Feeding strategy of the rock hyrax and its relation to the rock hyrax problem in southern South West Africa

by

J.E. Lensing *

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

Received: 7 April 1982
Accepted: 15 October 1982

*Present address:
Vrolijkheid Nature Conservation Station
Private Bag 614
Robertson
6705
Republic of South Africa

ABSTRACT

A study of the diet and food preferences of the rock hyrax was conducted on rangeland in southern South West Africa in response to complaints by Karakul sheep farmers that the species was competing with livestock for grazing. The botanical composition of the diet was quantitatively determined by analysing stomach contents using leaf epidermis anatomy to identify Monocotyledons and gross morphology to identify Dicotyledons. The diversity of the diet and the role of moisture content in the selection of forage species is examined. Food preferences were determined by comparing the relative availability of herbage species with principal foods. The results show that the rock hyrax is an intermediate, opportunistic feeder. An evaluation of the hyrax problem indicates that a small proportion (estimated at about one per cent) of the potential agricultural yield of the study areas is lost annually.

CONTENTS

1 INTRODUCTION

In the arid regions of the Cape Province of South Africa and in southern South West Africa where extensive sheep farming is practised, the rock hyrax, *Procavia capensis* (Pallas 1766) (*Hyracoidea: Procaviidae*), occurs commonly in mountainous and rocky terrain. This animal has been the cause of concern to farmers because it is said to compete with sheep for forage in the sparse vegetation characteristic of these areas and in South West Africa the species is a proclaimed problem animal in accordance with the provisions of the Nature Conservation Ordinance, no. 4 of 1975.

As early as 1946 an increase in the hyrax population in the Cape Midlands was documented by Thomas (1946). He stated that this increase was caused by the extensive predator control programmes (jackal-proof fencing etc.) which became effective at the time and that hyrax "pick out the best grazing ... and eat everything before them." The Department of Nature and Environmental Conservation of the Cape Provincial Administration subsequently initiated research on the hyrax (Hanse 1962) and various reports were produced. Several aspects were dealt with including a general study of the problem (Hanse 1962), reproduction (Millar 1971, Millar and Glover 1970 and Millar and Glover 1973), reproductive physiology (Millar 1972 and Millar and Fairall 1976) and a description of a light-shielding structure in the eye of the rock hyrax (Millar 1973). However, no attempt has been made to define the problem precisely and its extent in the Cape Province has not been studied.

Although several species of hyrax occur in East Africa, all of which have received attention from biologists, no mention is made in the literature of their being a threat to farming activities. Reports have been published on research conducted into the feeding of hyrax in East Africa by Coe (1962), Sale (1965a, 1965b and 1966), Turner and Watson (1965) and Hoeck (1975). These results have provided useful background information pertinent to the Southern African problem.

An assessment of the extent of the hyrax problem in South West Africa from a farmer-questionnaire survey (Lensing and Joubert 1977) indicated that the problem is localised and does not occur to any appreciable extent north of 26°S. It is strictly limited to mountainous areas, namely the Karas Mountains, the Schwarzrand and the escarpment.

The present study was aimed at defining and evaluating the hyrax problem (sic) in southern South West Africa by investigating the species' feeding habits. The large numbers of hyrax present enabled a population sample to be collected which made it possible to employ the technique of stomach content analysis. Stomach content and faecal analysis was pioneered by Baumgartner and Martin (1939) and Dusi (1949) and stomach content analysis has since become a popular technique for ascertaining the diet of herbivores (e.g. Martin 1955, Chapman 1957, Hewson 1962, Carleton 1966, Hayden 1966, Sparks 1968, Field 1970 and 1972 and Turkowsky 1975). It has also been used by South African workers for a variety of species (e.g. Bigalke 1972, Liversidge 1972, De Graaf, Schulz and Van der Walt 1973, Hall-Martin 1974 and Wilson, Hirst and Ellis 1977) but, as far as can be ascertained, not for rock hyrax.

