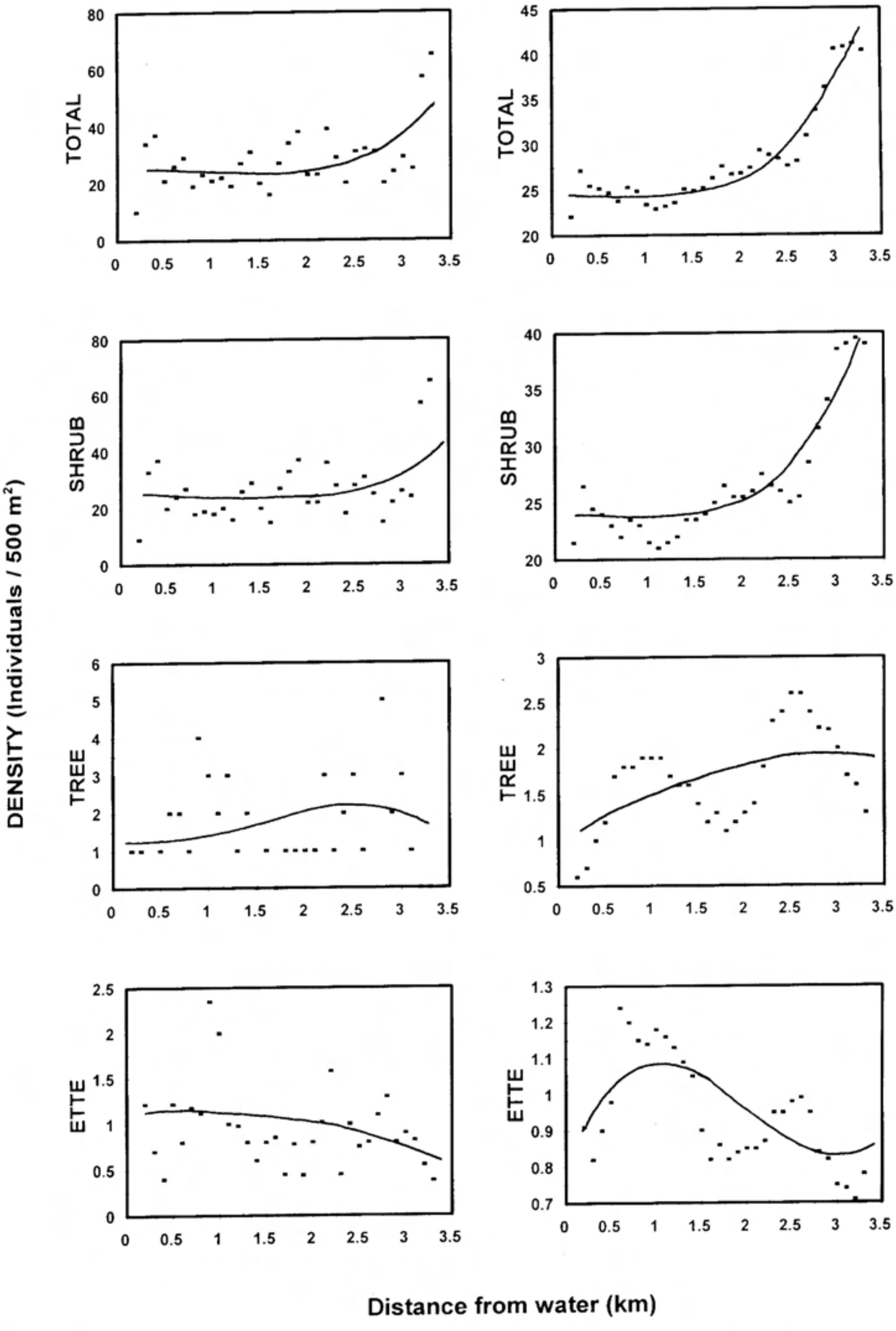

Fig. 5 Structural variables as a polynomial function of distance from water, using the interval sampling technique on basaltic soils. The original data are on the left and the smoothed data on the right. ETTE = Evaporation Tree Equivalents.

