CHAPTER 6

HABITAT SELECTION BY THE CARACAL IN THE KGALAGADI TRANSFRONTIER PARK.

H.I.A.S. Melville

Centre for Wildlife Management, University of Pretoria, Pretoria, 0002

J.du P. Bothma

Centre for Wildlife Management, University of Pretoria, Pretoria, 0002

Abstract

Caracal habitat selection was studied in the semi-arid Kgalagadi Transfrontier Park. It was necessary to stratify the homogeneous vegetation of the shrubby Kalahari Dune Bushveld into its components by using a non-mapping method. During the study, caracals were tracked by spoor for 537.9 km with the assistance of an experienced Kalahari San tracker to interpret observable behaviour patterns. Behaviour patterns relative to habitat components were recorded and analysed to determine whether caracals displayed habitat component selection. Information regarding the behaviour in specific plant associations by caracals was recorded and analysed, based on vegetation data that were collected by using foot-point transects. Caracals do not select dune crests and dune slopes for specific activities more than expected, but the dune streets are used less frequently than expected, except when killing prey. Caracals also show a definite selection for dune slope aspect in relation to specific types of behaviour.

Keywords: Caracal; habitat component selection; shrubby Kalahari dune bushveld; spoor tracking; plant association selection

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Introduction

Use of the environment is central to the study of the ecology of animals, particularly with regard to the habitats that they occupy (Johnson 1980). Habitat is defined here as the environment in which an animal lives (Lawrence 1998). The habitat selection that an animal displays enables it to use those areas that cater for its fundamental needs to feed, reproduce and rest (Brewer 1994). Habitat selection is a function of active selection and enables animals to persist in certain habitats. The extent of habitat use is dependent on the quality and abundance of both the biotic and abiotic resources present in an area (Boyce & McDonald 1999).

The caracal *Caracal caracal* is found throughout Africa, and across the Arabian Peninsula into central Asia. On a broad scale, caracals occur in a spectrum of habitats ranging from montane forests in the southern Cape region of South Africa, to the arid desert fringes in Saudi Arabia and Kazakhstan (Bothma & Walker 1999). The areas from which they are excluded include the coastal forests in KwaZulu-Natal in South Africa, areas along the western seaboard of southern Africa, the tropical forests of central Africa and the hyper arid regions of the deserts that fall within it's area of distribution (Stuart & Wilson 1988; Skinner & Smithers 1990; Estes 1995). There is a high degree of intra-habitat variation within the broad habitat types mentioned above. Therefore, to gain a better insight into the finer aspects of its ecology, an investigation into the habitat selection and utilisation of the caracal on such a finer scale is important.

In previous caracal studies, habitats were stratified according to plant community boundaries (Norton & Lawson 1985; Moolman 1986; Van Heezik & Seddon 1998). The current study was conducted in the shrubby Kalahari Dune Bushveld (Van Rooyen 2001) of the Kgalagadi Transfrontier Park. Although a homogeneous vegetation type covers the entire study area, there is distinct, localised, recurrent vegetation stratification over short distances within this vegetation type. The current study aims to determine whether caracals in the Kgalagadi Transfrontier Park display a higher than expected use pattern for certain components of this dune bushveld habitat. The hypothesis that was tested was that caracals in the Kgalagadi Transfrontier Park are expected to use all the habitat components in proportion to their availability.

Study area

This study was done in an area along the Namibian border near Mata-Mata in the southwestern portion of the Kgalagadi Transfrontier Park. For logistic reasons it was decided to confine the research to an area that extended 60 km north from the Mata-Mata rest camp along the Namibian border (20° 00' E longitude) to approximately 20 km into the interior of the Kgalagadi Transfrontier Park.

The Kalahari Gemsbok National Park was proclaimed in 1931, but it only became a reality in 1935 when a number of farms along the southern bank of the Aoub River were acquired. Today, the Park exists in much the same ecological state as it was then (Van Wyk & Le Riche 1984). An agreement to formally combine the Kalahari

Gemsbok National Park (South Africa) with the bordering Gemsbok National Park (Botswana) to form the Kgalagadi Transfrontier Park was signed by representatives of the governments of South Africa and Botswana in 1999. This agreement was ratified at an amalgamation ceremony that was held on the 12 May 2000 (Donaldson 2000).

The Mata-Mata area lies in the Shrubby Kalahari Dune Bushveld of the Savanna Biome (Low & Rebelo 1996). This area is an arid savanna with temperatures varying from –10° C to 45° C in the shade with an annual mean rainfall of 153.47 mm occurring mainly in the hot season. The landscape is one of undulating dunes with sparse vegetation at altitudes varying from 1000 to 1100 m above sea level (Low & Rebelo 1996).

The vegetation is characterised by the trees *Acacia erioloba*, *Acacia haematoxylon* and *Boscia albitrunca*, a shrub layer of *Grewia retinervis* and *Rhus tenuinervis,* and a well-developed grass layer consisting mainly of *Stipagrostis amabilis, Eragrostis lehmanniana, Aristida meridionalis, Schmidtia kalihariensis* and *Centropodia glauca* (Low & Rebelo 1996). There is little variation in the soil forms because the area is predominantly covered by aeolian sand overlying calcrete (Low & Rebelo 1996).

The Kgalagadi Transfrontier Park forms the southern part of the greater Kalahari ecosystem. Because of the arid nature of the area, many of the plants there are ephemeral. After sufficient rain, these plants germinate quickly to complete their life cycle in a short time (Eloff 1984).

Because of the harshness of the environment, the southern Kalahari is an area that is only sparsely inhabited by humans. This above any other factor contributes to the uniqueness of the area, and it enhances the value of the area for field research in wildlife management and conservation.

Methods

In this study it was necessary to use potentially ambiguous terminology to describe the divisions and subdivisions of the habitat in which the research was conducted. To avoid confusion, the following definitions were applied to the habitat subdivisions that were used in this study:

- Habitat : The broad habitat type in which the study was conducted is known as the Shrubby Kalahari Dune Bushveld (Van Rooyen 2001).
- Habitat component : This is a subdivision of the habitat, and it includes the dune crests, the dune slopes and the dune streets. For the purposes of this study, this is the first and most coarse habitat subdivision that was used (Fig. 1).
- Dune crest : The sparsely vegetated top portion of a dune that is a transitional area between the two opposing sides (slopes) of the same dune. This habitat component has no directional aspect (Fig. 1).
- Dune slope : The dune face that is transitional between the dune crest and the dune street. This habitat component has a directional orientation or aspect. Dune slopes vary in gradient with the southwest-facing slopes being steeper than the northeast-facing ones (Van der Walt & Le Riche 1999) (Fig. 1).
- Dune street : The mostly flat area between two dunes that is transitional between the opposing dune slopes of two adjacent dunes. This area usually

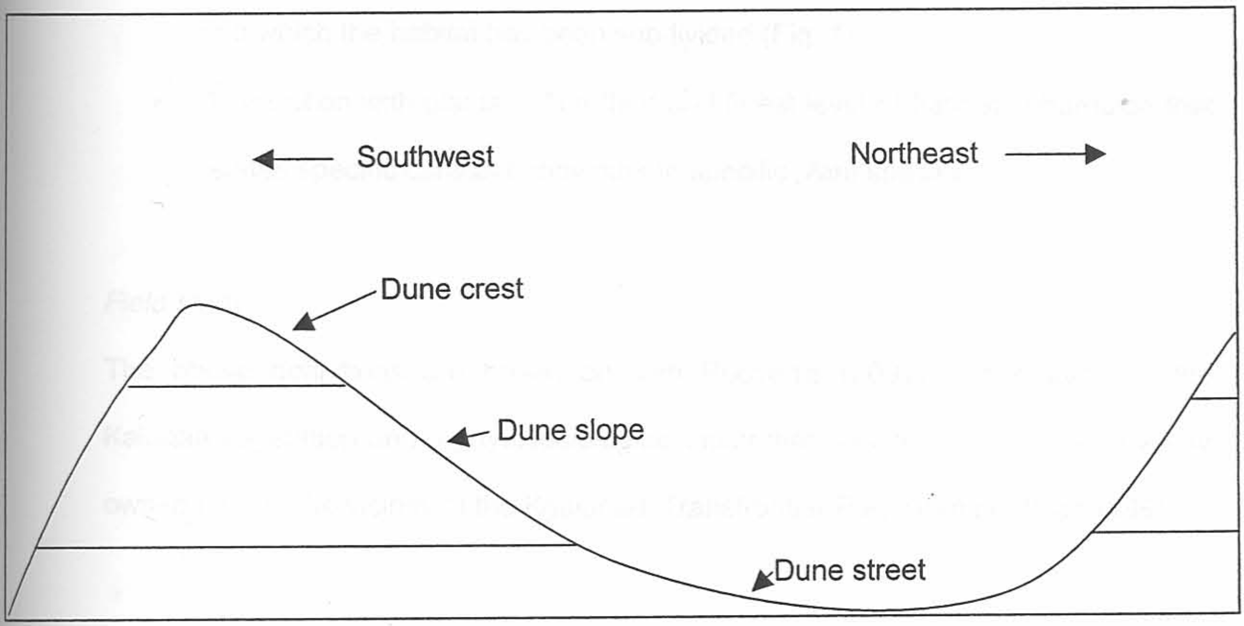

Fig. 1. The stratification of the habitat components, in relation to the dunes that was used in the present study in the Kgalagadi Transfrontier Park. The southwest-facing dune slopes are markedly steeper than the northeast-facing ones.

has a more compact soil and is dominated by the grass *Schmidtia kaliharіensis* and the low shrub *Rhigozum trichotomum* (Van Rooyen 2001) (Fig. 1).

- Aspect : The directional orientation of the dune slope. In most cases this orientation is either northeast or southwest (Van der Walt & Le Riche 1999). However, some dunes are orientated differently, and in these cases the dune slopes also have different orientations. The orientation of the dune slopes towards or away from the sun causes the northeast-facing slopes to be warmer than the southwest-facing ones. This is the second, less coarse level into which the habitat has been subdivided (Fig. 1).
- Association with plants : The third and finest level of habitat subdivision that relates specific caracal behaviours to specific plant species.

Field study

The above definitions are based on Van Rooyen's (2001) classification of the Kalahari vegetation and a phytosociological study that was conducted on a privately owned farm in the vicinity of the Kgalagadi Transfrontier Park (Van der Walt 1999)

In previous caracal studies (Moolman 1986, Norton & Lawson 1985) it was possible to stratify the habitats according to distinct vegetation units that could be clearly defined by using mapping techniques. In the present study this approach was not feasible because of the low level of macro-habitat variation within the Shrubby Kalahari Dune Bushveld (Van Rooyen 2001).

Because the use of mapping techniques for the stratification of the separate components of the Shrubby Kalahari Dune Bushveld was not practical, it was decided to use the non-mapping technique that was proposed by Marcum & Loftsgaarden (1980) to stratify the habitat components of the study area. In the present study, where obvious habitat stratification occurs within a designated vegetation type over a short distance, the non-mapping method is superior to the conventional mapping method. An aerial photograph on a scale of 1:50 000 and a point grid overlay was used to determine the ratio in which the habitat components occurred in the study area, and upon which the analyses of habitat selection were based. A computer random number generator was used to define randomised grid coordinates upon which the habitat ratio was calculated (Marcum & Loftsgaarden 1980).