This paper is the third in a series of three, the first and second of which (Lensing 1980 and Lensing and Le Roux 1982) respectively described the abaxial leaf epidermis anatomy of the Monocotyledon species encountered in the study and the technique used to determine relative herbage availability. It describes the results of the stomach content analyses and the food preferences of the rock hyrax.

2 STUDY AREAS AND METHODS

2.1 Study areas

Almost the whole of the Groot Karas Mountains, where the study was conducted, is utilised for extensive stock farming. Due to a lack of arable land, crop farming is not practised and the main product is Karakul pelts. Farms vary in size from approximately 4 000 ha to over 15 000 ha. Landowners keep large flocks of Karakul sheep and many farmers also keep small flocks of goats and dorper sheep. Farms are well-fenced with jackal-proof fencing and rotational grazing systems are in use.

The locality, climate and vegetation of the two study areas, the farms Sandmodder no. 73 (26° 57′S; 18° 55′E) and Warmfontein no. 280 (27° 7′S; 19° 15′E), Keetmanshoop District, southern South West Africa have been adequately described in previous papers (Lensing 1980 and Lensing and Le Roux 1982). Both farms were selected because of their high density hyrax population and because they represent the most typical hyrax habitat of the region.

2.2 Materials and methods

2.2.1 Population sampling

At Sandmodder monthly population sampling was conducted from March 1975 to July 1976 from the more or less continuous hyrax population along the Leeu River which traverses the farm in a ravine. Sampling commenced at a ford in the river opposite the homestead and was continued progressively upstream each month up to the confluence of the tributaries of the Leeu River, namely the Klip-Gosub and Sand-Gosub. At Warmfontein a similar system was applied, sampling being conducted progressively along the low rocky ridges on either side of a dry, sandy watercourse running parallel to the main road between Narubis and Aroab. By sampling in a different locality each month possible bias in the sample caused by the effects of certain individuals becoming wary of gunfire was avoided. However, possible subpopulation differences could not be avoided.

A 0,22 Magnum rifle fitted with a 3 × to 9 × telescope was used to collect the animals. The randomness of the sample was ensured by selecting animals according to random numbers which indicated their positions relative to an arbitrarily chosen reference point on the cliff face or ridge.

Sampling commenced 40 to 50 minutes after sunrise after or during the morning feeding period (Sale 1965a, Turner and Watson 1965 and Hoeck 1975) and after five animals had been shot they were retrieved. The investigator then either remained at the same place or moved to a new position and continued sampling until 10 animals had been collected. This procedure was repeated for four days every month at each study area. Sometimes, however, adverse weather conditions made it impossible to collect 10 animals.

2.2.2 Composite samples

The stomach contents of each animal were removed, their wet mass determined and placed in an F.A.A. solution. Composite samples were prepared by placing the first 10 samples collected or as many as were available for each month in a single plastic container with a tight-fitting snap-on lid. The F.A.A. was not poured off. The wet masses of the composite samples were determined to the nearest 25g.

2.2.3 Size of aliquot samples (pilot analysis)

In Tables 1 and 2 the number of samples comprising each monthly composite sample, their mean wet mass as well as the wet mass of each composite sample are presented. Using the two smallest monthly composite samples (June 1975 from Sandmodder and March 1975 from Warmfontein), the validity of aliquot samples was tested by extracting eight aliquot samples (each theoretically equivalent to one quarter of one average hyrax stomach content) and progressively washing them through a series of sieves (see below) until analysis by dry mass was practicable. The number of aliquots required in both cases was thus determined to be four. The first four and second four aliquots from each study area were then analysed according to the methods described below (Tables 3 and 4) and the results compared by means of a χ^2-test for two independent samples (Siegel 1956). The masses of the unidentified material were excluded from the tests.

TABLE 1: Numbers of samples comprising composite samples of rock hyrax stomach contents from Sandmodder.