Table 1

Summary of relationships between structural variables and distance from watering point using the logistic and polynomial function in the Satara Land system in the Kruger National Park

Technique	Data source	Variable (as density)	Logistic	r^2	Polynomial	r^2
Continuous	Original	Total	$y = 39.2 - 22.25/(1 + e^{-9.7 + 0.71x})$	0.49	$y = 12.3 + 0.002x + 6.1x^2 - 0.02x^3$	0.46
		Shrub	$y = 36.6 - 21.1/(1 + e^{-8.5 + 0.64x})$	0.46	$y = 11.4 + 0.02x + 5.4x^2 - 0.02x^3$	0.44
		Tree	$y = 0.9 + 1.9/(1 + e^{31.9 - 1.7x})$	0.30	$y = 2.8 - 0.6x - 0.07x^2 - 0.01x^3$	0.30
		ETTE	$y = -12.1 + 13/(1 + e^{-96.6 + 3.32x})$	0.02	$y = 1.69 - 0.25x - 0.06x^2 - 0.01x^3$	0.20
Continuous	Smoothed	Total	$y = 37.4 - 21.4/(1 + e^{-5.9 + 0.48x})$	0.97	$y = 13 + 0.009x + 14.8x^2 - 0.02x^3$	0.97
		Shrub	$y = 35.2 - 20.8/(1 + e^{-5.5 + 0.47x})$	0.97	$y = 12 + 0.015x + 9.3x^2 - 0.02x^3$	0.97
		Tree	$y = 1.14 + 1.2/(1 + e^{142 - 7.4x})$	0.54	$y = 3.1 - 0.66x - 0.08x^2 - 0.02x^3$	0.73
		ETTE	$y = 0.8 + 0.9/(1 + e^{-2.1 + 0.8x})$	0.71	$y = 1.8 - 0.25x - 0.06x^2 - 0.01x^3$	0.94
Interval	Original	Total	$y = 75.4 - 49.6/(1 + e^{-27.4 + 0.8x})$	0.58	$y = 26.5 - 0.02x + 1.4x^2 - 0.06x^3$	0.38
		Shrub	$y = 77.9 - 54.6/(1 + e^{-30.2 + 0.8x})$	0.61	$y = 25.3 - 0.03x + 1.5x^2 - 0.06x^3$	0.36
		Tree	$y = 1.4 + 0.8/(1 + e^{30.9 - 1.4x})$	0.07	$y = 1.15 + 0.01x + 0.3x^2 - 0.01x^3$	0.04
		ETTE	$y = 0.3 + 0.6/(1 + e^{-89.1 + 2.7x})$	0.09	$y = 1.01 + 0.01x - 0.09x^2 + 0.001x^3$	0.07
Interval	Smoothed	Total	$y = 49.6 - 25/(1 + e^{-8.2 + 0.2x})$	0.93	$y = 24.8 + 0.01x - 1.5x^2 + 0.09x^3$	0.92
		Shrub	$y = 46.9 - 23.6/(1 + e^{-9.7 + 0.3x})$	0.91	$y = 23.7 - 0.03x + 0.8x^2 - 0.03x^3$	0.90
		Tree	$y = 1.4 + 0.7/(1 + e^{156.2 - 7.2x})$	0.44	$y = 0.98 + 0.05x + 0.001x^2 - 0.0005x^3$	0.32
		ETTE	$y = 0.8 + 0.2/(1 + e^{-110 + 8.3x})$	0.51	$y = 0.84 + 0.05x - 0.07x^2 + 0.001x^3$	0.48

The same distance was sampled in four different directions on both crests and footslopes. All four structural variables: total, tree, shrub and ETTE densities were compared. Variables at the same distance intervals in different directions on both the crests and footslopes were analysed for significant differences using multifactor analysis of variance (Statgraphics 1993).