Spoor-tracking data for caracal were collected according to the method of Bothma and Le Riche (1984) and Stander *et al.* (1997). A high number of habitat selection observations linked to global positioning system (GPS) locations were made based on 154 separate sets of caracal tracks over a total spoor tracking distance of 537.9 km. Radio-location data are less useful than spoor tracking data for this purpose because the errors involved in radio-tracking tend to lead to an underestimation of preference in habitats that occur in small patches (White & Garrot 1986). Moreover, because of the richness of the spoor-tracking data and the relative paucity of the radio-tracking data in the current study, it was decided to base the habitat selection analysis on the spoor-tracking data only.

While tracking spoor, several aspects of caracal behaviour were recorded that could be incorporated into the habitat use data. The tracking data were divided into two components, movement and stationary data, for the purposes of analysis. The caracal movements were recorded as strings of habitat components encountered while moving between consecutive stationary types of behaviour. Additional factors that related to the various types of behaviour, including dune slope aspect and plant relationships, were recorded.

Baseline vegetation frequency data were collected by conducting ten step-point transects of 100 m each in each of the defined habitat components (Mentis 1981) (Table 1). The results from the vegetation transects were converted into a vegetation ratio of occurrence against which plant association data could be compared. The results from the vegetation transects were compiled to reflect the relative plant frequencies in each habitat component, and as a combined plant frequency across all three habitat components (Table 1).

Data analysis

Chi-squared analyses were used to establish whether a significant selection for or against using a specific habitat component or plant species was shown by caracals. In those cases where significant values were found, the Bonferroni approach was used to establish which habitat components or plant species were selected or avoided (Marcum & Loftsgaarden 1980; Moolman 1986; Caley 1994; Alvarez-Cardenas *et al.* 2001). The flexibility of this method allowed it to be used not only for the analysis of habitat component selection but also for the detection of specific plant association use. The data were analysed seasonally for the hot season (October to March) and the cold season (April to September), and on a combined seasonal basis.

e 1: The percentage contribution of various plant species in the specific vegetation parameters of the Kgalagadi Transfrontier Park from June 2000 to August 2002, based on step-point transects.

Plant	Percentage contribution over all habitat components	Percentage contribution on dune crests	Percentage contribution on dune slopes	Percentage contribution on dune streets
Acacia erioloba	0.0	0.0	0.1	0.0
Acacia haematoxylon	0.5	0.8	0.3	0.4
Acacia mellifera	0.1	0.0	0.2	0.0
Acanthosicyos naudinianus	2.5	4.1	2.8	0.7
Aristida meridionalis	0.8	1.1	1.2	0.1
Asparagus spp.	0.0	0.0	0.1	0.0
Bare patch	35.3	42.1	35.6	28.5
Boscia albitrunca	0.3	0.7	0.1	0.0
Brachiaria glomerata	0.7	0.7	1.2	0.1
Bulbostylis hispidula	0.3	0.1	0.2	0.5
Centropodia glauca	2.0	1.2	1.8	3.0
Chenopodium album	0.1	0.1	0.2	0.0
Crotalaria sphaerocarpa	0.2	0.0	0.5	0.0
Crotolaria spartioides	0.1	0.2	0.0	0.0
Dicoma spp.	0.0	0.0	0.1	0.0
Elephantorrhiza elephantina	0.5	0.0	0.5	1.0
Eragrostis lehmanniana	11.6	8.1	16.2	10.7
Eragrostis porosa	0.4	0.0	0.9	0.5
Eragrostis trichophora	0.1	0.2	0.0	0.0
Gisekia africana	0.8	1.2	0.6	0.6
Harpagophytum procumbens	0.7	0.0	0.0	1.9
Heliotropium ciliatum	7.4	8.3	7.3	6.7
Hermannia burchelli	0.4	0.4	0.6	0.3
Hermannia tomentosa	1.7	0.9	1.6	2.4
Hermbstaedtia fleckii	0.5	0.1	1.3	0.0
Hirpicium gazanioides	0.1	0.3	0.0	0.0
Indigofera alternans	0.4	0.2	0.4	0.6
Indigofera auricoma	0.2	0.3	0.4	0.0
Indigofera flavicans	0.2	0.4	0.1	0.1
Limeum argute-carinatum	0.1	0.2	0.0	0.0
Limeum fenestratum	0.5	0.6	0.4	0.5
Limeum sulcatum	0.5	0.1	0.3	1.1
Lycium boscifolium	0.0	0.1	0.0	0.0
Merremia verecunda	0.0	0.0	0.1	0.0
Monechma divaricatum	0.0	0.0	0.1	0.0
Monechma incanum	0.2	0.0	0.6	0.1
Nolletia arenosa	0.0	0.0	0.1	0.0
Oxygonum delagoense	1.5	2.5	2.2	0.0
Pergularia daemia	0.1	0.0	0.2	0.0
Phyllanthus angolensis	0.1	0.1	0.1	0.0
Phyllanthus maderaspatensis	0.2	0.6	0.0	0.0
Phyllanthus sericeus	0.0	0.0	0.1	0.0
Plinthus sericeus	0.2	0.4	0.3	0.0
Requienia sphaerosperma	1.5	1.5	1.2	1.6
Rhigozum trichotomum	5.6	1.4	3.1	12.0

Table 1: *Continued*

Plant	Percentage contribution over all habitat components	Percentage contribution on dune crests	Percentage contribution on dune slopes	Percentage contribution on dune streets
Rhus tenuinervis	0.0	0.0	0.1	0.0
Salsola spp.	1.4	2.8	1.2	0.3
Schmidtia kalihariensis	10.0	1.2	10.3	18.2
Senna italica	0.1	0.0	0.1	0.3
Sericorema remotiflora	0.1	0.0	0.2	0.0
Sesamum triphyllum	0.3	0.4	0.3	0.2
Stipagrostis amabilis	6.2	12.9	1.9	3.9
Stipagrostis ciliata	1.0	2.2	0.1	0.6
Stipagrostis hirtigluma	0.4	0.0	0.3	1.0
Stipagrostis obtusa	0.1	0.0	0.3	0.0
Stipagrostis uniplumis	0.8	0.0	1.3	1.1
Tribulus zeyheri	0.9	1.2	1.1	0.6
Xenostegia tridentata	0.5	0.8	0.3	0.5
	100.0	100.0	100.0	100.0

Where caracal behaviours were recorded on the dune slopes, the aspect of each slope was recorded. The percentage use of the various behaviours on each dune slope aspect is reflected in Table 2.

All stationary behaviour data were combined into a single database comprising 6200 independent GPS locations that were related to specific behaviours. The proportional occurrence of the stationary types of behaviour in each of the defined habitat components was also calculated. Once these data had been analysed together, the data were separated into independent stationary types of behaviour. The same analysis protocol was then applied to the individual behaviours to test whether behaviour specific habitat component selection occurred.

The variable distance between dune crests (Van der Walt & Le Riche 1999) and the resultant variability in the distances that caracals could travel within each vegetation component necessitated the weighting of the movement data. The weighting was done by dividing the number of habitat component observations recorded for each set of caracal tracks by the distance for which that caracal spoor was followed during the tracking session. The unweighted and weighted data sets were both subjected to analysis. For the analyses, each habitat component within each movement string was regarded as an independent observation

Caracal behavioural patterns were associated not only with habitat components but also with specific plant species. Therefore, whenever a specific type of behaviour was noted to occur within 100 mm radius of a plant, based on the position of the spoor track, the behaviour was considered to be associated with that plant. Where no plant was observed within 100 mm of the spoor track, the behaviour was regarded

Table 2: *The percentage utilisation of variously orientated dune slopes, by caracals in the Kgalagadi Transfrontier Park from June 2000 to August 2002.*

Type of behaviour	Season	Aspect															
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
Combined behaviours	SW	0.8	-	54.3	-	2.5	0.6	0.7	-	0.7	0.0	37.5	0.0	1.8	-	0.9	-
Combined behaviours	S	1.1	-	55.4	-	1.7	-	0.3	-	0.5	-	38.2	-	1.6	-	1.2	-
Combined behaviours	W	0.6	-	53.3	-	3.2	1.2	1.1	-	0.8	0.1	37.0	0.1	2.0	-	0.7	-
Standing	SW	1.0	-	53.4	-	1.7	0.3	0.3	-	0.6	-	40.3	-	1.3	-	1.2	-
Standing	S	1.5	-	54.9	-	1.0	-	-	-	0.8	-	38.8	-	1.2	-	1.8	-
Standing	W	0.5	-	52.1	-	2.2	0.5	0.5	-	0.5	-	41.5	-	1.4	-	0.8	-
Sitting	SW	1.2	-	-	-	7.4	2.0	3.9	-	1.2	-	77.0	-	5.5	-	2.0	-
Sitting	S	0.8	-	-	-	4.8	-	2.4	-	-	-	85.6	-	5.6	-	0.8	-
Sitting	W	1.5	-	-	-	9.9	3.8	5.3	-	2.3	-	68.9	-	5.3	-	3.0	-
Lying-up	SW	1.5	-	47.8	-	2.0	-	0.5	-	1.0	-	41.4	-	5.9	-	-	-
Lying-up	S	2.5	-	41.0	-	2.5	-	0.8	-	-	-	48.4	-	4.9	-	-	-
Lying-up	W	-	-	58.0	-	1.2	-	-	-	2.5	-	30.9	-	7.4	-	-	-
Urinating	SW	-	-	67.6	-	5.4	-	-	-	-	-	27.0	-	-	-	-	-
Urinating	S	-	-	60.0	-	-	-	-	-	-	-	40.0	-	-	-	-	-
Urinating	W	-	-	72.7	-	9.1	-	-	-	-	-	18.2	-	-	-	-	-
Defecating	SW	-	-	43.8	-	-	-	-	-	-	-	43.8	-	12.5	-	-	-
Defecating	S	-	-	66.7	-	-	-	-	-	-	-	33.3	-	-	-	-	-
Defecating	W	-	-	38.5	-	-	-	-	-	-	-	46.2	-	15.4	-	-	-
Rolling	SW	-	-	68.8	-	6.3	6.3	-	-	-	6.3	12.5	-	-	-	-	-
Rolling	S	-	-	75.0	-	-	-	-	-	-	-	25.0	-	-	-	-	-
Rolling	W	-	-	66.7	-	8.3	8.3	-	-	-	8.3	8.3	-	-	-	-	-
Clawing and scraping	SW	9.1	-	59.1	-	13.6	-	4.6	-	-	-	9.1	4.6	-	-	-	-
Clawing and scraping	S	-	-	75.0	-	12.5	-	-	-	-	-	12.5	-	-	-	-	-
Clawing and scraping	W	14.3	-	50.0	-	14.3	-	7.1	-	-	-	7.1	7.1	-	-	-	-
Crouching	SW	0.8	-	52.5	-	2.5	-	*	-	0.8	-	41.7	-	0.8	-	0.8	-
Crouching	W	0.8	-	52.5	-	2.5	-	*	-	0.8	-	41.7	-	0.8	-	0.8	-
Starting a run	SW	-	-	50.0	-	1.8	-	1.8	-	1.8	-	42.9	-	1.8	-	-	-
Starting a run	W	-	-	50.0	-	1.8	-	1.8	-	1.8	-	42.9	-	1.8	-	-	-
Killing	SW	-	-	53.9	-	15.4	7.7	-	-	-	-	23.1	-	-	-	-	-
Killing	S	-	-	85.7	-	-	-	-	-	-	-	14.3	-	-	-	-	-
Killing	W	-	-	16.7	-	33.3	16.7	-	-	-	-	33.3	-	-	-	-	-
Eating	SW	-	-	50.0	-	16.7	16.7	-	-	-	-	16.7	-	-	-	-	-
Eating	S	-	-	71.4	-	-	-	-	-	-	-	28.6	-	-	-	-	-
Eating	W	-	-	20.0	-	40.0	40.0	-	-	-	-	-	-	-	-	-	-

SW :- both summer and winter
S :- summer
W :- winter

to be associated with a bare patch. The same analysis protocol as above was applied to indicate whether caracals tended to select or avoid specific plants for specific types of behaviour. The number of potential plant associations differed according to each behaviour pattern. It was necessary, therefore, to apply different critical chi-squared values to the chi-squared calculations for each of the behaviours.