Month	Samples	Wet mass of stomach contents		Composite sample mass	Aliquot sample mass
		Mean	n		
1975:					
March	10	109	10	3 000	600
April	10	116	9	3 150	630
May	6	83	6	1 500	429
June	8	50	6	1 900	475
July	10	111	10	2 900	580
August	10	82	10	1 950	390
September	10	52	10	2 550	510
October	4	93	4	1 600	800
November	5	121	5	1 450	580
December	3	174	3	1 300	867
1976:					
January	4	120	4	1 450	725
February	4	148	4	1 450	725
March	10	93	10	2 300	460
April	10	140	10	3 050	610
May	10	52	8	1 500	300
June	10	103	10	2 600	520
July	10	76	10	2 100	420

TABLE 2: Numbers of samples comprising composite samples of rock hyrax stomach contents from Warmfontein.

Month	Samples	Wet mass of stomach contents		Composite sample mass	Aliquot sample mass
		Mean	n		
1975:					
March	10	70	8	3 250	650
April	10	72	10	2 550	510
May	10	127	10	2 600	520
June	8	102	8	2 400	600
July	8	112	6	2 550	638
August	10	108	10	2 300	460
September	10	144	10	4 000	800
October	5	134	5	1 750	700
November	4	73	3	1 250	625
December	6	158	6	2 000	667
1976:					
January	9	114	9	2 250	500
February	2	151	1	550	550
March	10	205	10	4 100	820
April	10	118	10	2 850	570
May	10	92	10	2 100	467
June	10	74	10	2 400	480

TABLE 3: Results of a pilot analysis of the Sandmodder June 1975 composite rock hyrax stomach content sample.

Category	Mass (g) or count*	
	Samples 1 to 4	Samples 5 to 8
Unidentified	5,843	7,348
Dicotyledon stems	0,069	0,088
Dicotyledon fragments:	0,479	0,592
Acacia mellifera	0,437	0,564
Rhigozum obovatum	trace†	0
Ziziphus mucronata	0,042	0,028
Monocotyledon fragments:	0,021	0,012
Enneapogon scaber	8	14
Stipagrostis ciliata	4	0
Trachyandra arvensis	2	4

* Fragment count (applicable to Monocotyledon species but not Monocotyledon fragments as a group).
† Dry masses less than 0,001 g.

TABLE 4: Results of a pilot analysis of the Warmfontein March 1975 composite rock hyrax stomach content sample.

Category	Mass (g) or count*	
	Samples 1 to 4	Samples 5 to 8
Unidentified	12,057	5,458
Dicotyledon stems	0,525	0
Dicotyledon fragments:	4,229	5,056
Acacia mellifera	4,065	4,986
Boscia albitrunca	0	0,003
Grewia tenax	0,008	0
Hermannia tomentosa	0	0,007
Maytenus linearis	0,043	0,014
Rhigozum obovatum	0,048	0
Solanum burchelli	0,043	0,046
Withania somnifera	0,022	0
Monocotyledon fragments:	trace†	trace
Trachyandra arvensis	11	3

* Fragment count (applicable to Monocotyledon species but not Monocotyledon fragments as a group).
† Dry masses less than 0,001 g.

The results showed no significant difference: for Sandmodder $\chi^2 = 0{,}01$ at $p > 0{,}05$ and for Warmfontein $\chi^2 = 0{,}47$ at $p > 0{,}05$, proving that an aliquot sample equivalent in mass to one average stomach content was adequate for analysis. Since the aliquots were taken from the smallest composite samples, it was assumed that equivalent pro-rata aliquots would be adequate for all other composite samples. However, because of the small amounts of material retained by the sieves the aliquots extracted for the analyses were doubled. The wet masses (including fluid) of these samples are presented in the fourth column of Tables 1 and 2.

