

# Herbage availability inventories in rock hyrax habitat in southern South West Africa

by

J. E. Lensing\*

and

C. J. G. le Roux\*\*

Directorate of Nature Conservation  
Private Bag 13306  
Windhoek  
9000  
South West Africa/Namibia

Received: 14 September 1981

\*Present address:

Vrolijkheid Nature Conservation Station  
Private Bag 614  
Robertson  
6705  
Republic of South Africa

\*\*Present address:

Döhne Agricultural Research Station  
Private Bag X15  
Stutterheim  
4930  
Republic of South Africa

## CONTENTS

1 Introduction	45
2 Study areas	46
2.1 Location	46
2.2 Climate	46
2.3 Vegetation	49
3 Methods	49
3.1 Survey sites	49
3.2 Vegetation communities, stratification and replications	49
3.3 Survey procedure	49
3.4 Data processing	50
4 Results and discussion	52
4.1 Sampling error	53
4.2 Density as a possible source of error	53
4.3 Other sources of error	54
4.4 Characteristics of the availability pattern	54
5 Conclusions	55
6 Acknowledgements	55
7 References	56

## 1 INTRODUCTION

Petrides (1975) regards the principal foods of an animal population as those which it eats in the greatest quantities while preferred food species are regarded as species which are proportionately more "frequent" in the diet of an animal than in the available environment. Petrides stated further that "to determine food preference relationships in the field it is necessary to measure the amounts of various foods available ... for feeding and the extent to which those foods are actively removed ... by herbivores". During a study of the feeding ecology of the rock hyrax, *Procavia capensis* Pallas 1766, in southern South West Africa, a vegetation survey technique was developed to determine relative food availability. The data were required for comparison with the quantitatively determined diet of rock hyrax to determine food preferences. This paper describes the technique, points out some of its shortcomings and indicates how it may be improved.

A great many studies of the food habits of herbivores have been done the world over and although most workers made observations on the phenology and composition of the vegetation of the areas in which they conducted research, few determined the availability of the various food species involved on a quantitative basis. Those who did, used a wide variety of methods depending on prevailing conditions. In grassland or the more open range types, yield or biomass can be determined directly by clipping the herbaceous layer in sam-

## ABSTRACT

Surveys of the vegetation in rock hyrax habitat in the Karas Mountains, southern South West Africa, were conducted to approximate the relative availability of herbage for use in a food habits study. The survey technique (based on plant dimensions) and its shortcomings are described. It was found that sampling was inadequate for infrequently encountered species but consistently reflected the relative proportions of the common trees, shrubs and grasses. Rock hyrax habitat is suitable for browsers.

ple plots as was done by Heady and Torell (1959), Van Dyne and Heady (1965) and Galt, Theurer, Ehrenreich, Hale and Martin (1969) who all worked on fistulated livestock. Clipping was also done by Casebeer and Koss (1970) on East African plains, Flinders and Hansen (1972) who worked on the food habits of jackrabbits in Colorado, and Harlow, Whelan, Crawford and Skeen (1975) who worked on deer in oak forests in Virginia.

Some workers estimated or determined biomass by an indirect method, for example Flinders and Hansen (1972) who estimated standing biomass in 450 cm<sup>2</sup> quadrats, McAllister and Bornman (1972) who derived dry mass from percentage canopy cover and Schwartz and Nagy (1976) who estimated biomass in 0,5 m<sup>2</sup> quadrats. Heady and Torell (1959) calculated the dry mass of clipped samples by a point method in the laboratory. Telfer (1972) and Joyal (1976) both worked in areas where all browsing could easily be attributed to one or two species of herbivores and estimated standing crop from counts of utilised and unutilised twigs and the mean length of shoots from the tip to the mean diameter at the point of browsing.

Standard or adapted phytosociological parameters were employed as a direct measure of availability by a number of workers. Stoddard (1967) estimated canopy cover; Eastman and Jenkins (1970) quantified the vegetation by constancy (frequency of occurrence) and canopy cover; Nixon, McClain and Russel (1970) counted trees and shrubs by a quarter method and in plots and estimated canopy cover for grasses and forbs; Heady and Torell (1959) and Roos, Rethman and Kotzé (1973) determined cover by point methods. De Graaf, Schulz and Van der Walt (1973) made use of percentage basal cover while Turkowsky (1975) determined ground cover from pace transects and Pearson and Sternitzke (1976) estimated browse cover.

Frequency or occurrence were determined by Dirschl (1963) in 0,5 m<sup>2</sup> quadrats, Sparks (1968) by a step-point method and Field (1970 and 1972) and Leuthold and Leuthold (1972). Harlow *et al.* (1975) and Peden (1976) employed presence and absence data while Scotcher, Stewart and Breen (1978) calculated frequencies adjusted according to the area occupied by the various communities. The Braun-Blanquet coefficient of abundance was employed by Borowski and Kossak (1972 and 1975) and Kossak (1976).

During his studies on the feeding of two hyrax species (*Procavia johnstoni* and *Heterohyrax brucei*) in the Serengeti National Park, Hoeck (1975) made detailed surveys of the plant species composition of each koppie studied to determine similarities between the vegetation on the various koppies. He used parallel transects to record the number of times each plant species touched a vertical rod placed at intervals of 0,5 m along the transect and calculated crown cover and "foliage density".

All strata of the vegetation in this study were regarded as being available to rock hyrax because the animals

were observed to climb trees and feed even from the tips of branches. Predictive relationships have been developed between various plant dimensions and the biomass of browse available (Barnes, 1976; Rutherford, 1979a), but such equations are usually specific for individual species or species groups and require the prior determination of the actual biomass of the whole, or parts of, individuals of each species (Newbould, 1967; Rutherford, 1979b), a time-consuming process.

Since the objective of the present study was to provide a rapid inventory of *relative* availability, this approach was unnecessary. A technique using canopy volumes was decided on, similar to the method developed by Anderson and Walker (1974) and Walker (1976) for assessing damage and monitoring composition changes. Availability data determined by this method were used by Guy (1976) to calculate selectivity ratings in a study of elephant feeding behaviour. Plant dimensions were used as a source of data in the herbaceous layer as well because relative availability for all species was required to be directly comparable.

## 2 STUDY AREAS

### 2.1 Location

High density hyrax populations occur in the ravines and gorges of the Groot Karas Mountains and in the transition between the mountain complex and the southern Kalahari to the east in the Keetmanshoop and Karasburg Districts of southern South West Africa.

The farm Sandmodder no. 73 (26° 57'S; 18° 55'E) in the Keetmanshoop District was chosen as being representative of the mountain complex itself (Fig. 1). The Leeu River has its origin at Sandmodder where its two tributaries, the Sand-Gosub and the Klip-Gosub, unite, and traverses the farm in a ravine for a considerable distance. The surveys were conducted along this ravine because it is typical rock hyrax habitat and contains a high density hyrax population.