Results

The proportional representation of the various habitat components when using the non-mapping method of Marcum & Loftsgaarden (1980) in the study area is 12.7% dune crests: 53.8% dune streets: 33.5% dune slopes. If the caracals used the habitat components in their frequency of occurrence, this then will be the expected proportion of use for the various types of behaviour in each of the three habitat components. This expected ratio was also used as the basis for further habitat selection analyses.

Habitat component selection

Analysis of the stationary behaviour on a year-round basis indicated that the caracals tended to select or avoid certain habitat components (chi-square = 14.98; df = 2; $P \leq 0.05$). When subjected to further analysis to determine which habitat components were selected or were avoided, the Bonferroni confidence intervals (0.91) (Marcum & Loftsgaarden 1980) that were calculated were (-0.17, -0.03) for the dune crests, (-0.182, 0.22) for the dune slopes and (0.08, 0.30) for the dune streets. This indicates that caracals utilise the dune crests in greater proportion than expected, the dune slopes as expected and the dune streets less than expected (Table 3). For the non-movement data 22.8 % of the observations were on a dune crest, 41.6 % were on a

Table 3: *Habitat component selection displayed by caracals, in the Kgalagadi Transfrontier Park, based on a chi-squared analysis in conjunction with 91% Bonferroni confidence intervals, from June 2000 to August 2002*

Behaviour	Both seasons combined				Significance conclusion
	Chi-squared value	*P*-value	Habitat	Confidence interval	
Unweighted movement	10.78	≤0.05	Dune	(-0.198; -0.008)	+
			Slope	(-0.235; -0.005)	+
			Street	(0.124; 0.336)	-
Weighted movement	8.36	≤0.05	Dune	(-0.119; -0.067)	+
			Slope	(-0.147; -0.073)	+
			Street	(0.16; 0.24)	-
Total non-movement	14.98	≤0.05	Dune	(-0.17; -0.03)	+
			Slope	(-0.182; 0.022)	=
			Street	(0.08; 0.3)	-
Standing	7.42	≤0.05	Dune	(-0.23; 0.006)	=
			Slope	(-0.22; 0.08)	=
			Street	(0.03; 0.33)	-
Sitting	12.8	≤0.05	Dune	(-0.261; -0.023)	+
			Slope	(-0.25; 0.05)	=
			Street	(0.09; 0.39)	-
Lying-up	2.18	≤0.05	Combined	No selection	
Urinating	11.06	≤0.05	Dune	(-0.28; -0.04)	+
			Slope	(-0.156; 0.124)	=
			Street	(0.03; 0.33)	-
Defecating	7.91	≤0.05	Dune	(-0.234; -0.0002)	+
			Slope	(-0.21; 0.07)	=
			Street	(0.04; 0.34)	-
Rolling	18.83	≤0.05	Dune	(-0.32; -0.06)	+
			Slope	(-0.04; 0.2)	=
			Street	(-0.03; 0.25)	-
Clawing and scraping	3.3	≤0.05	Combined	No selection	
Crouching	8.53	≤0.05	Dune	(-0.086; 0.085)	=
			Slope	(-0.28; -0.04)	+
			Street	(0.04; 0.3)	-
Starting a chase	26.24	≤0.05	Dune	(-0.069; 0.035)	=
			Slope	(-0.23; -0.09)	+
			Street	(0.1; 0.24)	-
Killing	6.32	≤0.05	Dune	(0.004; 0.17)	-
			Slope	(-0.26; 0.04)	=
			Street	(-0.13; 0.17)	=
Eating	9.5	≤0.05	Dune	(-0.055; 0.133)	=
			Slope	(-0.38; -0.08)	+
			Street	(0.04; 0.34)	-

Table 3: *Continued*

Behaviour	Summer				Significance conclusion
	Chi-squared value	*P* value	Habitat	Confidence interval	
Unweighted movement	9.14	≤0.05	Dune	(-0.187; 0.033)	=
			Slope	(-0.29; 0.01)	=
			Street	(0.06; 0.36)	-
Weighted movement	5.68	≤0.05	Combined	No selection	
Total non-movement	11.12	≤0.05	Dune	(-0.113; 0.027)	=
			Slope	(-0.22; -0.02)	+
			Street	(0.05; 0.27)	-
Standing	10.77	≤0.05	Dune	(-0.128; 0.022)	=
			Slope	(-0.21; -0.01)	+
			Street	(0.06; 0.28)	-
Sitting	18.19	≤0.05	Dune	(-0.013; 0.026)	=
			Slope	(-0.28; -0.06)	+
			Street	(0.11; 0.33)	-
Lying-up	1.59	≤0.05	Combined	No selection	
Urinating	10.96	≤0.05	Dune	(-0.247; 0.009)	+
			Slope	(-0.24; 0.059)	=
			Street	(0.07; 0.32)	-
Defecating	11.66	≤0.05	Dune	(-0.186; 0.04)	=
			Slope	(-0.32; -0.02)	+
			Street	(0.04; 0.34)	-
Rolling	26.61	≤0.05	Dune	(-0.62; -0.24)	+
			Slope	(0.05; 0.37)	-
			Street	(0.02; 0.42)	-
Clawing and scraping	1.36	≤0.05	Combined	No selection	
Crouching	NA		NA	No summer records	
Starting a chase	NA		NA	No summer records	
Killing	2.88	≤0.05	Combined	No selection	
Eating	5.83	≤0.05	Combined	No selection	

Table 3: *Continued*

Behaviour	Winter				Significance conclusion
	Chi-squared value	*P* value	Habitat	Confidence interval	
Unweighted movement	12.48	≤0.05	Dune	(-0.25; -0.011)	+
			Slope	(-0.26; 0.04)	=
			Street	(0.09; 0,39)	-
Weighted movement	11.43	≤0.05	Dune	(-0.169; 0.051)	=
			Slope	(-0.26; 0.04)	=
			Street	(0.02; 0.32)	-
Total non-movement	20.01	≤0.05	Dune	(-0.21; -0.07)	+
			Slope	(-0.16; 0.04)	=
			Street	(0.09; 0.31)	-
Standing	18.214	≤0.05	Dune	(-0.22; -0.072)	+
			Slope	(-0.15; 0.05)	=
			Street	(0.05; 0.35)	-
Sitting	30.41	≤0.05	Dune	(-0.29; -0.13)	+
			Slope	(-0.14; 0.08)	=
			Street	(0.15; 0.35)	-
Lying-up	5.12	≤0.05	Combined	No selection	
Urinating	11.02	≤0.05	Dune	(-0.29; -0.09)	+
			Slope	(-0.09; 0.19)	=
			Street	(-0.005; 0.29)	=
Defecating	7.62	≤0.05	Dune	(-0.25; -0.01)	+
			Slope	(-0.17; 0.1)	=
			Street	(0.02; 0.32)	-
Rolling	0.35	≤0.05	Combined	No selection	
Clawing and scraping	1.74	≤0.05	Combined	No selection	
Crouching	8.53	≤0.05	Dune	(-0.086; 0.085)	=
			Slope	(-0.28; -0.04)	+
			Street	(0.04; 0.3)	-
Starting a chase	26.24	≤0.05	Dune	(-0.069; 0.035)	=
			Slope	(-0.23; -0.09)	+
			Street	(0.1; 0.24)	-
Killing	14.57	≤0.05	Dune	(0.055; 0.199)	-
			Slope	(-0.27; 0.03)	=
			Street	(-0.155; 0.145)	=
Eating	17	≤0.05	Dune	(-0.05; 0.178)	=
			Slope	(-0.44; -0.16)	+
			Street	(0.08; 0.38)	-

+ :- component used in greater proportion than its expected occurrence
- :- component used in smaller proportion than its expected occurrence
= :- component used in the same proportion as its expected occurrence

dune slopes and 35.6 % in a dune street. These frequencies differ significantly ($P \leq 0.05$) from the observed and therefore expected habitat component ratio (Table 4).

The behaviour-specific analyses are summarised in Table 3. The data indicate that caracals do select or avoid various habitat components when performing certain types of behaviour, but not other types.

There are also seasonal habitat component use patterns. In hot season the dune crests are used in proportion to their expected occurrence, the dune slopes are used more often than what would be expected, and the dune streets are used less often so. In the cold season the dune crests are used more often than expected and the dune slopes as expected in proportion to their occurrence (Table 3). In both the hot season and the cold season, the dune streets are therefore used less often than expected, which indicates definite avoidance of this habitat component (Table3).

Caracals utilise the northeast-facing dune slopes more often than the southwest-facing ones for a number of types of behaviour (Table 2). Of all types of behaviour, 54.3 % of the observations on the dune slopes were done on the northeast-facing slopes, while 37.5 % occur on the southwest-facing dune slopes. The rest occur on other, less prevalent dune slope aspects (Table 2).

Analysis of the movement data indicates that the caracal selects or avoids certain habitat components (unweighted data: chi-square = 10.78, df = 2, $P \leq 0.05$; weighted data : chi-square = 8.36, df = 2, $P \leq 0.05$). The weighted and unweighted habitat frequency analysis results differed from those of the stationary behaviour aspects. The caracals utilise the dune crests and dune slopes more often than would be

The percentage use by caracals of various habitat components across seasons and seasonally whilst ning specified types of behaviour in the Kgalagadi Transfrontier Park from June 2000 to August 2002

Behaviour	Season	Habitat component use		
		Dune crest	Dune slope	Dune street
General habitat ratio		12.7	33.4	53.8
Combined unweighted	SW	23.3	45.3	31.4
	S	20.4	46.8	32.8
	W	25.8	43.9	30.3
Combined weighted	SW	22.2	43.7	34.1
	S	18.7	44.2	37.1
	W	25.2	43.3	31.5
Combined behaviours	SW	22.9	35.5	41.6
	S	17.4	37.8	44.9
	W	27.3	33.7	39.0
Standing	SW	23.8	40.1	36.1
	S	18.2	44.4	37.4
	W	27.5	37.9	34.6
Sitting	SW	27.0	42.7	30.3
	S	18.1	49.9	32.0
	W	34.5	36.6	29.0
Lying-up	SW	15.2	41.5	43.4
	S	10.5	42.0	47.5
	W	21.1	40.2	38.8
Urinating	SW	29.1	35.0	35.9
	S	25.5	42.6	31.9
	W	32.1	28.6	39.3
Defecating	SW	24.4	40.0	35.6
	S	20.0	50.0	30.0
	W	25.7	37.1	37.2
Rolling	SW	33.3	42.4	24.2
	S	55.9	32.4	11.8
	W	9.4	53.1	37.5
Clawing and scraping	SW	12.5	41.7	45.8
	S	16.7	38.9	44.4
	W	10.0	43.3	46.7
Crouching	SW	12.8	49.6	37.6
	W	12.8	49.6	37.6
Starting a chase	SW	20.9	35.7	43.4
	W	20.9	35.7	43.4
Killing	SW	4.0	44.0	52.0
	S	7.1	42.9	50.0
	W	0.0	45.5	54.6
Eating	SW	8.8	55.9	35.3
	S	11.1	50.0	38.9
	W	6.3	62.5	31.3

SW :- Summer and winter combined
S :- Summer
W :- Winter

expected, and the dune streets less often than expected (Table 3). When represented as a ratio, both the unweighted frequencies of use for the movement behaviours (23.3 % for the dune crests, 45.3 % for the dune slopes, and 31.4 % for the dune streets) and the weighted frequencies (22.2 % for the dune crests, 43.7 % for the dune slopes, and 34.1 % for the dune streets) do not differ significantly from those of the stationary behaviour (unweighted data : chi-square = 0.42, df = 2, $P \leq 0.05$; weighted data :chi-square = 0.092, df = 2, $P \leq 0.05$).