2.2.4 The use of sieves

Fragments too small to identify were arbitrarily excluded by washing each sample through a series of sieves, the smallest of which had a mesh size of 3,36 mm. Two larger sieves (5,60 mm and 6,70 mm) were added to the stack to facilitate sorting. In analyses of pronghorn antelope (*Antilocapra americana*) rumen contents containing eight categories of food plants Dirschl (1962) used sieves with mesh sizes of 2,83 mm, 4,0 mm and 5,66 mm. He showed that the dry mass proportion of each category on one sieve did not differ from the proportions on any of the other sieves, indicating that the use of sieves did not cause a loss of accuracy or introduce bias. He also showed that the larger the mesh, the less time was required for the manual separation of the fragments retained by the sieve.

2.2.5 Analysis procedure

The material passing through the sieves was caught up in a fine linen handkerchief and its dry mass determined on an analytical balance. The contents of each of the sieves was placed in a tray with a little water and manually sorted into the following categories:

1 Dicotyledon stems: Fragments of stems with insufficient leaves attached to be indentifiable.
2 Monocotyledon stems, flowers etc: No attempt was made to identify Monocotyledon stems unless a piece of leafblade was attached. Grass flowers and seeds were also placed in this category.
3 Monocotyledon (leaf) fragments.
4 Dicotyledon fragments (including stem fragments with sufficient leaf material attached to be identifiable).

The dry mass of each of the first three categories was determined and the Monocotyledon fragments were counted. If there were less than 100, they were bulk-stained in a two per cent aqueous solution of Safranin "O" using the method described by Liversidge (1970). Thereafter each fragment was scraped, mounted in glycerine on a microscope slide and identified according to the method and key described by Lensing (1980). If there were more than 100 fragments, they were placed in a 500 ml round, wide-necked container half-filled with water and a sample of 100 randomly extracted by stirring the water and catching up a few fragments at a time on a piece of window gauze. The sample was then stained, scraped, mounted and identified as described above.

The Dicotyledon fragments (category 4 above) were identified macroscopically as far as possible using a catalogue of herbarium specimens and a collection of "wet" samples in F.A.A. The unidentified fragments were sorted in two categories, namely fragments unidentifiable due to their small size and not recognised (therefore unknown) fragments, and their dry masses determined.

Non-food items such as the slimy stomach lining of the hyrax, hair, tapeworms and even a feather were rejected.

3 RESULTS

The dry masses for each monthly aliquot sample were firstly grouped as follows:

1 Not retained (by sieves): Material caught up in the handkerchief.

2 Retained (by sieves): Divided into two groups:
   (a) Total Monocots: All Monocotyledon material, whether identified or not and expressed as a percentage of "Retained".
   (b) Total Dicots: The same as for "Total Monocots".

The "Retained" category was then regrouped into the following categories:

1 Unclassified: Material lacking in sufficient diagnostic characters to be identified. The following categories were included:
   (a) Monocot stems etc.: Monocotyledon flowers, seeds and stems without leaves.
   (b) Dicot stems: Dicotyledon stems without leaves.
   (c) Dicots too small: Dicotyledon fragments too small to identify.

2 Classified: Identifiable material retained by the sieves. Divided into the following categories:
   (a) Monocots: Listed as species categories and unrecognised fragments (unknown).
   (b) Dicots: The same as for " Monocots".

It was assumed that the proportions of food items in classified material are the same as the proportions in the material that is too small to identify or otherwise lacking in sufficient diagnostic characters. To prevent distortion of the proportions in the list of food items, the species categories and unknowns were expressed as percentages of the total classified material. The results are presented in Tables 5 and 6. Dry masses of less than 0,001 g under the classified category are represented as a trace and species or unknowns comprising 3,0 per cent or less are lumped in a category termed "others". Monocotyledon species are presented as a single category because they occurred in small quantities in most months.

To allow comparison with relative food availability the monthly analyses were grouped into the four seasons defined by Lensing and Le Roux 1982) and are presented in Tables 7 and 8:

Wet season:	February to end April
Cool dry season:	May to end August
Transition period:	September to mid-October
Hot dry season:	Mid-October to end January

In the latter tables the various Monocotyledon species are represented by fragment counts from which percentages of the total classified material were derived except where Monocotyledons as a group comprise 3,0 per cent or less.