The farm Warmfontein no. 280 (27° 7'S; 19° 15'E), also in the Keetmanshoop District, is typical of the transition zone between the mountain complex and the southern Kalahari (Fig. 1). Here a dry sandy watercourse meanders between the low rocky ridges typical of the area. The ridges on both sides of this stream were selected for study purposes.

### 2.2 Climate

The nearest weather station to the Great Karas Mountains is at Keetmanshoop. A rainfall station is maintained at the Warmfontein study area and the nearest rainfall station to the Sandmodder study area is at Na-Os (27° 12'S; 18° 59'E) (Fig. 1). Temperature (27 years)

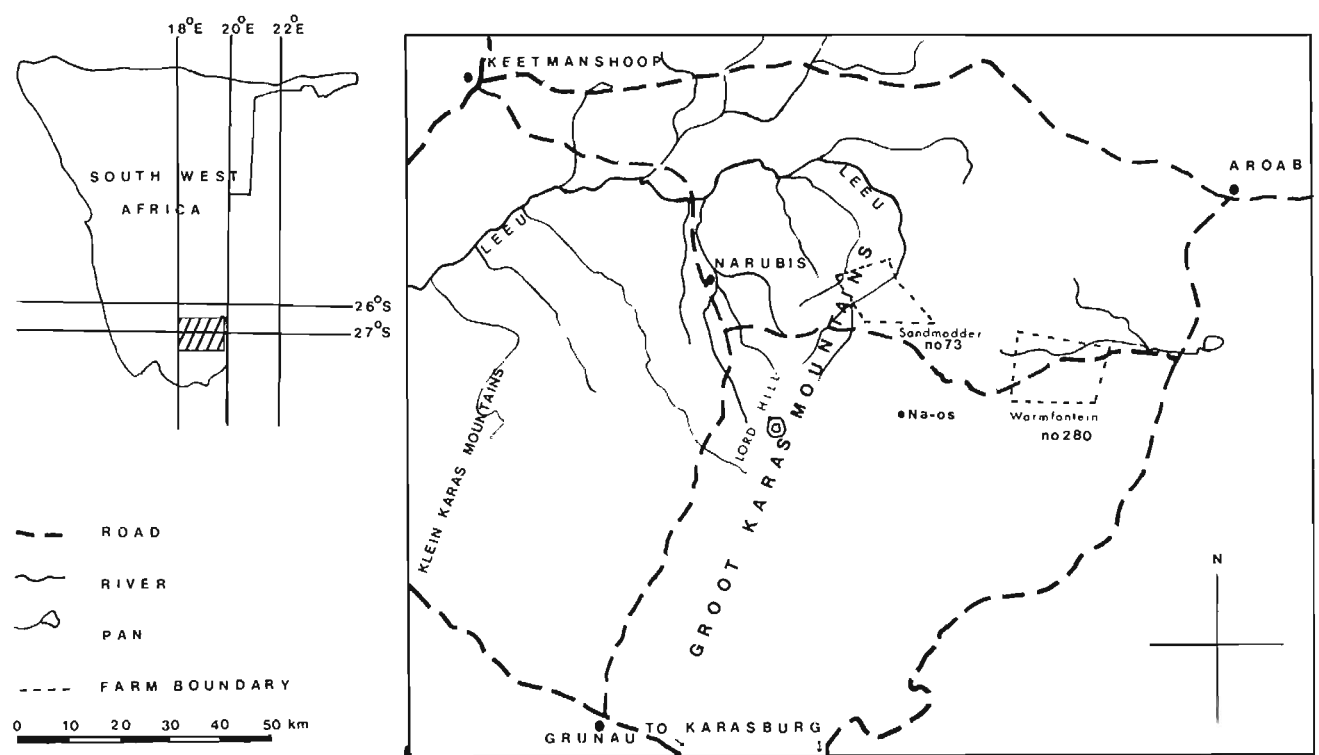


FIGURE 1: Map of the Kectmanshoop vicinity showing the geographical location of the farms Sandmodder no. 73 and Warmfontein no. 280. Only relevant watercourses are shown.

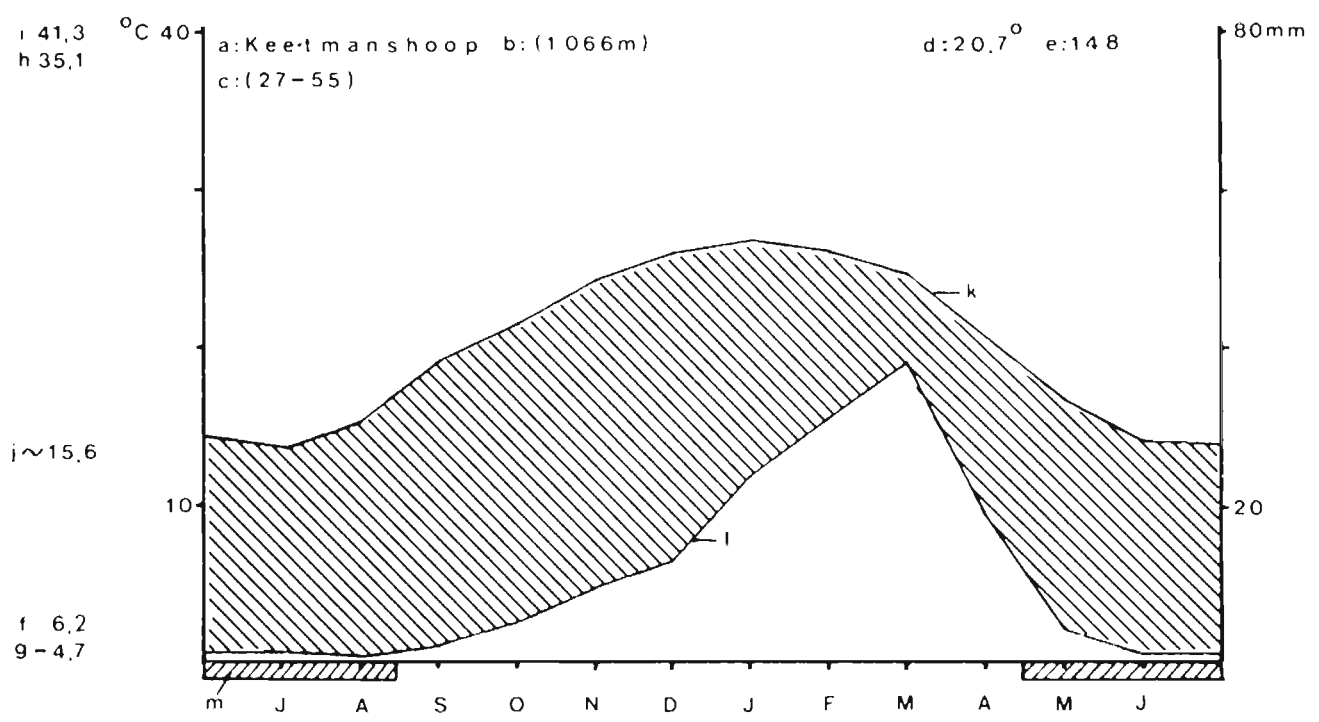


FIGURE 2: Climatic diagram for Keetmanshoop, South West Africa (after Walter, 1973).