When analysed on a seasonal basis the unweighted movement data (chi-square = 9.14, df = 2, $P \leq 0.05$) indicate that dune crests and dune slopes are being used in proportion to their occurrence, while the dune streets are being used less often than expected (Table 3). The weighted movement data (chi-square = 5.68, df = 2, $P \leq 0.05$) show no specific habitat component preference in the hot season (Table 3). However, in the cold season the unweighted movement data (chi-square = 12.48, df = 2, $P \leq 0.05$) indicate that the caracals use the dune crests more often than expected, the dune slopes are used in proportion to their occurrence as expected, and the dune streets are used less often than expected (Table 3). The weighted data (chi-square = 11.43, df = 2, $P \leq 0.05$) show that caracals use the dune crests and dune slopes in proportion to their occurrence, and the dune streets less often than expected (Table 3).

Selection of dune slope aspect

Van der Walt & Le Riche (1999) stated that the two predominant dune slope aspects in the southern Kalahari are those that face northeast and southwest. The southwest-facing dune slopes are steeper and cooler than the northeast-facing dune slopes. Baseline data on the contribution of the various dune slope aspects to the dune slope habitat component could not be calculated and statistical analysis of the dune slope aspect data could therefore not be done. The extent to which caracals utilise certain dune slope aspects is therefore represented here as a percentage of the total number of observations of particular types of behaviour within the dune slope habitat component.

When all types of stationary behaviour are combined, caracals used the northeast-facing dune slopes more often than the southwest-facing ones all year round, but there was no evidence of any seasonal variation in dune slope aspect selection (Table 2). The trend of using northeast-facing dune slopes in preference to southwest-facing ones held for most types of behaviour. However, there were notable exceptions when sitting, defecating, killing and eating. Sitting was never recorded on northeast-facing slopes. When defecating, the year-round trend was for caracals to use the northeast-facing and southwest-facing dune slopes in proportion to their occurrence. However, in the hot season, the northeast-facing slopes were used most often but in the cold season southwest-facing slopes were used most often. Killing and eating of prey on a year-round basis was mainly done on the northeast-facing dune slopes. The selection for northeast-facing dune slopes when killing and eating is especially strong in the hot season. In the cold season, the northeast-facing dune slopes are not used much for killing and eating prey (Table 2).

Plant associations

The caracals stopped and stood close to 52 different plant species during this study. In most cases, the caracals did so in proportion to the frequency of occurrence of these plant species, but *Acacia erioloba*, *Acacia haematoxylon*, *Acacia mellifera*, *Aptosimum elongatum*, *Boscia albitrunca*, *Citrullus lanatus*, *Enneapogon* *cenchroides*, *Grewia flava*, *Helichrysum argyroshaerum*, *Hermannia tomentosa*, *Lycium boscifolium* and *Rhus tenuinervis* were used significantly ($P \leq 0.05$) more often than expected, based on their frequency of occurrence. The only plant species that was used less often than expected was *Schmidtia kalihariensis* ($P \leq 0.05$). This annual grass forms dense stands, which makes moving through them difficult (Table 5).

When sitting, there was no evidence of any significant association with specific plant species on the dune crests. On the dune slopes, the caracals sat close to 29 plant species. Of these species, *Acacia haematoxylon*, *Acacia mellifera*, *Boscia albitrunca* and *Helichrysum argyrosphaerum* were associated with more often than expected ($P \leq 0.05$), and no plant species was associated with less often than expected. In the dune streets the caracals also sat close to 29 plant species, of which *Acacia haematoxylon*, *Boscia albitrunca*, *Helichrysum argyrosphaerum* and an unidentified *Salsola* species were associated with more often than expected ($P \leq 0.05$), while *Schmidtia kalihariensis* was again the only plant species that was associated with less often than expected ($P \leq 0.05$) (Table 5).

When lying-up on the dune crests, caracals associated with 15 different plant species. The only plant species that was associated with more often than expected ($P \leq 0.05$) was *Boscia albitrunca*, and no plant species association was recorded less often than expected. On the dune slopes, *Boscia albitrunca* and *Rhigozum trichotomum* were associated with more often than expected ($P \leq 0.05$), and *Schmidtia kalihariensis* and *Tribulus zeyheri* were associated with less often than expected ($P \leq 0.05$). In the dune streets the caracals associated with 23 plant species when lying-up, but the only plant species that was associated with more

Table 5: *The plant utilisation by caracals in the Kgalagadi Transfrontier Park from June 2000 to August 2002, as determined by using chi-squared analysis in conjunction with 95 % Bonferroni confidence intervals.*

Type of behaviour	Habitat component	Degrees of freedom	Critcal chi-squared value [0.05]	Calculated chi-squared value	Z value [0.05]	Plant	Confidence interval	Significance
Standing	Combined components	52	79.08	108.39	2.448	*Acacia erioloba*	(-0.015; -0.004)	+
						Acacia haematoxylon	(-0.084; -0.044)	+
						Acacia mellifera	(-0.037; -0.019)	+
						Acanthosicyos naudinianus	(-0.019; 0.057)	=
						Aptosimum elongatum	(-0.013; -0.005)	+
						Bare patch	(-0.01; 0.21)	=
						Boscia albitrunca	(-0.107; -0.073)	+
						Centropodia glauca	(-0.029; 0.039)	=
						Chascanum pumilum	(-0.0037; -0.0001)	+
						Chenopodium album	(-0.0085; 0.0065)	=
						Chrysocoma obtusata	(-0.0029; 0.0001)	=
						Citrullus lanatus	(-0.0037; -0.0001)	+
						Crotalaria spartioides	(-0.014; 0.0064)	=
						Crotalaria sphaerocarpa	(-0.0069; 0.0053)	=
						Dimorphotheca polyptera	(-0.0041; 0.0043)	=
						Ehretia rigida	(-0.0019; 0.0003)	=
						Elephantorrhiza elephantina	(-0.015; 0.019)	=
						Enneapogon cenchroides	(-0.0037; -0.0001)	+
						Eragrostis lehmanniana	(-0.047; 0.111)	=
						Geigeria ornativa	(-0.00097; 0.00041)	=
						Gisekia africana	(-0.014; 0.029)	=
						Grewia flava	(-0.0072; -0.0018)	+
						Harpagophytum procumbens	(-0.0134; 0.026)	=
						Helichrysum argyrospaerum	(-0.015; -0.0067)	+
						Heliotropium ciliatum	(-0.015; 0.113)	=
						Hermannia burchellii	(-0.012; 0.019)	=
						Hermannia tomentosa	(-0.12; -0.06)	+
						Hirpicium echinus	(-0.0073; 0.0075)	=
						Indigofera alternans	(-0.0151; 0.0165)	=
						Indigofera flavicans	(-0.0094; 0.012)	=
						Limeum sulcatum	(-0.012; 0.021)	=
						Lycium bosciifolium	(-0.012; -0.0012)	+
						Monechma incanum	(-0.023; 0.0016)	=
						Nolletia arenosa	(-0.0102; 0.00003)	=
						Oxygonum delagoense	(-0.02; 0.037)	=
						Phaeoptilum spinosum	(-0.001; 0.009)	=
						Plinthus sericeus	(-0.01; 0.012)	=

Table 5: *Continued*

Type of behaviour	Habitat component	Degrees of freedom	Critcal chi-squared value [0.05]	Calculated chi-squared value	Z value [0.05]	Plant	Confidence interval	Significance
Standing	Combined components					*Asparagus* spp.	(-0.004; 0.004)	=
						Other	(-0.06; 0.056)	=
						Radyera urens	(-0.001; 0.009)	=
						Requienia sphaerosperma	(-0.023; 0.034)	=
						Rhigozum trichotomum	(-0.044; 0.07)	=
						Rhus tenuinervis	(-0.015; -0.0036)	+
						Schmidtia kalihariensis	(0.001; 0.147)	-
						Senecio eenii	(-0.0034; 0.000003)	=
						Senna italica	(-0.0076; 0.0094)	=
						Serecoricorema remotiflora	(-0.0056; 0.0063)	=
						Sesamum triphyllum	(-0.0092; 0.01)	=
						Stipagrostis amabilis	(-0.025; 0.093)	=
						Stipagrostis ciliata	(-0.02; 0.028)	=
						Stipagrostis uniplumis	(-0.032; 0.0127)	=
						Terminalia sericea	(-0.0015; 0.0004)	=
						Tribulus zeyheri	(-0.015; 0.031)	=
						Xenostegia trdentata	(-0.013; 0.021)	=
Sitting	Dune crest	27	40.11	39.37		No evidence of plant associations		
Sitting	Dune street	30	43.77	84.63	2.448	Bare Patch	(-0.17; 0.09)	=
						Acacia erioloba	(-0.017; 0.003)	=
						Acacia haematoxylon	(-0.072; -0.014)	+
						Acacia mellifera	(-0.036; 0.03)	=
						Acanthosicyos naudinianus	(-0.017; 0.026)	=
						Aptosimum elongatum	(-0.017; 0.003)	=
						Asparagus spp.	(-0.0085; 0.0035)	=
						Boscia albitrunca	(-0.029; -0.0002)	+
						Centropodia glauca	(-0.031; 0.057)	=
						Chascanum pumilum	(-0.007; 0.003)	=
						Citrullus lanatus	(-0.007; 0.003)	=
						Crotalaria sphaerocarpa	(-0.017; 0.003)	=
						Eragrostis lehmanniana	(-0.064; 0.104)	=
						Grewia flava	(-0.007; 0.003)	=
						Helichrysum argyrospaerum	(-0.069; -0.019)	+
						Heliotropium ciliatum	(-0.04; 0.09)	=
						Hermannia burchellii	(-0.0138; 0.0142)	