TABLE 5: Results of analyses of monthly aliquot samples of rock hyrax stomach contents from the farm Sandmodder No. 73, Keetmanshoop District, South West Africa for the period March 1975 to July 1976.

Category	March		April		May		June		July		August		September		October		November		December		January		February		March		April		May		June		July	
	Mass*	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent
Not retained	18,099		14,512		20,125		14,885		33,847		22,363		4,475		42,886		31,414		42,727		18,586		26,082		18,017		34,886		12,214		26,690		20,805	
Total Monocots	3,541	53,2	0,330	5,1	0,059	1,4	0,078	3,6	0,039	0,9	0,096	1,8	0,083	2,9	0,098	0,8	0,243	3,4	10,187	75,3	5,678	60,9	0,631	5,1	1,266	29,1	0,852	17,6	0,029	1,5	0,475	8,3	0,022	1,7
Total Dicots	3,112	46,8	6,183	94,9	4,192·	98,6	2,079	96,4	4,072	99,1	5.138	98,2	2,813	97,1	11,532	99,2	6,934	96,6	3,341	24,7	3,640	39,1	11,666	94.9	3,087	70,9	3,986	82,4	1,860	98,5	5,270	91,7	1,240	98,3
Unclassified	1,049		0,481		0,094		1,072		2,455		4.499		2,640		1,946		0,778		0,641		2,049		10,115		1,310		3,651		1,209		1,958		0,852	
Monocot stems etc.			trace†						trace												0,003		0,006		0,254		0,795				0,452			
Dicot stems	0,089		0,481		0,094		0,096		0,593		0,399		0,086		0,727		0,778		0,181		0,124		0,383		0,385				0,173				0,135	
Dicots too small	0,960						0,976		1,862		4,100		2,554		1,219				0,460		1,922		9,726		0,671		2,856		1,036		1,506		0,717	
Classified	5 604	100	6,032	100	4,157	100	1,085	100	1,656	100	0.735	100	0,256	100	9,684	100	6,399	100	12,887	100	7,269	100	2,182	100	3,043	100	1,187	100	0,680	100	3,787	100	0,416	100
Monocots	3,541	63,2	0,330	5,5	0,059	1,4	0,078	7,2	0,039	2,4	0,096	13,1	0,083	32,4	0,098	1,0	0,243	3,8	10,187	79,0	5,675	78,1	0,625	28.6	1,012	33,3	0,057	4,8	0,029	4,3	0,023	0,6	0,022	5,3
Dicots	2,063	36,8	5,702	94,5	4,098	98,6	1,007	92,8	1,617	97,6	0.639	86,9	0,173	67,6	9.586	99,0	6,156	96,2	2,700	21,0	1,594	21,9	1,557	71.4	2,031	66,7	1,130	95,2	0,651	95,7	3,764	99,4	0,394	94,7
Acacia erioloba																			0,938	7,3														
Acacia karroo							0,046	4,2	0,088	5,3			0,098	38,3			0,286	4,5																
Acacia mellifera	0,108	1,9	5,117	84,8	3,708	89,2	0,718	66,2	0,598	36,1					5,192	53,6	5,322	83,2	1,175	9,1	1,402	19,3	1,326	60,8	1,361	44,7	0,541	45,6	0,594	87,4	3,553	93,8	0,050	12,0
Baleria lanceolata							0.049	4,5																									0,101	24,3
Catophractes alexandri									0,242	14,6																								
Curroria decidua											0,037	5,0																					0,009	2.2
Dicoma capensis																																		
Diospyros lycioides											0,003	0,4																						
Grewia tenax											0,095	12,9																						
Maytenus linearis																																	0,194	46,6
Pappea capensis									0,059	3,6																								
Rhigozum trichotomum											0,045	6,1					0,017	0,3																
Senecio sisymbriifolius																											0,089	7,5						
Ziziphus mucronata	1,955	34,9	0,350	5,8			0,098	9,0	0,541	32,7	0,459	62,5	0.875	29,3	3,530	36,5	0,531	8,3	0,541	4,2			0,085	3,9	0,565	18,6	0,397	33,5	0,034	5,0	0,197	4,7	0,040	'9,6
Unknown							0,096	8,9							0,634	6,6							0,108	5,0										
Others			0,235	3,9	0,390	9,5			0,089	5,4					0,163	2,3			0,046	0,4	0,192	2,7	0,038	1,7	0,105	3,6	0,103	8,7	0,023	3,4	0,032	0,9		

* Dry mass in g. † All dry masses less than 0,001 g.