Key:  
a = Station  
b = Height above sea level  
c = Duration of observations in years (the first indicates temperature, the second rainfall)  
d = Mean annual temperature in °C  
e = Mean annual rainfall in mm

f = Mean daily minimum of the coldest month  
g = Lowest temperature recorded  
h = Mean daily maximum of the warmest month  
i = Highest temperature recorded  
j = Mean daily temperature variations  
k = Curve of mean monthly temperature  
l = Curve of mean monthly rainfall  
m = Months with absolute minimum below 0°C  
Relative period of drought





PLATE 1: Riparian vegetation on the farm Sandmodder no. 73, Keetmanshoop District, in the transition period. The shrubs in the foreground are *Rhigozum trichotomum* and *Acacia mellifera* and *Ziziphus mucronata* can be seen in the middle and background.



PLATE 2: Ridge-top vegetation on the farm Warmfontein no. 280, Keetmanshoop District, in the wet season. On the left in the foreground is *Rhigozum obovatum* and *Catophractes alexandri* can be seen in the middle foreground.



and rainfall (55 years) data recorded at Keetmanshoop were used to compile a climatic diagram (Fig. 2) according to Walter (1973) to summarise the climate. The mean annual rainfall at Na-Os (31 years' data) and Warmfontein (23 years' data) is 191,6 mm and 180,0 mm respectively, most of which occurs in the form of thunderstorms which often cause flash floods. The mean humidity recorded at 08h00, 14h00 and 20h00 is 47,0, 21,0 and 26,0 per cent respectively. The mean annual evaporation is 317,8 mm per month and reaches a peak of 480,0 mm in December. The mean daily maximum temperature at Keetmanshoop reaches 35,1°C in January and only declines significantly when the rains arrive in February or March. In the hot dry months of November to January the heat at the bottom of a typical ravine or canyon in the mountains is intense due to the large exposed rock surfaces. There is a considerable difference between day and night temperatures in the winter (mean daily maximum and minimum temperatures in July are 21,1°C and 6,2°C respectively) and frost is common, particularly in the valleys and ravines where temperature inversions occur.

### 2.3 Vegetation

The vegetation of the Groot Karas Mountains is classified by Giess (1971) as dwarf shrub savanna (Vegetation type 9) which is dominated by Karoo shrubs and grasses. The plateaux of the mountain complex are dominated physiognomically by dwarf shrubs and where the range is in good condition the herbaceous layer is dominated by perennial species of *Stipagrostis*. The watercourses and valleys, where deeper soils are found, support a fairly well-developed riparian thicket (Plate 1) dominated by *Acacia* spp., *Ziziphus mucronata* and *Pappea capensis*. On the banks of the watercourses common perennial grasses are *Asthenatherum glaucum*, *Cynodon dactylon*, *Cenchrus ciliaris*, *Chloris virgata* and *Eragrostis* spp., while sedges such as *Cyperus longus*, *Mariscus aristatus* and *Fimbristylus exilis* also occur.

The vegetation further east, in the vicinity of Warmfontein, may be described as a transition between the dwarf shrub savanna and the southern Kalahari vegetation (Giess, 1971). In addition to dwarf shrubs, larger shrubs such as *Acacia mellifera*, *Boscia albitrunca* and *Grewia flava* are found on top of the ridges (Plate 2). At Warmfontein the watercourses do not possess a continuous riparian thicket but scattered trees such as *Acacia haematoxylon*, *Boscia albitrunca*, *Ziziphus mucronata* and *Acacia karroo* occur. The grass cover in and around the watercourses is dominated by *Stipagrostis* spp.

## 3 METHODS

### 3.1 Survey sites

Stomach content samples required to determine the diet of the rock hyrax were collected by sampling the Sand-

modder population along the Leeu River upstream from the homestead. The cliff-tops on either side of the ravine were examined for signs of utilisation by hyrax. In this manner, a roughly defined "feeding zone" some 20 to 50 m wide, parallel to the cliff edge, was determined. The vegetation outside this zone was considered to be unavailable to the hyrax. As the riparian thicket and the vegetation of the cliff-tops on either side of the ravine were fairly uniform along this section of the river an accessible area was chosen as a representative survey site. The site straddled the river and the cliffs on either side of the ravine.

At Warmfontein, rock hyrax population sampling was conducted along the rocky ridges on either side of the wide sandy watercourse. Similar feeding zones were identified but few signs of utilisation of the vegetation in the river-bed were found and it was therefore excluded from the survey site. The site encompassed the river-bed, the ridges on both sides and the feeding zones on the ridge-tops on both sides.

### 3.2 Vegetation communities, stratification and replications

At Sandmodder three communities were physiognomically identified, notably the riparian thicket at the bottom of the ravine, the cliff-face community and the cliff-top community. As the cliff-faces were almost perpendicular, the vegetation here is sparse and consists of only a few smaller shrubs and annual grasses and forbs. For practical considerations this community was excluded from the survey. At Warmfontein there were also three communities, namely the riparian vegetation (which was excluded from the survey), the ridge-slope community (called the scree community) and the ridge-top community. For the purposes of this investigation the vegetation was divided into the following strata:

Grasses and forbs: All non-woody plants

Shrubs: All woody plants up to a height of 2,5 m

Trees: All woody plants taller than 2,5 m

Phenological changes in the vegetation affect food availability. Four periods of seasonal change in the vegetation were arbitrarily distinguished and the survey repeated in each of the seasons. The durations of each season and the times when surveys were conducted are presented in Table 1. The cool dry season survey was repeated in 1976 to determine the effect of the above-average 1976 wet season on food availability.

### 3.3 Survey procedure

#### 3.3.1 Sampling

A point-centre quarter method (Cottam and Curtis, 1956) was used for sampling the vegetation. The points were distributed by means of a pace transect. At the Sandmodder survey site two transects were placed in each of the communities on either side of the river, 24 points to each community, the points spaced 25 m

TABLE 1: Duration of seasons and dates of food availability surveys conducted on the farms Sandmodder no. 73 and Warmfontein no. 280, Keetmanshoop District, South West Africa.

Season	Duration	Survey
Wet season	February to end April	End March 1976
Cool dry season	May to end August	End July 1975, end July 1976
Transition period	September to middle October	End September 1975
Hot dry season	Middle October to end January	Middle December 1975

apart. In the riverine community the two transects paralleled the river-bed while in the cliff-top community the transects paralleled the cliff edge. The same procedure was adopted at Warmfontein where 12 points were distributed on each of the ridge-tops and 12 points in each of the scree communities of the same ridges.