Results and Discussion

Basaltic soils

A multifactor analysis of variance showed that none of the variables, obtained by means of continuous versus interval sampling, differed significantly ($P > 0.05$) at the same distance interval. Both sampling techniques appear to be suitable to sample the woody vegetation around watering points. The area sampled in the interval technique is larger than that sampled in the continuous transect, yet both exceed the area (2 x 50 m) recommended by Smit (1989) and fall within the range recommended by Walker (1976). In heterogeneous vegetation interval sampling could accentuate local differences.

Although the multifactor analysis of variance indicated no significant differences at distance intervals, differences became apparent when the curves were fitted to the data (Figs. 2–5). These differences might be due to the positioning of the interval transects, emphasising local differences. In general, interval sampling gave higher total and shrub densities and lower tree and ETTE densities than the continuous sampling technique, particularly closer to the watering point. Continuous sampling produced an upper asymptote for total and shrub density, while the interval sampling did not show an upper limit.

The smoothed data gave a better fit than the original data in all cases (Figs. 2–5; Table 1). As suggested by Gauch (1982) smoothing reduces noise in the data set. Both the logistic and polynomial curves from the smoothed data modelled the impact around watering points well, with r^2 values up to 0.97 obtained (Table 1). The highest r^2 values were obtained with the continuous sampling technique (Table 1). When interval sampling was used, the logistic equation gave marginally higher r^2 values for the smoothed data than the polynomial. In both the continuous and interval sampling sets, total and shrub density gave the highest r^2 values (Table 1).

Various authors (Graetz & Ludwig 1978; Heady & Heady 1982; Andrew 1988; Thrash 1993, 1998; Verlinden *et al.* 1998) have used the logistic function satisfactorily to model piosphere grazing pressure gradients around watering points. Because of its flexible nature, the polynomial equation can also be used to model changes in vegetation along gradients (Schmidt 1992; Van Rooyen *et al.* 1994). In this study the polynomial curve followed the shape of the logistic curve to a large extent and no distinct advantages of the polynomial equation emerged.

Granitic soils

On the granitic soils where interval sampling had been done in different directions from the trough the analysis of variance indicated no significant difference ($P > 0.05$) for any of the structural variables, on both the crest and footslope areas, in different directions from the watering point. Therefore, combining transects from different directions, to attain a representative sample away from the watering point, was an acceptable practice.

Conclusions

The continuous sampling technique gave good results on the basaltic soils in the Satara Land System where soil type remains constant. However, on the granitic soils in the Skukuza Land System the regular changes in soil type make this sampling technique unsuitable to apply.

The interval sampling technique gave good results on both the basaltic and granitic soils and was especially suited to the changes found in soil type on the granitic soils. Because the interval sampling technique allows stratification for homogeneous soil types with distance away from watering points it is recommended for future surveys. Interval sampling has the further advantage that sampling need not be done in one directional line but can be done in different directions from the trough.

The area sampled (10 m x 50 m) at 100 m intervals seemed to provide a representative sample of the structure of the woody vegetation at that distance interval. Comparative tests done on the granitic soils, showed that at the same distance interval, even in different directions, similar results were obtained. Therefore, the assumption can be made that, within a homogeneous landform, only one direction needs to be sampled on a specific soil type to give a representative sample of the woody vegetation found around the watering point.

When all data sets are taken into consideration (Brits 1999), the logistic equation described the relationship between structural variables and distance from water better than the polynomial equation. On the grounds of previous studies (Graetz & Ludwig 1978; Heady & Heady 1982; Andrew 1988; Thrash 1993; Thrash & Derry 1999) and the fact that the logistic equation gave better results using smoothed data (Brits 1999), it is recommended that the data be smoothed and the logistic function be used to model the impact of large herbivores on the structure of the woody vegetation around watering points.

Acknowledgements

Prof. G.K. Theron, who initially supervised this project, is sincerely thanked for his inputs and inspiration. The assistance and financial support of the University of Pretoria, National Research Foundation and the South African National Parks is gratefully acknowledged.