Table 5: *Continued*

Type of behaviour	Habitat component	Degrees of freedom	Critcal chi-squared value [0.05]	Calculated chi-squared value	Z value [0.05]	Plant	Confidence interval	Significance
Sitting	Dune street	30	43.77	84.63	2.448	*Hermannia tomentosa*	(-0.0423; 0.0417)	=
						Indigofera alternans	(-0.026; 0.019)	=
						Limeum fenestratum	(-0.016; 0.0218)	=
						Monechma incanum	(-0.03; 0.002)	=
						Nolletia arenosa	(-0.007; 0.003)	=
						Other	(0.006; 0.144)	-
						Oxygonum delagoense	(-0.013; 0.0036)	=
						Requienia sphaerosperma	(-0.036; 0.034)	=
						Rhigozum trichotomum	(-0.019; 0.145)	=
						Salsola spp.	(-0.111; -0.075)	+
						Schmidtia kalihariensis	(0.054; 0.246)	-
						Stipagrostis amabilis	(-0.019; 0.077)	=
						Stipagrostis ciliata	(-0.019; 0.0224)	=
						Stipagrostis uniplumis	(-0.035; 0.023)	=
Sitting	Dune slope	30	43.77	72.32	2.448	*Acacia erioloba*	(-0.0243; 0.0021)	=
						Acacia haematoxylon	(-0.048; -0.006)	+
						Acacia mellifera	(-0.035; -0.001)	+
						Aptosimum elongatum	(-0.0059; 0.0025)	=
						Asparagus spp.	(-0.0147; 0.0104)	=
						Bare patch	(-0.23; 0.01)	=
						Boscia albitrunca	(-0.077; -0.029)	+
						Centropodia glauca	(-0.025; 0.041)	=
						Citrullus lanatus	(-0.015; 0.001)	=
						Crotalaria sphaerocarpa	(-0.023; 0.015)	=
						Cucumis africana	(-0.0059; 0.0025)	=
						Enneapogon cenchroides	(-0.0059; 0.0025)	=
						Eragrostis lehmanniana	(-0.01; 0.17)	=
						Grewia flava	(-0.015; 0.0015)	=
						Helichrysum argyrospaerum	(-0.023; -0.001)	+
						Hermannia tomentosa	(-0.042; 0.026)	=
						Indigofera alternans	(-0.0157; 0.0163)	=
						Lycium bosciifolium	(-0.0095; 0.0025)	=
						Monechma incanum	(-0.028; 0.015)	=
						Nolletia arenosa	(-0.012; 0.007)	=
						Other	(0.033; 0.227)	-
						Oxygonum delagoense	(-0.019; 0.053)	=

Table 5: *Continued*

Type of behaviour	Habitat component	Degrees of freedom	Critcal chi-squared value [0.05]	Calculated chi-squared value	Z value [0.05]	Plant	Confidence interval	Significance
Sitting	Dune slope	30	43.77	72.32	2.448	*Acanthosicyos naudinianus*	(-0.016; 0.064)	=
						Requienia sphaerosperma	(-0.0366; 0.0234)	=
						Rhigozum trichotomum	(-0.067; 0.027)	=
						Rhus tenuinervis	(-0.017; 0.005)	=
						Salsola spp.	(-0.058; 0.008)	=
						Schmidtia kalihariensis	(-0.005; 0.145)	=
						Stipagrostis amabilis	(-0.03; 0.04)	=
						Stipagrostis ciliata	(-0.017; 0.005)	=
						Stipagrostis uniplumis	(-0.021; 0.037)	=
Lying-up	Dune crest	16	26.3	44.37	2.446	Bare patch	(-0.13; 0.23)	=
						Acacia erioloba	(-0.039; 0.029)	=
						Acacia haematoxylon	(-0.12; 0.022)	=
						Acanthosicyos naudinianus	(-0.032; 0.084)	=
						Boscia albitrunca	(-0.219; -0.021)	+
						Enneapogon cenchroides	(-0.048; 0.02)	=
						Eragrostis lehmanniana	(-0.045; 0.128)	=
						Hermannia tomentosa	(-0.074; 0.034)	=
						Monechma incanum	(-0.048; 0.02)	=
						Other	(0.102; 0.298)	-
						Oxygonum delagoense	(-0.066; 0.058)	=
						Requienia sphaerosperma	(-0.044; 0.046)	=
						Rhigozum trichotomum	(-0.117; 0.031)	=
						Rhus tenuinervis	(-0.048; 0.02)	=
						Salsola spp.	(-0.148; 0.032)	=
						Stipagrostis amabilis	(-0.05; 0.17)	=
						Stipagrostis ciliata	(-0.086; 0.05)	=
Lying-up	Dune street					*Citrullus lanatus*	(-0.027; 0.007)	=
						Other	(0.17; 0.39)	-
						Oxygonum delagoense	(-0.017; 0.007)	=
						Rhigozum trichotomum	(-0.107; 0.097)	=
						Stipagrostis amabilis	(-0.046; 0.066)	=
						Stipagrostis uniplumis	(-0.047; 0.029)	=
						Tribulus zeyheri	(-0.017; 0.007)	=

Type of behaviour	Habitat component	Degrees of freedom	Critcal chi-squared value [0.05]	Calculated chi-squared value	Z value [0.05]	Plant	Confidence interval	Significance
Lying-up	Dune slope	28	41.34	82.529	2.447	Bare patch	(-0.17; 0.11)	=
						Acacia erioloba	(-0.078; 0.07)	=
						Acacia haematoxylon	(-0.058; 0.006)	=
						Acacia mellifera	(-0.0273; 0.0107)	=
						Aptosimum elongatum	(-0.0169; 0.0071)	=
						Aristida meridionalis	(-0.037; 0.031)	=
						Boscia albitrunca	(-0.163; -0.055)	+
						Centropodia glauca	(-0.047; 0.035)	=
						Enneapogon cenchroides	(-0.017; 0.007)	=
						Eragrostis lehmanniana	(-0.053; 0.153)	=
						Grewia flava	(-0.017; 0.007)	=
						Helichrysum argyrospaerum	(-0.017; 0.007)	=
						Heliotropium ciliatum	(-0.001; 0.129)	=
						Hermannia burchellii	(-0.021; 0.023)	=
						Hermannia tomentosa	(-0.028; 0.042)	=
						Lycium hirsutum	(-0.017; 0.007)	=
						Monechma incanum	(-0.042; 0.016)	=
						Nolletia arenosa	(-0.0181; 0.0099)	=
						Other	(0.04; 0.2)	-
						Oxygonum delagoense	(-0.021; 0.055)	=
						Requienia sphaerosperma	(-0.028; 0.034)	=
						Rhigozum trichotomum	(-0.136; -0.004)	+
						Rhus tenuinervis	(-0.018; 0.0099)	=
						Salsola spp.	(-0.071; 0.015)	=
						Schmidtia kalihariensis	(0.021; 0.169)	-
						Stipagrostis amabilis	(-0.06; 0.03)	=
						Stipagrostis ciliata	(-0.042; 0.006)	=
						Stipagrostis uniplumis	(-0.028; 0.036)	=
						Tribulus zeyheri	(0.068; 0.122)	-
Urinating	Dune crest	10	18.31	63.48	2.44	*Acacia haematoxylon*	(-0.12; 0.061)	=
						Aptosimum elongatum	(-0.125; 0.051)	=
						Boscia albitrunca	(-0.12; 0.06)	=
						Eragrostis lehmanniana	(-0.066; 0.154)	=
						Grewia flava	(-0.125; 0.051)	=
						Heliotropium ciliatum	(-0.064; 0.156)	=
						Hermannia tomentosa	(-0.58; -0.14)	+

Table 5: *Continued*

Type of behaviour	Habitat component	Degrees of freedom	Critcal chi-squared value [0.05]	Calculated chi-squared value	Z value [0.05]	Plant	Confidence interval	Significance
Urinating	Dune crest	10	18.31	63.48	2.44	Other	(0.28; 0.68)	-
						Oxygonum delagoense	(-0.17; 0.08)	=
						Salsola spp.	(-0.29; 0.05)	=
						Stipagrostis amabilis	(-0.024; 0.21)	=
Urinating	Dune street	12	21.03	70.54	2.44	Bare patch	(-0.09; 0.29)	=
						Aptosimum elongatum	(-0.11; 0.07)	=
						Centropodia glauca	(-0.077; 0.081)	=
						Crotalaria spartioides	(-0.35; 0.024)	=
						Eragrostis lehmanniana	(-0.066: 0.174)	=
						Helichrysum argyrospaerum	(-0.35; 0.024)	=
						Hermannia tomentosa	(-0.56; -0.16)	+
						Other	(0.2; 0.42)	-
						Oxygonum delagoense	(-0.14; 0.058)	=
						Requienia sphaerosperma	(-0.086; 0.074)	=
						Salsola spp.	(-0.148; 0.042)	=
						Schmidtia kalihariensis	(0.04; 0.26)	-
						Stipagrostis amabilis	(-0.071; 0.082)	=
Urinating	Dune slope	8	15.51	75.33	2.44	*Acacia haematoxylon*	(-0.09; 0.042)	=
						Bare patch	(0.082; 0.422)	-
						Centropodia glauca	(-0.081; 0.063)	=
						Heliotropium ciliatum	(-0.091; 0.129)	=
						Hermannia tomentosa	(-0.64; -0.24)	+
						Other	(0.28; 0.58)	-
						Requienia sphaerosperma	(-0.137; 0.053)	=
						Salsola spp.	(-0.297; 0.001)	=
						Stipagrostis amabilis	(-0.132; 0.061)	=
Defecating	Dune crest	7	14.07	128.52	2.44	Bare patch	(-0.42; 0.36)	=
						Acacia erioloba	(-0.303; 0.121)	=
						Acanthosicyos naudinianus	(-0.26; 0.16)	=
						Hermannia tomentosa	(-0.288; 0.14)	=
						Other	(0.24; 0.48)	-
						Oxygonum delagoense	(-0.276; 0.144)	=
						Schmidtia kalihariensis	(-0.725; 0.575)	=
						Stipagrostis amabilis	(-0.181; 0.259)	=

Table 5: *Continued*

Type of behaviour	Habitat component	Degrees of freedom	Critcal chi-squared value [0.05]	Calculated chi-squared value	Z value [0.05]	Plant	Confidence interval	Significance
Defecating	Dune street	7	14.07	30.72	2.44	*Salsola* spp.	(-0.18; 0.077)	=
						Bare patch	(-0.52; 0.17)	=
						Hermannia tomentosa	(-0.363; 0.071)	=
						Indigofera alternans	(-0.18; 0.08)	=
						Other	(0.38; 0.62)	-
						Oxygonum delagoense	(-0.182; 0.07)	=
						Schmidtia kalihariensis	(-0.12; 0.26)	=
						Senecio eeni	(-0.183; 0.075)	=
Defecating	Dune slope	6	12.59	49.98	2.44	Bare patch	(-0.28; 0.34)	=
						Citrullus lanatus	(-0.22; 0.08)	=
						Hermannia tomentosa	(-0.53; 0.026)	=
						Other	(0.46; 0.7)	-
						Requienia sphaerosperma	(-0.44; 0.06)	=
						Rhigozum trichotomum	(-0.19; 0.12)	=
						Sesamum triphyllum	(-0.22; 0.1)	=
Rolling	Dune crest	2	5.99	15.13	2.42	Bare patch	(-0.59; -0.09)	+
						Other	(0.33; 0.57)	-
						Stipagrostis amabilis	(-0.33; 0.13)	=
Rolling	Dune street	8	15.51	40.13	2.44	Bare patch	(-0.63; -0.15)	+
						Acacia haematoxylon	(-0.11; 0.05)	=
						Citrullus lanatus	(-0.12; 0.048)	=
						Eragrostis lehmanniana	(-0.04; 0.188)	=
						Grewia flava	(-0.122; 0.05)	=
						Helichrysum argyrospaerum	(-0.19; 0.05)	=
						Other	(0.29; 0.59)	-
						Rhigozum trichotomum	(-0.03; 0.198)	=
						Stipagrostis uniplumis	(-0.113; 0.087)	=
Rolling	Dune slope	3	7.81	31.33	2.43	Bare patch	(-0.73; -0.31)	+
						Aptosimum elongatum	(-0.2; 0.08)	=
						Helichrysum argyrospaerum	(-0.2; 0.08)	=
						Other	(0.54; 0.76)	-