### 3.3.2 Measurements and tallies

The area surrounding each point was divided into four quadrants using an imaginary line running at right angles to the pace transect and crossing the transect at the point. All shrubs outside a 12 m radius from the point were disregarded. The nearest shrub in each quadrant was recorded and the following measurements noted:

H = height to the nearest cm

L = height above ground level of the lowest leaf to the nearest cm

D<sub>1</sub> and D<sub>2</sub> = any two canopy diameters measured at right angles to each other (roughly halfway between L and H) to the nearest cm

OD = optical density of the canopy estimated on a 5-point scale using the estimated percentage of lateral area occupied by foliage:

1 = 1–20 per cent

2 = 21–40 per cent

3 = 41–60 per cent

4 = 61–80 per cent

5 = 81–100 per cent

The nearest tree in each quadrant was treated in exactly the same manner as the shrubs except that canopy dimensions were measured to the nearest 5 cm. All trees outside a 12 m radius from the point were disregarded.

Density of trees and shrubs was determined by counting the number of individuals in imaginary circles with predetermined radii with the point as centre. The radii of the circles were predetermined so as to contain, on average, at least one tree and one shrub: In each community at each study area the number of trees and shrubs were counted in a belt transect of 2×200 m. The area of the transect was divided by the counts to obtain the respective circle areas, the radii of which were determined as 8 m for trees in the Sandmodder River community, 12 m for trees in the other communities and 2 m for shrubs in all communities.

For grasses and forbs a 2 m rod marked off in 10 cm lengths was allowed to drop randomly in each quadrant. An imaginary line, 10 cm from the rod, running parallel to and on the right-hand side of the rod was used as an exclusion criterion. If any part of the base of a grass or forb touched this line or fell inside the line, it was included in the tally. Each grass or forb was recorded and the following measurements noted:

D = the diameter of the canopy at its widest point, parallel to the rod, within 10 cm of the rod, to the nearest cm.

H = the height of the canopy at its highest point to the nearest cm.

For practical reasons, optical density values could not be recorded for grasses and forbs. However, to obtain the same basis of derivation as for trees and shrubs optical density values were arbitrarily assigned to each grass and forb species for each season using the same five-point scale.

### 3.4 Data processing

The following formulae were used to calculate relative availability for trees and shrubs:

$$BV_i (\text{biovolume}) = \frac{\sum_{i=1}^n (H-L) \times D_1 \times D_2 \times OD}{10^6} \quad (1)$$

where

n = number of observations for the species

10<sup>6</sup> = cubic centimetres in 1 cubic metre

$$RF (\text{relative frequency}) = \frac{\text{number of quadrants in which species is recorded}}{\text{number of quadrants in which trees or shrubs are recorded}} \quad (2)$$

$$DP (\text{density proportion}) = RF \times T \quad (3)$$

where

T = density of woody plants per ha.

$$RA_i (\text{relative availability}) = \frac{BV_i \times DP}{n} \quad (4)$$

Although BV is a volume calculated in cubic metres it is not expressed in volumetric terms because of the optical density by which it is multiplied. As BV is a simple relative measure it is expressed simply in "units". The same applies to RA which is also a relative measure and is equivalent to BV extrapolated and expressed on a per ha basis, thus "units per ha".

For grasses and forbs, the following formulae were used:

$$BV_g (\text{biovolume}) = \frac{\sum_{i=1}^n (H \times D \times 10)}{10^3} \times OD \quad (5)$$

simplified to:

$$BV_g = \frac{\sum_{i=1}^n (H \times D \times OD)}{1000} \quad (6)$$

where

10 = width in cm of the 200 cm transects

(see 3.3.2)

$10^3$  = cubic centimetres in 1 cubic decimetre

$$RA_g (\text{relative availability}) = \frac{BV_g \times 10^8}{384\,000 \times 10^3} \quad (7)$$

simplified to:

$$RA_{gl} = BV_g \times 0,260 \quad (8)$$

where

$10^8$  = square centimetres in 1 ha

384 000 = area in  $\text{cm}^2$  of  $4 \times 48$  transects of  $200 \times 10$  cm

$10^3$  = denominator to bring the value of  $RA_g$  up to the equivalent of cubic metres

A Hewlett-Packard 9830 A minicomputer was used for processing the data. The programmes were printed in a thesis of which this paper formed part (Lensing, 1979).

TABLE 2: Relative herbage availability expressed in units per ha and as relative percentages for all strata of the vegetation in rock hyrax habitat on the farm Sandmodder no. 73, Keetmanshoop District.

VEGETATION CATEGORY	SURVEY									
	July 1975		October 1975		December 1975		March 1976		July 1976	
	RA	Per cent	RA	Per cent	RA	Per cent	RA	Per cent	RA	Per cent
Trees and shrubs:	73 423,2	99,8	63 882,1	99,6	75 244,7	99,8	144 256,4	99,3	96 899,6	99,3
<i>Acacia karroo</i>	21 043,7	28,6	14 626,2	22,8	13 985,3	18,5	34 601,5	23,8	23 669,0	24,2
<i>Acacia mellifera</i>	5 244,7	7,1	4 087,1	6,4	2 795,4	3,7	10 192,2	7,0	4 020,3	4,1
<i>Pappia capensis</i>	14 702,9	20,0	19 849,6	30,9	14 892,8	19,7	32 883,4	22,6	23 350,3	23,9
<i>Rhigozum obovatum</i>	3 588,8	4,9	3 014,7	4,7			5 549,5	3,8	4 698,4	4,8
<i>Ziziphus mucronata</i>	25 905,1	35,2	21 029,7	32,8	40 760,5	54,0	60 053,6	41,3	39 663,1	40,6
Others*	2 938,1	4,0	1 274,8	2,0	2 810,7	3,7	976,1	0,7	1 498,6	1,5
Grasses and forbs:**	137,6	0,2	281,1	0,4	185,0	0,2	1 021,9	0,7	717,7	0,7

\* Number of species: July 1975 = 19, October 1975 = 17, December 1975 = 17, March 1976 = 19, July 1976 = 18

\*\* Number of species: July 1975 = 17, October 1975 = 13, December 1975 = 13, March 1976 = 28, July 1976 = 26

TABLE 3: Relative herbage availability expressed in units per ha and as relative percentages for all strata of the vegetation in rock hyrax habitat on the farm Warmfontein no. 280, Keetmanshoop District.