TABLE 6: Results of analyses of monthly aliquot samples of rock hyrax stomach content from the farm Warmfontein No. 280, Keetmanshoop District, South West Africa for the period March 1975 to June 1976.

Category	March		April		May		June		July		August		September		October		November		December		January		February		March		April		May		June	
	Mass*	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent	Mass	Per cent
Not retained	28,624		14,877		10,643		16,493		18,603		28,388		33,688		14,366		20,654		18,640		15,721		14,646		38,176		33,575		22,173		14,060	
Total Monocots	0,010	0,1	0,324	9,0	0,051	2,0	0,029	0,4	0,042	1,6	0,004	0,1	0,095	1,6	0,192	1,6	1,155	21,7	3,377	33,5	3,049	37,1	0,577	6,3	0,358	2,4	0,118	2,8	0,027	0,8	0,038	3,3
Total Dicots	10,823	99,9	3,277	91,0	2,534	96,0	6,675	99,6	2,638	98,4	3,586	99,9	5,933	98,4	11,610	98,4	4,158	78,3	6,700	66,5	5,163	68,9	8,641	93,7	14,767	97,6	4,062	97,2	3,186	99,2	1,124	96,7
Unclassified	7,610		1,515		0,081		4,044		2,143		2,342		4,959		2,711		1,371		3,426		4,028		2,534		2,603		2,490		2,194		0,838	
Monocot stems etc.			0,021		trace†																				0,004		0,008					
Dicot stems	0,679		0,689		0,081		1,107		1,646		1,022		0,906		0,459		6,382		0,304		0,200		0,501		1,085		0,486		0,272		0,183	
Dicots too small	6,931		0,805				2,937		0,497		1,320		4,053		2,252		0,989		3,122		3,828		2,033		1,514		1,996		1,922		0,655	
Classified	3,223	100,0	2,086	100,0	2,504	100,0	2,660	100,0	0,537	100,0	1,248	100,0	1,069	100,0	9,091	100,0	3,942	100,0	6,651	100,0	1,184	100,0	6,684	100,0	12,522	100,0	1,690	100,0	1,019	100,0	0,324	100,0
Monocots	0,010	0,3	0,303	14,5	0,051	2,0	0,029	1,1	0,042	7,8	0,044	0,3	0,095	8,9	0,192	2,1	1,155	29,3	3,377	50,8	3,049	72,9	0,577	8,6	0,354	2,8	0,110	6,5	0,027	2,7	0,038	11,7
Dicots	3,213	99,7	1,783	85,5	2,453	98,0	2,631	98,9	0,495	92,2	1,244	99,7	0,974	91,1	8,899	97,9	2,787	70,7	3,274	49,2	1,135	27,1	6,107	91,4	12,168	97,2	1,580	93,5	0,992	97,3	0,286	88,3
Acacia karroo																	0,193	4,9									0,010	0,6			0,029	9,0
Acacia mellifera	2,629	81,6	0,711	34,1	2,368	94,6	1,347	50,6					0,704	65,9	4,259	46,9	2,591	65,7			0,728	17,4	6,088	91,1	11,608	92,7	1,422	84,1	0,304	29,8	0,046	14,2
Barleria lanceolata											0,197	15,8																				
Boscia albitrunca			0,104	5,0															0,341	5,1												
Catophractes alexandri															1,128	12,4			2,253	33,9												
Cucumis sp.	0,228	7,1					1,096	41,2							0,322	3,5																
Datura innoxia					0,085	3,4																										
Diospyros lycioides									0,017	3,2			0,097	9,1	0,499	4,9													0,019	1,9		
Euphorbia inaequilatera																													0,463	45,4		
Forsskaolea candida																																
Grewia flava			0,130	6,2																									0,038	3,7		
Grewia tenax																																
Hermannia engleri									0,038	7,1									0,295	4,4												
Leucosphaera bainesii																															0,021	6,5
Oxalis purpurascens																															0,024	7,4
Phyllanthus maderaspatensis																																
Psoralea obtusifolia							0,097	3,7			0,195	15,6					0,003	0,1														
Rhigozum trichotomum	0,121	3,8							0,038	7,1																					0,166	51,2
Solanum nigrum																													0,078	7,7		
Thamnosma africanum																											0,148	8,8	0,046	4,5		
Ziziphus mucronata			0,064	3,1					0,387	72,1	0,819	65,6	0,033	3,1	2,708	29,8					0,314	7,5							0,044	4,3		
Unknown			0,720	34,5									0,043	4,0					0,385	5,8	0,093	2,2	0,019	0,3	0,560	4,5	trace				trace	
Others	0,235	7,3	0,054	2,6			0,091	3,4	0,015	2,8	0,033	2,6	0,097	9,1	0,033	0,4																