Table 5: *Continued*

Type of behaviour	Habitat component	Degrees of freedom	Critcal chi-squared value [0.05]	Calculated chi-squared value	Z value [0.05]	Plant	Confidence interval	Significance
Clawing and scraping	Dune crest	3	7.81	75.8	2.43	*Acacia erioloba*	(-1.1; -0.04)	+
						Acacia haematoxylon	(-0.63: 0.25)	=
						Bare patch	(-0.24; 0.68)	=
						Other	(0.552; 0.588)	-
Clawing and scraping	Dune street	3	7.81	49.99	2.43	*Acacia erioloba*	(-1.06; -0.74)	+
						Bare patch	(0.08; 0.4)	-
						Other	(0.57; 0.78)	-
						Stipagrostis amabilis	(-0.14; 0.12)	=
Clawing and scraping	Dune slope	3	7.81	93.51	2.43	*Acacia erioloba*	(-0.98; -0.55)	+
						Acacia haemotoxylon	(-0.307; 0.047)	=
						Bare patch	(0.083; 0.457)	-
						Other	(0.526; 0.758)	-
Crouching	Dune crest	7	14.07	33.28	2.44	Bare patch	(-0.49; -0.03)	+
						Boscia albitrunca	(-0.22; 0.04)	=
						Chenopodium album	(-0.1; 0.039)	=
						Crotalaria sphaerocarpa	(-0.103; 0.043)	=
						Eragrostis lehmanniana	(-0.048; 0.146)	=
						Other	(0.227; 0.459)	-
						Requienia sphaerosperma	(-0.21; 0.048)	=
						Stipagrostis amabilis	(-0.007; 0.207)	=
Crouching	Dune street	17	27.59	45.994	2.44	*Acacia erioloba*	(-0.034; 0.0144)	=
						Bare patch	(-0.34; 0.003)	+
						Centropodia glauca	(-0.044; 0.062)	=
						Elephantorrhiza elephantina	((-0.034; 0.0339)	=
						Enneapogon cenchroides	(-0.037; 0.017)	=
						Eragrostis lehmanniana	(-0.23; 0.03)	=
						Helichrysum argyrospaerum	(-0.056; 0.016)	=
						Heliotropium ciliatum	(-0.058; 0.1)	=
Crouching	Dune street	17	27.59	45.994	2.44	*Hermmania tomentosa*	(-0.07; 0.051)	=
						Indigofera alternans	(-0.035; 0.028)	=
						Monechma incanum	(-0.055; 0.017)	=
						Other	(-0.042; 0.166)	=

Table 5: *Continued*

Type of behaviour	Habitat component	Degrees of freedom	Critcal chi-squared value [0.05]	Calculated chi-squared value	Z value [0.05]	Plant	Confidence interval	Significance
Crouching	Dune street	17	27.59	45.994	2.44	*Requienia sphaerosperma*	(-0.036; 0.046)	=
						Rhigozum trichotomum	(-0.004; 0.17)	=
						Salsola spp.	(-0.38; 0.34)	=
						Schmidtia kalihariensis	(0.06; 0.26)	-
						Stipagrostis ciliata	(-0.034; 0.027)	=
						Stipagrostis uniplumis	(-0.076; 0.03)	=
Crouching	Dune slope	18	28.87	43.493	2.446	Bare patch	(-0.34; -0.04)	+
						Acacia erioloba	(-0.0306; 0.0144)	=
						Acacia mellifera	(-0.0308; 0.0158)	=
						Boscia albitrunca	(-0.045; 0.013)	=
						Centropodia glauca	(-0.043; 0.045)	=
						Citrullus lanatus	(-0.062; 0.01)	=
						Enneapogon cenchroides	(-0.028; 0.012)	=
						Eragrostis lehmanniana	(-0.1; 0.137)	=
						Helichrysum argyrospaerum	(-0.029; 0.0122)	=
						Heliotropium ciliatum	(-0.014; 0.126)	=
						Hermannia tomentosa	(-0.069; 0.033)	=
						Other	(0.086; 0.27)	-
						Oxygonum delagoense	(-0.041; 0.051)	=
						Requienia sphaerosperma	(-0.058; 0.03)	=
						Rhigozum trichotomum	(-0.075; 0.049)	=
						Schmidtia kalihariensis	(-0.01; 0.156)	=
						Stipagrostis ciliata	(-0.062; 0.012)	=
						Stipagrostis uniplumis	(-0.0436; 0.036)	=
						Tribulus zeyheri	(-0.03; 0.034)	=
Killing	Combined components	8	15.51	23.14	2.44	Bare patch	(-0.4; 0.14)	=
						Acacia mellifera	(-0.133; 0.055)	=
						Other	(0.27; 0.51)	-
						Oxygonum delagoense	(-0.265; 0.055)	=
						Requienia sphaerosperma	(-0.081; 0.029)	=
						Rhigozum trichotomum	(-0.094; 0.126)	=
						Salsola spp.	(-0.124; 0.072)	=
						Schmidtia kalihariensis	(-0.25; 0.13)	=
						Stipagrostis amabilis	(-0.089; 0.133)	=

Table 5: *Continued*

Type of behaviour	Habitat component	Degrees of freedom	Critcal chi-squared value [0.05]	Calculated chi-squared value	Z value [0.05]	Plant	Confidence interval	Significance
Eating	Combined components	14	23.68	61.79	2.44	*Acacia haematoxylon*	(-0.24; 0.024)	=
						Aptosimum elongatum	(-0.159; 0.039)	=
						Bare patch	(-0.054; 0.354)	=
						Boscia albitrunca	(-0.159; 0.043)	=
						Cucumis africana	(-0.1; 0.041)	=
						Helichrysum argyrospaerum	(-0.157; 0.039)	=
						Heliotropium ciliatum	(-0.049; 0.139)	=
						Hermannia tomentosa	(-0.241; 0.033)	=
						Lycium bosciifolium	(-0.098; 0.042	=
						Other	(0.243; 0.477)	-
						Oxygonum delagoense	(-0.242; 0.032)	=
						Rhigozum trichotomum	(-0.115; 0.109)	=
						Salsola spp.	(-0.09; 0.06)	=
						Schmidtia kalihariensis	(-0.08; 0.16)	=
						Tribulus zeyheri	(-0.096; 0.048)	=

\+ :- Plant used in greater proportion than its expected occurrence
\- :- Plant used in smaller proportion than its expected occurrence
= :- Plant used in the same proportion as its expected occurrence

often than expected there ($P \leq 0.05$) was *Acacia haematoxylon*. In addition, bare patches were used significantly more often ($P \leq 0.05$) than expected when lying-up. Only *Heliotropium ciliatum* was associated with less often than expected ($P \leq 0.05$) by caracals in dune streets when lying-up (Table 5).

When urinating on dune crests the caracals urinated close to 10 plant species, compared with 11 plant species in the dune streets and seven on the dune slopes. Across all the three habitat components, the caracals only associated with *Hermannia tomentosa* more often than expected ($P \leq 0.05$) when urinating. On the dune crests and dune slopes, no plant species were associated with less often than expected when urinating. In the dune streets, *Schmidtia kalihariensis* was associated with less often than expected ($P \leq 0.05$) for urination, and on the dune slopes bare patches were used less often than expected ($P \leq 0.05$) (Table 5).

When defecating, the caracals associated with six plant species on the dune crests and the dune streets and with five on the dune slopes. No plant species was associated with more or less often than expected for defecation. When caracals roll on the dune crests, only the tufted grass *Stipagrostis amabilis* was associated with this behaviour. On the dune slopes, two plant species were associated with rolling, while in the dune streets it was seven. In the three habitat components, bare patches were used significantly more often ($P \leq 0.05$) than expected when caracals rolled (Table 5).

When clawing trees and scraping the ground during scent-marking, caracals did so in association with two plant species in each of the habitat components. Across the three habitat components the only plant species that was associated with behaviour more often than expected ($P \leq 0.05$) was *Acacia erioloba*. On the dune slopes and in the dune streets bare patches were used less often than expected ($P \leq 0.05$) (Table 5) for such scent-marking.

Crouching was associated with six plant species on the dune crests, 16 plant species in the dune streets and 17 plant species on the dune slopes. In these three habitat components, caracals crouched more often than expected ($P \leq 0.05$) on bare patches. The only plant species that was associated with less often than expected when crouching ($P \leq 0.05$) was *Schmidtia kalihariensis* in the dune streets (Table 5).

Seven plant species in the three habitat components were present in the proximity of kills, but none of them were associated with killing more or less often than expected. Thirteen plant species in the three habitat components were recorded in association with eating prey by caracals, but none of them were used more or less often than expected (Table 5).

Discussion

The habitat component ratio that was calculated with the non-mapping method (Marcum & Loftsgaarden 1980) differed greatly from the one that was calculated by Van der Walt (1999). According to Van der Walt (1999) the dune crests contributed 2 %, the dune slopes contributed 22 % and the dune streets 69 % to the total habitat, with two additional components making up the surface area deficit of 7 % in the area that study.

Habitat component selection

Proportionally, the dune streets form the highest component proportion of the habitat that is available to caracals in the Kgalagadi Transfrontier Park, contributing 53.8 % of the habitat available in the current study area, with the dune crest and dune slope habitat components contributing 12.7 % and 33.5 % to the available habitat respectively. Caracals, however, tend to select for the two latter habitat components rather than the larger dune street component. Therefore, in effect they only use 46.1 % of the total available habitat area to any great extent (Table 3).

There are a number of possible explanations for the use of the dune slopes and crests in a higher than expected proportion. The most obvious explanation is that the elevation of the dune slopes and the dune crests provides natural vantage points from which caracals can scan the surrounding area for potential prey and other predators as was found for domestic cats (Leyhausen 1979) and leopards (Bothma & Le Riche 1989). Moreover, sufficient cover for hunting is available on the dune slopes and the dune crests and the vegetation density there does not inhibit the movements of a caracal, as much as the higher vegetation density in the dune streets would do. Moolman (1986) and Van Heezik & Seddon (1998) suggested that caracals select certain habitat types based on the availability of cover. The suitability of the habitat for successful hunting seems to be a prerequisite for habitat selection by caracals. The dense stands of *Rhigozum trichotomum* shrubs and the annual grass *Schmidtia kalihariensis* that occur in the dune streets (Table 1) will make the dune streets less suitable for hunting than the other habitat components, especially because it impares both sight and movement.

The high percentage of caracal behaviour that was observed on the dune slopes is believed to be partially attributable to the presence of rodents there where they naturally occur in higher densities. Rodents are also abundant on dune slopes but they are largely absent from the dune crests (Nel *et al.* 1984). Moreover, rodents form an essential component of a caracal's diet in the Kgalagadi Transfrontier Park (Melville *et al*. 2004). For hunting, the dune slopes are therefore preferable to the dune streets for a caracal. This is further substantiated by the preference that is shown by caracals when they start to run from a stationary or crouching position at the onset of a chase (Table 3). Moolman (1986) suggested that caracals in the Mountain Zebra National Park utilise certain habitat types because of the high incidence of their preferred prey there. In Saudi Arabia, caracals also prefer habitats that support large prey populations (Van Heezik & Seddon 1998).