VEGETATION CATEGORY	SURVEY									
	July 1975		October 1975		December 1975		March 1976		July 1976	
	RA	Per cent	RA	Per cent	RA	Per cent	RA	Per cent	RA	Per cent
Trees and shrubs:	8 591,5	94,4	9 517,6	95,5	10 228,5	98,5	18 927,3	91,1	10 687,6	87,7
<i>Acacia mellifera</i>	4 532,9	49,8	6 476,7	65,0	7 428,1	71,5	13 688,3	65,9	6 064,6	49,7
<i>Berkheya spinosissima</i>	472,5	5,2								
<i>Boscia albitrunca</i>	356,5	3,9								
<i>Boscia foetida</i>	590,6	6,5	354,9	3,6						
<i>Cadaba aphylla</i>	839,6	9,2	318,6	3,2	581,8	5,6			834,3	6,8
<i>Catophractes alexandri</i>	448,8	4,9	636,7	6,4	504,5	4,9	1 169,3	5,6	976,4	8,0
<i>Ozoroa namaensis</i>			494,1	5,0			862,7	4,2	1 250,5	10,3
<i>Parkinsonia africana</i>							1 186,8	5,7		
<i>Phaeoptilum spinosum</i>	339,7	3,7								
<i>Rhigozum trichotomum</i>	334,4	3,7	401,4	4,0					640,2	5,3
Others*	677,1	7,4	835,2	8,4	1 714,1	16,5	2 020,2	9,7	921,6	7,6
Grasses and forbs:**	508,0	5,6	448,8	4,5	160,9	1,5	1 851,4	8,9	1 503,3	12,3
<i>Stipagrostis uniplumis</i>									468,4	3,8

\* Number of species: July 1975 = 15, October 1975 = 17, December 1975 = 18, March 1976 = 20, July 1976 = 16

\*\* Number of species: July 1975 = 18, October 1975 = 13, December 1975 = 11, March 1976 = 29, July 1976 = 24

TABLE 4: Relative availability of grasses and forbs in rock hyrax habitat on the farm Sandmodder no. 73, Keetmanshoop District. Percentages are relative to grasses and forbs as a group.

SPECIES	SURVEY									
	July 1975		October 1975		December 1975		March 1976		July 1976	
	RA	Per cent	RA	Per cent	RA	Per cent	RA	Per cent	RA	Per cent
<i>Antheophora pubescens</i>	16,8	12,3	13,9	5,0						
<i>Aristida adscensionis</i>	9,4	6,9	14,3	5,1	19,5	10,5			77,5	10,8
<i>Asphenatherum glaucum</i>					17,2	9,3				
<i>Chloris virgata</i>							47,9	4,7		
<i>Cynodon dactylon</i>							65,6	6,4	42,8	6,0
<i>Enneapogon scaber</i>	38,5	28,0	81,6	29,0	56,9	30,8			46,0	6,4
<i>Eragrostis nindensis</i>	15,3	11,1	70,4	25,1	27,5	14,9	31,8	3,1	100,7	14,0
<i>Eragrostis trichophora</i>							91,7	9,0	54,2	7,6
<i>Schmidtia kalahariensis</i>	39,8	28,9	26,4	9,4			326,4	31,9	158,1	22,0
<i>Stipagrostis hirtigluma</i>					9,2	5,0				
<i>Stipagrostis hochstetterana</i>	8,1	5,9					52,1	5,1		
<i>Stipagrostis uniplumis</i>			52,1	18,6	43,7	23,6	267,3	26,2	181,0	25,2
Others*	9,5	6,9	22,2	7,9	11,0	5,9	139,1	13,6	57,4	8,0
Total	137,6	100,0	281,1	100,0	185,0	100,0	1 021,9	100,0	717,7	100,0

\*Number of species: July 1975 = 11, October 1975 = 7, December 1975 = 7, March 1976 = 21, July 1976 = 19

TABLE 5: Relative availability of grasses and forbs in rock hyrax habitat on the farm Warmfontein no. 280, Keetmanshoop District. Percentages are relative to grasses and forbs as a group.

SPECIES	SURVEY									
	July 1975		October 1975		December 1975		March 1976		July 1976	
	RA	Per cent	RA	Per cent	RA	Per cent	RA	Per cent	RA	Per cent
<i>Antheophora pubescens</i>	64,7	12,7	21,6	4,8	28,2	17,5	170,6	9,2	109,0	7,3
<i>Aristida adscensionis</i>							124,9	6,9	135,4	9,0
<i>Cleome oxyphylla</i>	25,6	5,0	21,4	4,8	23,0	14,3				
<i>Cucumis sagittatus</i>	20,3	4,0								
<i>Enneapogon cenchroides</i>	55,7	11,0					76,4	4,1		
<i>Enneapogon scaber</i>	97,0	19,1	84,9	18,9	56,5	35,1	148,6	8,0	169,9	11,3
<i>Eragrostis nindensis</i>	18,5	3,6					92,8	5,0	67,6	4,5
<i>Eragrostis trichophora</i>							68,7	3,7	55,6	3,7
<i>Panicum arbusculum</i>	36,1	7,1	15,1	3,4	9,0	5,6	72,2	3,9		
<i>Rhynchelytrum villosum</i>							473,0	25,5	163,1	10,9
<i>Schmidtia kalahariensis</i>	32,7	6,4	33,8	7,5			103,4	5,6		
<i>Stipagrostis uniplumis</i>	118,9	23,4	242,5	5,5	33,9	21,0	207,0	11,2	468,4	31,2
<i>Trichodesma africanum</i>							121,9	6,6	100,9	6,7
Others*	38,4	7,6	29,4	6,5	10,4	6,4	268,3	14,5	233,4	15,5
Total	508,0	100,0	448,8	100,0	160,9	100,0	1 851,4	100,0	1 503,3	100,0

\*Number of species: July 1975 = 9, October 1975 = 7, December 1975 = 6, March 1976 = 18, July 1976 = 16

#### 4 RESULTS AND DISCUSSION

Relative food availabilities for all strata of the vegetation are presented in Tables 2 (Sandmodder) and 3 (Warmfontein). To limit the size of the tables and to facilitate interpretation of the results, all species with a relative percentage availability of 3,0 per cent or less were placed in the category "others". Grasses and forbs con-

tributed a very small percentage to total availability especially at Sandmodder with the result that the species composition for this stratum is not reflected in Tables 2 and 3. They are thus presented separately in Tables 4 (Sandmodder) and 5 (Warmfontein) in which the percentages are relative to grasses and forbs only. All species with a value of 3,0 per cent or less were again placed in the category "others".



#### 4.1 Sampling error

As the primary objective of the surveys was simply to determine relative food availability for comparison with the diet of the rock hyrax, no attempt was made to elucidate seasonal fluctuations in terms of environmental factors. In assessing the technique used, some aspects of the fluctuations are nevertheless worthy of further scrutiny. It is improbable that the availability of grasses and forbs can increase from the end of one wet season to the start of the next unless significant quantities of rain have fallen. Significant rainfall was not recorded from July to December in 1975, yet some of the species listed in Tables 4 and 5 show increases in availability. Indeed, the total availability of grasses and forbs shows increases in some cases. These increases must be attributed to sampling error.