References

ANDREW, M.H. 1988. Grazing impact in relation to livestock watering points. *Trends in Ecology and Evolution* 3: 336–339.

BRITS, J. 1999. Ecological impact of large herbivores on woody vegetation at selected watering points in the Kruger National Park. MSc dissertation, University of Pretoria, Pretoria.

BRYNARD, A.M. 1969. 'n Geskiedkundige oorsig oor die waterverskaffingsprogram vir wild in die Nasionale Krugerwildtuin. Unpublished report to the National Parks Board of Trustees, Pretoria.

COETZEE, B.J. 1983. Phytosociology, vegetation structure and landscape is of the Central District, Kruger National Park, South Africa. Dissertations Botanicae, Cramer & Vaduz, Heidelberg.

FRIEDEL, M.H. 1988. The development of veld assessment in the Northern Transvaal Savanna. II. Mixed Bushveld. *Journal of the Grassland Society of Southern Africa* 5: 55–63.

GAUCH, H.G. 1982. Multivariate analysis in community ecology. Cambridge studies in Ecology. Cambridge University Press, Cambridge.

GERTENBACH, W.P.D. 1987. 'n Ekologiese studie van die suidelike mopanieveld in die Nasionale Krugerwildtuin. PhD thesis, University of Pretoria, Pretoria.

GRAETZ, R.D. & J.A. LUDWIG. 1978. A method for the analysis of piosphere data applicable to range assessment. *Australian Rangeland Journal* 1: 117–125.

GREEN, R.H. 1979. Sampling design and statistical methods for experimental biologists. John Wiley & Sons, New York.

HEADY, H.F. & E.B. HEADY. 1982. Range and wildlife management in the tropics. Longman, London.

LANGE, R.T. 1969. The piosphere, sheep track and dung patterns. *Journal of Range Management* 22: 396–400.

PIENAAR, U. DE V. 1985. Indications of progressive desiccation of the Transvaal Lowveld over the past 100 years, and implications for the water stabilization programme in the Kruger National Park. Unpublished Report, Kruger National Park, Skukuza.

SCHMIDT, A.G. 1992. Guidelines for the management of some game ranches in the mixed bushed communities of the north-western Transvaal, with special reference to Rhino Ranch. MSc dissertation, University of Pretoria, Pretoria.

SMIT, G.N. 1989. Quantitative description of woody plant communities. Part 1. An approach. *Journal of the Grassland Society of Southern Africa* 6: 192–194.

THRASH, I. 1993. Implications of providing water for indigenous large herbivores in the Transvaal Lowveld. PhD thesis, University of Pretoria, Pretoria.

THRASH, I. 1998. Impact of water provision on herbaceous vegetation in Kruger National Park, South Africa. *Journal of Arid Environments* 38: 437–450.

THRASH, I. & J.F. DERRY. 1999. The nature and modelling of piospheres: a review. *Koedoe* 42: 73–94.

TROLLOPE, W.S.W., L.A. TROLLOPE, H.C. BIGGS, D. PIENAAR & A.L.F. POTGIETER. 1998. Long term changes in the woody vegetation of the Kruger National Park, with special reference to the effects of elephants and fire. *Koedoe* 41: 103–112.

VAN ROOYEN, N., G.J. BREDENKAMP, G.K. THERON, J. DU P. BOTHMA & E.A.N. LE RICHE. 1994. Vegetational gradients around artificial watering points in the Kalahari Gemsbok National Park. *Journal of Arid Environments* 26: 349–361.

VENTER, F.J. 1990. A classification of land for management planning in the Kruger National Park. PhD thesis, University of Pretoria, Pretoria.

VERLINDEN, A., J.S. PERKINS, M. MURRAY & G. MASUNGA. 1998. How are people affecting the distribution of less migratory wildlife in the southern Kalahari of Botswana? A spatial analysis. *Journal of Arid Environments* 38:129–141.

WALKER, B.H. 1976. An approach to the monitoring of changes in the composition and utilization of woodland and savanna vegetation. *South African Journal of Wildlife Research* 6: 1–32.