An additional reason for the selection of the dune slopes and the dune crests is that caracals may avoid *Schmidtia kalihariensis*, a highly aromatic annual grass that exudes an acidic substance that can affect animals negatively, and that at times may form dense and almost impenetrable stands that inhibit movement (Van Rooyen 2001). *Schmidtia kalihariensis* occurs in a higher frequency in the dune streets than on either the dune slopes or the dune crests (Table 1). It forms 1.2 % and 10.3 % of the vegetation on the dune crests and the dune slopes respectively, and 18.1 % in the dune streets (Table 1). The southwest-facing dune slopes are possibly used less often than the northeast-facing ones because the southwest-facing slopes have steeper slip-faces than the northeast-facing ones (Van der Walt & Le Riche 1999). The mobility of caracals on steep slopes is probably inhibited by the sheer gradient. A combination of all these factors may therefore cause caracals to use the dune streets less often than expected, and the dune slopes and crests more often than expected.

Association with plants

The association of specific plants with specific types of behaviour is difficult to quantify, and it is important to note that there are definite limitations to the method that was applied in this study. To obtain base-line data for the frequency of occurrence of vegetation, foot-point transects were done. Due to the nature of this type of data collection, not all the plant species that are potentially available for association by the caracals were recorded in each habitat component. When caracals were associated with plant species that were not recorded in the vegetation transects, the actual value that was used in the statistical analysis for missing plants was zero. This zero value tended to bias the level of preference displayed for association with certain plant species when executing certain behaviours in certain habitat components. The base-line data were collected for all the plant species, but the caracals only associated with specific plants when conducting certain types of behaviour. The plants that were not involved in such association were clumped in the category "other" in the preference calculations (Table 5). This clumping exaggerated the chi-squared values for certain types of behaviour relative to certain plant species. The fact that the caracals do associate with certain plant species suggests a level of positive selection for the presence of that plant, even in cases where the statistical tests are not conclusive.

Standing

Standing is a type of behaviour that involves stopping and pausing while moving about normally. It is possible that stopping on the dune slopes and the dune crests is linked to hunting and the use of vantage points to locate prey as in leopards (Bothma & Le Riche 1989) or to locate and avoid other predators. A differential habitat component use pattern was found, with the caracals stopping on the dune slopes by preference in the hot season, and on the dune crests in the cold season. This could be explained by the fact that during the hot season, the prey of a caracal is more abundant and readily available than in the cold season when prey becomes more limited (Begg 2001). In the hot season this may cause the caracals to utilise the dune slopes more often because that is where their prey is more likely to occur then (Nel *et al.* 1984). In the cold season, however, it may be necessary for caracals to utilise the higher vantage points that are provided by the dune crests to locate their prey as in domestic cats (Leyhausen 1979) and leopards (Bothma & Le Riche 1989).

The preferential use of the northeast-facing dune slopes is probably related to a higher density of rodent burrows or colonies on these slopes. The higher rodent density on the northeast-facing dune slopes may be due to a denser substrate on the shallower northeast-facing dune slopes than on the steeper southwest facing dune slopes. A dense substrate is ideal for the excavation of burrows (Nel, pers. comm.)[1]. The higher ambient temperatures on the northeast-facing dune slopes, in the southern hemisphere may also influence the rodent density there. Habitat selection based on thermal conditions is alluded to in Lovegrove (1993) in a paper on the thermoregulation of endotherms. *Acacia mellifera* shrubs occur exclusively on the northeast-facing dune slopes in the study area, and these areas are used extensively by a number of rodent species, but especially by Brant's whistling rat *Parotomys brantsii* for burrowing or nesting (Van Rooyen, pers. comm.)[2]. This rodent is also abundant in the diet of caracal (Melville *et al* 2004). The presence of these rodents

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[1] Professor J.A.J. Nel; jan@sun.co.za, University of Stellenbosch, Stellenbosch, South Africa
[2] Dr. N. van Rooyen; e-mail: gvrooyen@icon.co.za Pretoria

may influence the preference that is shown by the caracals for the northeast-facing dune slopes. The preference for associating with certain trees, and dense shrubs and forbs suggests that the caracals use these plants as cover when hunting, and for shade when moving around in the early morning and late afternoon when they are known to be active in the daylight (Avenant & Nel 1998).

Occasionally a caracal was observed to stand near a rodent burrow. These caracals were possibly waiting for potential prey to emerge from the burrows. Caracals also stood near the entrance or even to go into aardvark *Orycteropus afer* and porcupine *Hystrix africaeustralis* burrows, either to hunt or to lie-up for the day. Caracals also frequently stopped to investigate springhare *Pedetes capensis* faecal deposits but the reason for doing so is obscure.

Sitting

Sitting can be part of resting or hunting. The same trends were found for sitting as were found for standing, with the dune crests and the dune slopes being used more often than expected, and the dune streets less often than expected (Table 3). A similar seasonal pattern of variation in the use of these habitat components was found for sitting as was found for standing, with the dune crests being utilised more often in the cold season, and dune slopes more often in the hot season. A characteristic of the sitting behaviour of caracals is that they use the southwest-facing dune slopes more often than expected for sitting (Table 2). This especially, happened in the hot season, when 85 % of all observed incidences of caracals sitting on a dune slope were on southwest-facing ones. Although caracals are predominately nocturnal, a certain amount of diurnal behaviour does occur (Avenant & Nel 1998). The northwest to southeast orientation of the dunes leaves the southwest-facing dune slopes in the shade for longer in the morning. Consequently they are cooler in the hot season than the northeast-facing ones. When sitting on a southwest-facing dune slope, a caracal may well be resting in a cooler part of its habitat, especially during the hot season. A further environmental factor that could be contributing to the selection of the southwest-facing dune slopes is the prevailing northwesterly wind (Van der Walt & Le Riche 1999) from which the southwest-facing dune slopes will be sheltered. This would also reduce the chances of prey animals detecting the scent of hunting caracals. When sitting during a hunt, the caracals that sat near rodent burrows probably waited for prey to emerge.

Lying-up

Caracals utilise all three of the habitat components in proportion to their occurrence when lying-up on a year-round basis. However, on a seasonal basis, the dune crests are used more frequently than expected during the cold season (Table 4). This pattern is probably related to thermoregulation because the dune crests are more exposed to direct sunlight than the more shaded southwest-facing dune slopes or the more heavily vegetated dune streets. Caracals may use the dune crests as vantage points from which to locate potential prey or to detect other predators as happens in leopards (Bothma & Le Riche 1989). Because caracals are known to display some diurnal behaviour in cool, overcast conditions (Avenant & Nel 1998), a hunt could presumably be initiated in the cold season from a position where a caracal is lying-up.

Caracals utilise the predominant southwest-facing and northeast-facing dune slopes in similar proportions in the hot season, but the increase in the use of the northeast-facing dune slopes during the cold season (Table 2) is probably related to thermoregulation as in leopards (Bothma & Le Riche 1984). Because of the cold southerly winds of the cold season, caracals probably utilise the northeast-facing slopes then to shelter from that wind, and to make use of the warmer north-easterly orientated dune slopes as lions and leopards do.

Caracals prefer *Boscia albitrunca* trees when lying-up, on the dune crests and on the dune slopes, but not in the dune streets (Table 5). The low frequency of use of *Boscia albitrunca* in the dune streets is related to the low frequency of occurrence of this tree in that habitat component (Table 1). In the two habitat components in which *Boscia albitrunca* does occur fairly abundantly, the caracals utilise these trees more often than expected to lie up under because they provide cover for escape from the heat and from prey when hunting as happens in leopards in the same region (Bothma & Le Riche 1984). The bare patches that are used in the dune streets to lie-up in are probably used as temporary resting sites when moving about rather than as places to lie-up for extended periods of rest. In the early morning, caracals frequently lie in the shade of plants with sparse shade. Due to the orientation of the sun and the proximity parameter of ≤100 mm that was imposed on the method of data collection when measuring associations with plants, these caracals were often recorded as lying-up on a bare patch when they were actually lying in the morning shade of particular plants.

Caracals were only recorded to lie-up near *Schmidtia kalihariensis* grass tufts on the dune slopes, but even there they used this plant less often than expected (Table 5). This is probably due to the characteristics of *Schmidtia kalihariensis* that would affect caracals negatively (Van Rooyen 2001). The low ground creeper *Tribulus zeyheri* was also only associated with on the dune slopes for lying-up, but less often than expected (Table 5), probably because of the spiky nature of the fruit that it produces (Van Rooyen 2001) which would make lying-up on these plants uncomfortable.

On five occasions during the present study the caracals used aardvark burrows to lie-up in, in the same manner as leopards (Bothma & Le Riche 1984) and brown hyaenas *Parahyaena brunnea* (Mills 1990). This behaviour was only recorded in the hot season. These burrows provide ideal cover from other predators, and they provide protection from the intense daytime heat of the hot season.

Urinating

Caracals often use scent-marking by urination as a form of olfactory communication (Stuart 1981; Estes 1995) in the same manner as other felids do (Schaller 1972; Verberne & Leyhausen 1976; Bothma & Le Riche 1984, Bothma 1998). This is also the case in the Kgalagadi Transfrontier Park. For urination, the caracals utilise the dune crests more often than expected in both seasons, possibly to optimise the use of the prevailing winds to distribute the scent over a long distance.

When caracals urinate on the dune slopes there is a tendency to utilise the northeast-facing dune slopes more often than the southwest-facing ones (Table 2). This pattern is more pronounced in the cold season than the hot season. The increased utilisation of the northeast-facing dune slopes in the cold season may be to take advantage of the prevailing southerly wind then to distribute the scent. Also, the desiccation effect will not be as pronounced on the northeast-facing dune slopes as on the southwest-facing ones. Consequently, the lifespan of such a scent will be increased.

Although caracals were observed to urinate on various plant species, the only species that was used consistently and more often than expected in all the habitat components was the low shrub *Hermannia tomentosa* (Table 5). This selection may be related to the dense and hairy nature of the foliage of this plant that would trap the scent for long periods (Van Rooyen 2001). The only habitat component in which caracals were observed to associate with *Schmidtia kalihariensis* when urinating, was the dune slopes, and even there it was used less often than expected (Table 5). The reason for avoiding *Schmidtia kalihariensis* when urinating is probably linked to the highly aromatic nature and acidic exudates of this grass species (Van Rooyen 2001). Caracals were also observed to urinate repeatedly against various tree trunks, especially *Boscia albitrunca* trees, which may indicate the use of scent posts to mark the boundaries of the ranges of an individual caracal.

Stuart (1981) reported that caracals occasionally scrape their feet through their own urine. This was also found in the Kgalagadi Transfrontier Park where this type of behaviour involved a caracal depositing urine on a pile of leaf litter and then scraping its hind paws through the wetted litter. It is generally regarded as an alternative form of scent-marking.