Woody plants, on the other hand, can increase in availability in the absence of rain. When temperatures rise in the transition period, some trees and shrubs experience regrowth and some of them bloom at this time, presumably because sufficient moisture remains in the soil from the previous wet season. Possibly only the larger species, or those growing in or near the watercourses, whose roots have access to water, will be able to exhibit regrowth. As the dry season progresses, however, and temperatures rise, the soil dries out and the whole environment becomes extremely arid. Some of the above species can then be expected to show a decline (lose their leaves a second time) toward December due to increasing climate adversity, while others can be expected to increase (continue growing) towards December *in spite of* increasing climate adversity. However, some of the species listed in Tables 2 and 3 exhibit unexpected increases in availability in this period. For example, *Ziziphus mucronata* (Table 2) increases from October 1975 to December 1975 from 21 029,7 units per ha to 40 760,5 units per ha, and in Table 3 *Acacia mellifera* and *Cadaba aphylla* increase from October to December, *Catophractes alexandri* increases from July to October but declines again from October to December and *Rhigozum trichotomum* increases from July to October. These fluctuations are indicative of sampling error.

A further sampling error characteristic of the results is differential rates of decline in availability. The *relative percentage* availability of a species (particularly grasses and forbs) may increase due to material being removed through utilisation and other causes at a slower rate than the removal from other species. It is also possible that a species with a high rate of decline will reach a low percentage early in the dry season or may decline to such an extent that it is not recorded in the survey. Some species, however, are not recorded in one season and then reappear later, sometimes in large quantities. Examples are *Ozoroa namaensis* (Table 3) which was not recorded in July 1975 but appeared as a sizeable quantity in October and thereafter (it was recorded in

December 1975 but was less than 3,0 per cent); and *Parkinsonia africana* (Table 3) which was not recorded from July to December 1975, appeared in March 1976 and was not recorded in July 1976. A further example is *Asthenatherum glaucum* (Table 4) which was not recorded in July 1975 and March 1976 but recorded in the other surveys (less than 3,0 per cent in October 1975 and July 1976). In December 1975 it constituted 9,3 per cent of the availability of grasses and forbs (17,2 units per ha).

#### 4.2 Density as a possible source of error

The density of trees and shrubs is an important component of the formula used to calculate relative availability. Density proportion (DP) for each species (see 3.4 – formula 3) is directly dependent upon total density (T). Total density (3.3.2) was determined by counting *all* woody plants in circles with predetermined radii, irrespective of their size.

The density values in Table 6 exhibit considerable variation (at Sandmodder Standard Deviation (SD) = 343,37 and Coefficient of Variation (CV) = 22,33 per cent; at Warmfontein SD = 204,9 and CV = 10,72 per cent). This may be caused by sampling error or by fluctuations in the numbers of woody plants due to environmental influences such as an increase in the seedlings of woody plants during the wet season which would have been included in the tallies. The density values were correlated with an environmental parameter reflecting adversity of conditions for the maintenance of plant growth, which for lack of more suitable climatic data, was compiled from rainfall, temperature and humidity as follows:

$$C = \frac{E-R}{T_x}$$

where

C = monthly climatic adversity index in mm per degree C per month

E = mean monthly evaporation in mm measured at Keetmanshoop

R = monthly rainfall recorded at Na-Os or Warmfontein during the period of study

T<sub>x</sub> = mean daily maximum temperature for the month recorded at Keetmanshoop

The hypothesis was that the density value at any given time is influenced by the prevailing environmental conditions of the preceding period following the last seasonal change. Mean values of C for the periods May to July 1975, August to October 1975, November to December 1975, January to April 1976 and May to July 1976 were therefore calculated and are compared graphically with the density values from Table 6 in Fig. 3. Significant negative correlations were found for both sets of data: For Sandmodder  $r = -0,988$  ( $t = -11,101$ ;  $df = 3$ ;  $p < 0,01$ ), while for Warmfontein  $r = -0,895$  ( $t = -3,482$ ;  $df = 3$ ;  $p < 0,05$ ). It is thus concluded that the

variation in density is mainly due to environmental factors and that the density data are not an important source of sampling error.

TABLE 6: Densities (per ha) of woody plants in rock hyrax habitat.

SURVEY TIME	DENSITY	
	Sandmodder no. 73	Warmfontein no. 280
1975:		
July	1 564	2 013
October	1 315	1 647
December	1 134	1 764
1976:		
March	2 036	2 160
July	1 638	1 976
Mean	1 537	1 912

LEGEND:

- Density at Sandmodder no. 73
- ..... Density at Warmfontein no. 280
- Climatic adversity for Na-Os
- .-.- Climatic adversity for Warmfontein

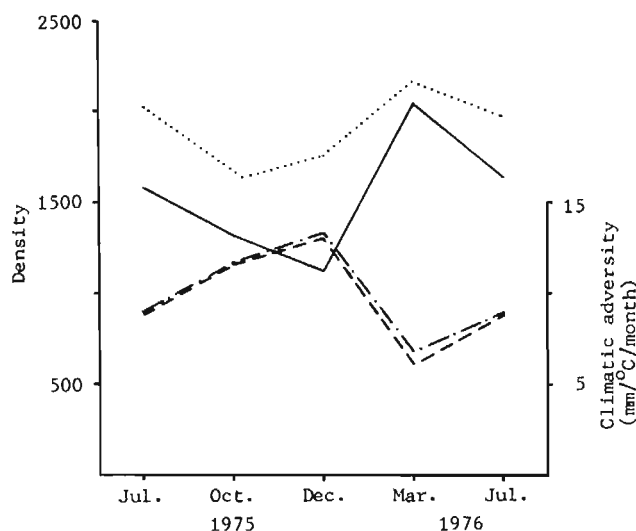


FIGURE 3: Density of woody plants per ha compared with mean climatic adversity,  $C=(E-R)/T_x$ , calculated from rainfall recorded at Na-Os and Warmfontein, Keetmanshoop District.

#### 4.3 Other sources of error

Although the pace transects always started from the same point and ended at the same point, it was impossible to place the point-centres at exactly the same spot each time the survey was repeated. Trampling of the point-site by the investigator and his assistant, although unavoidable, was a problem in any case with the result that the exclusion criteria were not always applicable to exactly the same individual trees and shrubs. A specific

individual might therefore be included and measured during one survey and excluded during the next and so on.

The method used to sample the grasses and forbs is also open to criticism. At Sandmodder in particular the grasses form a mosaic and species such as *Stipagrostis uniplumis* and *Asthenatherum glaucum* grow in patches. The randomly dropped rod may therefore fall within a patch of one of these species during one of the surveys but miss the patch during the next survey, particularly if the pace transect passes the edge of the patch. Needless to say, a single large tuft of, for example, *Stipagrostis uniplumis* may contribute significantly to BV during a single survey.

#### 4.4 Characteristics of the availability pattern

##### 4.4.1 Dwarf shrubs, grasses and forbs

At Sandmodder grasses and forbs contribute less than one per cent to availability in all seasons, while at Warmfontein they contribute from 1,5 per cent to 12,3 per cent. The difference between two study areas is due to the large number of trees and shrubs in the riparian thicket at Sandmodder. Both study areas most certainly can support a population of predominantly browsing animals such as rock hyrax.

The dwarf shrub species (e.g. *Petalidium linifolium*, *Barleria* spp., *Rhigozum trichotomum*, *Monechma spartioides* and *Hermannia* spp.) to which the vegetation type owes its name (Giess, 1971) also contribute a low proportion. None of the species listed in Table 2 are dwarf shrubs and those species recorded are all included in the category "Others" which varies from 0,7 per cent to 4,0 per cent. In Table 3 only one of the species listed (*Rhigozum trichotomum*) can be classified as a dwarf shrub species. In this case the category "Others" contributes more to total availability (7,4 per cent to 16,5 per cent) than is the case at Sandmodder, which is due to the larger number of dwarf shrubs in the scree community at Warmfontein.

##### 4.4.2 Wet season availability

Availability in both strata shows a distinct peak in March 1976. The above average rainfall of the 1976 wet season affected availability in the subsequent cool dry season (July 1976) in two ways:

- (1) Total availability for trees and shrubs as well as grasses and forbs for July 1976, although lower than March 1976, was higher than in all other surveys (Tables 2 to 5).
- (2) Forbs and annual grass species which were hitherto not recorded at either of the study areas made their appearance or were recorded in the survey in March

1976. The annual grass *Rhynchelytrum villosum* suddenly appeared in large quantities in the sampling area at Warmfontein where it comprised 25,5 per cent of the availability of grasses and forbs as a group (Table 6); in July 1976 it persisted and comprised 10,9 per cent. This species contributed significantly to the high percentage of grasses and forbs as a group for these two surveys (8,9 per cent and 12,3 per cent respectively) recorded in Table 6.

#### 4.4.3 Diversity

The numbers of species recorded for each of the two strata at Sandmodder and Warmfontein are represented in Fig. 4 and the SD and CV of each of the four series are presented in Table 7. The number of grasses and forbs at both study areas varies (fluctuates) considerably more than the number of woody species, because many forb species and annual grasses dry out completely during the dry season and are either blown away or

TABLE 7: Variation in the numbers of species recorded during five vegetation surveys in rock hyrax habitat.

Vegetation locality and stratum	Standard deviation	Per cent coefficient of variation
Sandmodder no. 73:		
Trees and shrubs	1,30	5,70
Grasses and forbs	7,16	36,91
Warmfontein no. 280:		
Trees and shrubs	1,80	5,98
Grasses and forbs	7,52	39,58

#### LEGEND:

- Woody plants Sandmodder no. 73
- Woody plants Warmfontein no. 280
- - - Grasses and forbs Sandmodder no. 73
- ..... Grasses and forbs Warmfontein no. 280

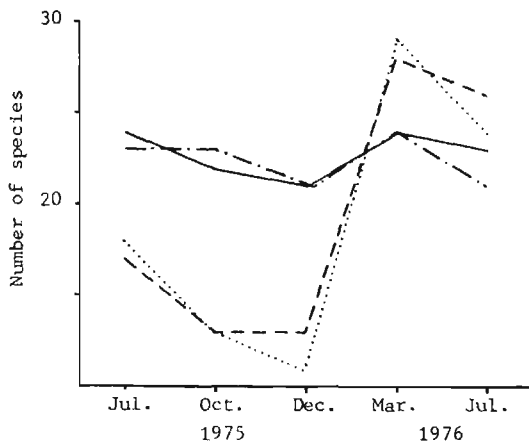


FIGURE 4: Number of species of woody plants (trees and shrubs) and grasses and forbs recorded during vegetation surveys in rock hyrax habitat.

trampled into fragments by livestock. These ephemeral species are then unavailable for all practical purposes for most of the year, but reappear again in the wet season. This wet season diversity does not, however, drastically change the overall structure of herbage availability.

## 5 CONCLUSIONS

Due to sampling error the survey technique used is unsuitable for determining the relative food availability of the most infrequently encountered trees, shrubs and grasses with large dimensions. The common trees and shrubs were nevertheless adequately sampled and the results can be used for determining food preferences by comparison with the diet of the rock hyrax. It is suggested for the benefit of future workers that the technique may be improved by using a different sampling method such as a series of fixed belt transects. The grasses and forbs could be measured at fixed intervals on one side of the belt transect which would obviate the problem of trampling by the investigator. Belt transects would also allow easier data processing.

The dwarf shrubs which characterise the dwarf shrub savanna veld-type (Giess, 1971) and grasses and forbs contribute small amounts to total herbage availability at both study areas and the habitat is suitable for browsers. Hoeck (1975) found that most of the available biomass in kopje habitat in the Serengeti National Park consisted of browse. This is relevant to the hyrax problem as a considerable amount of the total resource is unavailable to sheep. Peaks in herbage availability occur in all strata of the vegetation in the wet season. Above average rainfall caused higher availability in the succeeding dry season to which annuals contributed a significant proportion. In the more open hyrax habitat at Warmfontein the above average rainfall was beneficial to grazers.

## 6 ACKNOWLEDGEMENTS

The contents of this paper formed part of a thesis submitted to the University of Pretoria by the senior author for the degree M.Sc. (Wildlife Management). The study supervisors, Prof J. du P. Bothma (Department of Zoology) and Prof G. K. Theron (Department of Botany), are thanked for their valuable guidance and criticism. Prof Theron played a major role in the development of the technique. Mr Friedl Burger was largely responsible for data capture on the computer and, together with Messrs Willem Ulungu and Matias Ndjoua, helped with all phases of the field work.

The then Director of Nature Conservation, Mr B. J. G. de la Bat, is thanked for allowing the senior author to

submit the work as part of a thesis and the Acting Director, Mr P. S. Swart, is thanked for allowing publication of this paper. The Assistant Director (Research), Dr Eugene Joubert, is thanked for his advice and criticism.

To Mr S. W. Redecker of the Roads Department we are indebted for the many evenings he spent compiling the computer programmes. Miss A. Eggers of the Department of Water Affairs assisted with the programmes when Mr Redecker was unable to do so. The Director of Roads is thanked for permission to use his Department's computer.

Messrs Mike Müller and Willie Giess identified the plant specimens collected during the course of the study. Mr J. C. Maré of the Weather Bureau in Windhoek supplied all the climatic data presented in this report.