Defecation

Faecal deposition is known to contribute to olfactory communication in caracals (Estes 1995). The preferential deposition of faeces on the dune crests (Tables 3 & 4) probably enhances the distribution of the scent by the prevailing winds. Caracals deposit faeces in exposed positions throughout the year. In the hot season, however, the caracals utilise the dune slopes more often than expected when defecating, but the dune crests were used in proportion to their occurrence when doing so (Table 3). The preferred use of the northeast-facing dune slopes in the hot season when defecating increases the rate of desiccation and reduces the effective lifespan of the scent of the faeces. There is no evidence that specific plant species are selected in association with defecation (Table 5). It has been suggested that the deposition of exposed faecal deposits by caracals may only be related to the scent-marking of range boundaries (Stuart 1981; Stuart & Wilson 1988). In the present study caracals were never observed to use faecal middens or latrines, to deposit their scats in open scrape marks, nor to bury their scats.

Rolling

Estes (1995) suggested that rolling might contribute to olfactory communication in felids. In the present study, the caracals regularly rolled on bare patches of sand. This behaviour occurred more often on the dune crests than in any other habitat component. There was a strong seasonal difference in rolling behaviour. In the cold season, there was no significant habitat component selection for rolling, but in the hot season there was a distinct preference for rolling on the dune crests (Tables 3 & 4). Caracals also occasionally rolled in old carcasses.

Clawing and scraping

Stuart (1981) and Stuart & Wilson (1988) suggested that clawing and scraping might have a territorial marking function. Caracals in the Kgalagadi Transfrontier Park clawed trees in much the same manner as leopards (Bothma 1998). Additionally, caracals were observed to scrape the ground with their hind feet without urinating, and this behaviour was included with the analysis of clawing and scraping. In the present study, caracals were not observed to display any significant habitat component selection when clawing and scraping (Table 3). There was, however, a selection for *Acacia erioloba* trees when clawing trees (Table 5). This is probably related to fact that the coarse, deeply furrowed bark (Palgrave 1993; Van Rooyen 2001) is more abrasive on the claws (Estes 1995), and the flaking nature of the bark leaves a more visible mark on these trees than on other tree species. Caracals also tended to claw trees growing on the northeast-facing dune slopes and scraped the ground there more often than on other dune aspects, especially in the hot season. The clawing marks were generally found on the northeast side of the trees.

Crouching

Crouching was often a precursor to a caracal starting to chase a prey animal. Caracals preferred the dune slopes to the other habitat components when crouching, and this is probably linked to the high prevalence of rodents on the dune slopes (Nel, *et al.* 1984). The use of bare patches in which to crouch suggests that an unobstructed terrain from which to launch an attack on prey may be important in the hunting strategy of caracals (Table 5). There is no evidence that caracals favoured either of the predominant dune slope aspects when crouching (Table 2).

Starting a run

The act of starting a run flows from crouching within the context of hunting, and it is therefore logical that the selection of habitat component for this type of behaviour mirrors that of crouching. Of the habitat components that the caracals use, prey animals are found in the highest density on the dune slopes. There is no significant selection for any dune slope aspect when starting a run. No associations with plant species are relevant here because, in this case, the start of a run was related to movement rather than specific point on the ground.

Killing

There is some evidence that caracals avoid the dune crests when killing prey, and that they tend to utilise the other habitat components in proportion to their occurrence for the killing of prey (Tables 3 & 4). It is logical that the least number of kills were made on the dune crests because few prey animals will try to escape by running up a dune or along a dune crest. Moreover, the highest density of rodents occurs on the dune slopes and in the dune streets (Nel *et al.* 1984). It is for these reasons that the highest percentage of kills that were recorded also occurred on the dune slopes and in the dune streets. The northeast-facing dune slopes were used more often than the southwest-facing ones when killing prey, particularly in the hot season. This is probably because prey animals occur in higher densities on the northeast-facing dune slopes (Lovegrove 1993, Van Rooyen pers. comm.), and the less steep gradient of these dune slopes. No specific plant associations were noted in conjunction with caracals making kills. This was expected because of the great degree of chance inherent in killing prey. Therefore any active habitat selection related to this behaviour is unlikely.

Eating

Over the whole year and the cold season the dune crests were used less often than expected for eating. This is probably because of caracals eating their prey wherever they catch and kill them. The dune streets were also used less often than expected for eating, but the dune slopes were used more often than expected (Table 3). This probably relates to the occurrence of prey animals within the latter habitat component (Nel *et al.* 1984). No evidence of habitat component selection when eating was found in the hot season (Tables 3 & 4). High frequencies of observations of caracals eating were found on the northeast-facing dune slopes. In the hot season 75 % of all the records of a caracal eating its prey were on the northeast-facing dune slopes. This pattern is related to the proportionally high number of kills that are made on the northeast-facing dune slopes. Both these patterns probably also relate to a higher density of rodents occurring on the northeast-facing dune slopes (Nel, pers. comm.). There is no evidence that specific plant species were associated with when eating prey, and those plants that are present there were in proportion to their occurrence (Table 5).

Conclusions

Even in the apparently homogeneous habitat of the Kgalagadi Transfrontier Park, caracals display a level of habitat component selection across the full spectrum of variation. On a coarse habitat component level, the caracals tend to select the dune crests and dune slopes, while avoiding the dune streets. On a finer scale, the dune slopes with various aspects were used preferentially for a range of behavioural patterns. Caracals also display some degree of selectivity when associating with specific plant species for particular behavioural patterns. The overall conclusion is that caracals do not utilise the available habitat in proportion to its occurrence, but rather that they select specific components of it for specific types of behaviour.

References

ALVAREZ-CARDENAS, S., GUERRERO-CARDENAS, I., DIAZ, S., GALINA-TESSARO, P. & GALLINA, S. 2001. The variables of physical habitat selection by the desert bighorn sheep (*Ovis canadensis weemsi*) in the Sierra del Mechudo, Baja California Sur, Mexico. *J. Arid Env*. 49: 357-374.

AVENANT, N.L. & NEL, J.A.J. 1998. Home-range use, activity, and density of caracal in relation to prey density. *Afr. J. Ecol*. 36: 347-359.

BEGG, C.G. 2001. *Feeding ecology and social organisation of honey badgers* (Mellivora capensis) *in the southern Kalahari*. PhD thesis, University of Pretoria, Pretoria.

BOTHMA, J. DU P. & WALKER, C. 1999. 5. The caracal. In: BOTHMA, J. DU P. & C. WALKER. *Larger carnivores of the African savannas*. (Pp. 117-129). J.L. van Schaik Publishers. Pretoria.

BOTHMA, J. DU P. & LE RICHE, E.A.N. 1989. Evidence of a flexible hunting technique in Kalahari leopard. *S. Afr. J. Wildl. Res*. 19(2): 57-60.

BOTHMA, J. DU P. & LE RICHE, E.A.N. 1984. Aspects of the ecology and the behaviour of the leopard *Panthera pardus* in the Kalahari desert. Supplement to *Koedoe* 1984: 259-279.

BOTHMA, J. DU P. 1998. 1998. A review of the ecology of the southern Kalahari leopard. *Trans. Roy. Soc. S. Afr*. 53(2): 257-266.

BOYCE, M.S. & MCDONALD, L.L. 1999. Relating populations to habitats using resource selection functions. *TREE* 14(7): 268-272.

BREWER, R. 1994. 2. The ecology of individual organisms. Pp. 14-41. In: BREWER, R. (Ed.). *The science of ecology*. Saunders College Publishing. Orlando, Florida.

CALEY, P. 1994. Movements, activity patterns and habitat use of feral pigs (*Sus scofra*) in a tropical habitat. *Wildl. Res*. 24: 77-87.

DONALDSON, A. 2000. Born free. *Sunday Times* (14 May 2000) Times Media. Johannesburg.

ELOFF, F.C. 1984. The Kalahari ecosystem. Supplement to *Koedoe* 1984 11-20

ESTES, R.D. 1995. *The behaviour guide to African mammals*. Pp. 363-365. Russel Friedman Books, Halfway House.

JOHNSON, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology*. 61(1): 65-71.

LAWRENCE, E. 1998. *Henderson's dictionary of biological terms*. Longman Singapore Publishers, Singapore.

LEYHAUSEN, P. 1979. *Cat behaviour*. Translated by B.A. Tonkin. Garland Press, New York, U.S.A.

LOW, A.B. & REBELO, A.G. 1996. *Vegetation of South Africa, Lesotho and Swaziland*. Department of Environmental Affairs and Tourism, Pretoria.

MARCUM, L. C. & LOFTSGAARDEN, D.O. 1980. A nonmapping technique for studying habitat preferences. *J. Wildl. Manage*. 44(4): 963-968.

MELVILLE, H.I.A.S., BOTHMA, J. DU P. & MILLS, M.G.L. 2004. Prey selection by caracal in the Kgalagadi Transfrontier Park. *S .A. J. Wildl. Res* 34(1): 67-75.

MENTIS, M.T. 1981. Evaluation of the wheel-point and step-point methods of veld condition assessment. *Proc. Grassld. Soc. sthn. Afr.* 16: 89-94.

MILLS, M.G.L. 1990. *Kalahari hyaenas: Comparative behavioural ecology of two species*. Unwin Hyman , London.

MOOLMAN, L.C. 1986. *Aspekte van die ekologie en gedrag van die rooikat* Felis caracal *Schreber, 1776 in die Bergkwagga Nasionale Park en op die omliggende plase*. MSc. dissertation, University of Pretoria, Pretoria.

NORTON, P.M. & LAWSON, A.B. 1985. Radio tracking of leopards and caracals in the Stellenbosch area, Cape Province. *S. Afr. J. Wildl. Res*. 15:17-24.

PALGRAVE, K.C. 1993. *Trees of southern Africa*. Struik Publishers, Cape Town.

SCHALLER, G.B. 1972. *The Serengeti Lion*. University of Chicago Press, Chicago.

SKINNER, J.D. & R.H.N. SMITHERS. 1990. *Mammals of the southern African subregion*. University of Pretoria, Pretoria.

STANDER, P.E., GHAU, *//.*, TSISABA, D., ǂOMA. *//.*, & I UI, I. 1997. Tracking and the interpretation of spoor: a scientifically sound method in ecology. *J. Zool. Lond.* 242: 329-341.

STUART, C.T. & WILSON, V.J. 1988. *The cats of southern Africa*. Chipangali Wildlife Trust, Bulawayo.

STUART, C.T. 1981. Notes on the mammalian carnivores of the Cape Province, South Africa. *Bontebok* 1: 49-54.

VAN DER WALT, C. 1999. *The vegetation types and veld condition of Alpha; southern Kalahari*. B.Sc. (Honours) project. University of Pretoria, Pretoria.

VAN DER WALT, P. & LE RICHE, E. 1999. *The Kalahari and its plants*. Pieter van der Walt & Elias Le Riche, Pretoria.

VAN HEEZIK, Y.M. & SEDDON, P.J. 1998. Range size and habitat use of an adult male caracal in northern Saudi Arabia. *J. Arid Env.* 40: 109-112.

VAN ROOYEN, N. 2001. *Flowering plants of the Kalahari dunes*. Ekotrust, Pretoria.

VAN WYK, P. & LE RICHE, E.A.N. 1984. The Kalahari Gemsbok National Park, 1931 – 1981. Supplement to *Koedoe* 1984: 21-32.

VERBERNE, G. & LEYHAUSEN, P. 1976. Marking behaviour of some Viverridae and Felidae: time interval analysis of the marking pattern. *Behaviour* 58: 192-253.

WHITE, G.C. & GARROT, R.A. 1986. Effects of bio-telemetry triangulation error on detecting habitat selection. *J. Wildl. Manage*. 50: 509-513.