## 7 REFERENCES

- ANDERSON, G. D. and WALKER, B. H.  
1974: Vegetation composition and elephant damage in the Sengwa Wildlife Research Area, Rhodesia. *J. Sth. Afr. Wildl. Mgmt. Ass.* 4:1–14.
- BARNES, D. L.  
1976: A review of plant-based methods of estimating food consumption, percentage utilization, species preferences and feeding patterns of grazing and browsing animals. *Proc. Grassld. Soc. Sth. Afri.* 11:65–71.
- BOROWSKI, S. and KOSSAK, S.  
1972: The natural food preferences of the European bison in seasons free of snow cover. *Acta Theriol.* 17:151–169.  
1975: The food habits of deer in the Bialowieza Primeval Forest. *Acta Theriol.* 20:436–506.
- CASEBEER, R. L. and KOSS, G. G.  
1970: Food habits of wildebeest, zebra, hartebeest and cattle in Kenya Masailand. *E. Afr. Wildl. J.* 8:25–36.
- COTTAM, G. and CURTIS, J. T.  
1956: The use of distance measures in phytosociological sampling. *Ecology* 37:451–460.
- DE GRAAF, G., SCHULTZ, K. C. A. and VAN DER WALT, P. T.  
1973: Notes on rumen contents of Cape Buffalo (*Syncerus caffer*) in the Addo Elephant National Park. *Koedoe* 16:45–58.
- DIRSCHL, A. J.  
1963: Food habits of the pronghorn in Saskatchewan. *J. Wildl. Manage.* 27:81–93.
- EASTMAN, D. S. and JENKINS, D.  
1970: Comparative food habits of red grouse in northeast Scotland using faecal analysis. *J. Wildl. Manage.* 34:612–620.
- FIELD, C. R.  
1970: A study of the feeding habits of the hippopotamus in the Queen Elizabeth National Park, Uganda, with some management implications. *Zool. Afr.* 5:71–86.  
1972: The food habits of wild ungulates in Uganda by analyses of stomach contents. *E. Afr. Wildl. J.* 10:17–42.
- FLINDERS, J. T. and HANSEN, R. M.  
1972: Diets and habitats of jackrabbits in Northeastern Colorado. *Range Science Department Science Series no. 12, Colorado State University*: 29pp.
- GALT, H. D., THEURER, B., EHRENREICH, J. H., HALE, W. H. and MARTIN, S. C.  
1969: Botanical composition of diets of steers grazing a desert grassland range. *J. Range Manage.* 22:14–19.
- GIESS, W.  
1971: A preliminary vegetation map of South West Africa. *Dinteria* 4:1–114.
- GUY, P. R.  
1976: The feeding behaviour of elephant (*Loxodonta africana*) in the Sengwa Area, Rhodesia. *S. Afr. J. Wildl. Res.* 6:55–63.
- HARLOW, R. F., WHELAN, J. B., CRAWFORD, H. S. and SKEEN, J. E.  
1975: Deer foods during years of oak mast abundance and scarcity. *J. Wildl. Manage.* 39:330–336.
- HEADY, H. F. and TORELL, D. T.  
1959: Forage preferences exhibited by sheep with oesophageal fistulas. *J. Range Manage.* 12:28–34.
- HOECK, H. N.  
1975: Differential feeding behaviour of the sympatric hyraxes *Procavia johnstoni* and *Heterohyrax brucei*. *Oecologia (Berl.)* 22:15–47.
- JOYAL, R.  
1976: Winter foods of moose in La Vérendrye Park, Québec: an evaluation of two browse survey methods. *Can. J. Zool.* 54:1756–1770.
- KOSSAK, S.  
1976: The complex character of the food preferences of Cervidae and phytocenosis structure. *Acta Theriol.* 21:359–373.
- LENSING, J. E.  
1979: *Feeding habits of the rock hyrax, Procavia capensis (Pallas, 1766), in southern South West Africa*. M.Sc. thesis. University of Pretoria.
- LEUTHOLD, B. M. and LEUTHOLD, W.  
1972: Food habits of giraffe in Tsavo National Park, Kenya. *E. Afr. Wildl. J.* 10:129–141.
- McALLISTER, H. J. and BORNMAN, C. H.  
1972: Grazing preferences of impala. A quantitative faecal analytical and anatomical evaluation. *Trans. Roy. Soc. S. Afr.* 40:167–185.
- NEWBOULD, P. J.  
1967: *Methods for estimating the primary production of forests*. IBP Handbook no. 2. Blackwell Scientific Publications, Oxford. 60 pp.
- NIXON, C. M., McCLAIN, M. W. and RUSSEL, K. R.  
1970: Deer food habits and range characteristics in Ohio. *J. Wildl. Manage.* 34:870–886.
- PEARSON, H. A. and STERNITZKE, H. S.  
1976: Deer browse inventories in the Louisiana coastal plain. *J. Wildl. Manage.* 40:326–329.
- PEDEN, D. G.  
1976: Botanical composition of bison diets on shortgrass plains. *Am. Midl. Nat.* 96:225–229.
- PETRIDES, G. A.  
1975: Principal foods versus preferred foods and their relations to stocking rate and range condition. *Biol. Conserv.* 7:161–169.
- ROOS, J. H., RETHMAN, N. F. G. and KOTZE, G. D.  
1973: Preliminary results on species selection by animals on sour grassveld. *Proc. Grassld. Soc. Sth. Afr.* 8:77–81.
- RUTHERFORD, M. C.  
1979a: Plant-based techniques for determining available browse and browse utilization: a review. *Bot. Rev.* 45:203–228.  
1979b: Aboveground biomass subdivisions in woody species of the savanna ecosystem project study area, Nylsvley. *S. Afr. National Scientific Programmes Report no. 36*: 29 pp.

- SCHWARTZ, C. C. and NAGY, J. G.  
1976: Pronghorn diets relative to forage availability in North-eastern Colorado. *J. Wildl. Manage.* 40:469—478.
- SCOTCHER, J. S. B., STEWART, D. R. M. and BREEN C. M.  
1978: The diet of the hippopotamus in Ndumu Game Reserve, Natal, as determined by faecal analysis. *S. Afr. J. Wildl. Res.* 8:1—11.
- SPARKS, D. R.  
1968: Diet of black-tailed jackrabbits on sandhill rangeland in Colorado. *J. Range Manage.* 24:203—208.
- STODDART, D. M.  
1967: A note on the food of the Norway lemming. *J. Zool. Lond.* 151:211—213.
- TELFER, E. S.  
1972: Browse selection by deer and hares. *J. Wildl. Manage.* 36:1344—1349.
- TURKOWSKY, F. J.  
1975: Dietary adaptability of the desert cottontail. *J. Wildl. Manage.* 39:748—756.
- VAN DYNE, G. M. and HEADY, H. F.  
1965: Botanical composition of sheep and cattle diets on a mature annual range. *Hilgardia* 36:465—492.
- WALKER, B. H.  
1976: An approach to the monitoring of changes in the composition and utilization of woodland and savanna vegetation. *S. Afr. J. Wildl. Res.* 6:1—32.
- WALTER, H.  
1973: *Vegetation of the Earth in relation to climate and the eco-physiological conditions*. Springer Verlag. New York.