* Dry mass in g. † All dry masses less than 0,001 g.

TABLE 7: Results of analyses of rock hyrax stomach content from Sandmodder.

Category	Wet season		Cool dry season		Transition period		Hot dry season	
	Mass (g) or count*	Per cent	Mass (g) or count	Per cent	Mass (g) or count	Per cent	Mass (g) or count	Per cent
Total Dicots	28,084	80,9	23,857	96.8	14,345	98,8	13,915	46,3
Total Monocots	6.620	19,1	0,798	3,2	0,181	1,2	16,108	53,7
Classified	18,084	100.0	12,516	100,0	9,940	100,0	26,555	100,0
Dicots**	12,483	69,2	12,170	97,2	9,759	98,2	10,450	39,4
Acacia erioloba							0,938	3,5
Acacia mellifera	8,453	46,8	9,221	73,7	5,192	52,2	7,899	29,7
Ziziphus mucronata	3,352	18.6	1,462	11.7	3,605	36.3	1,076	4,1
Unknown					0,634	6,4		
Others	0.678	3,8	1,498	11,8	0.328	3.3	0,537	2,1
Monocots†	5,565	30,8	0,346	2,8	0,181	1,8	16.105	60,6
Anthephora pubescens	52	3.5						
Aristida congesta							18	3.6
Cynodon dactylon							50	10,1
Enneapogon brachystachyus							28	5,6
Enneapogon scaber	135	9,0						
Eragrostis nindensis							17	3,5
Eragrostis trichophora							54	10,9
Stipagrostis hirtigluma							36	7.3
Others	273	18.3					97	19,6

* Fragment count (Monocotyledon species)
** Number of species: Wet season = 19, cool dry season = 19, transition period = 7, hot dry season = 8
† Number of species: Wet season = 25, cool dry season = 25, transition period = 9, hot dry season = 17

TABLE 8: Results of analyses of rock hyrax stomach content from Warmfontein.

Category	Wet season		Cool dry season		Transition period		Hot dry season	
	Mass (g) or count*	Per cent	Mass (g) or count	Per cent	Mass (g) or count	Per cent	Mass (g) or count	Per cent
Total Dicots	41,570	96,8	19,743	99,0	17,543	98,4	16,021	67.9
Total Monocots	1,387	3,2	0,191	1,0	0,287	1,6	7,581	32,1
Classified	26,205	100,0	8,292	100,0	10,160	100,0	14,777	100,0
Dicots**	24,851	94,8	8,101	97,7	9.873	97.2	7.196	48.7
Acacia mellifera	22,458	85,7	4,076	49,2	4,963	48.8	3,500	23.7
Catophractes alexandri					1,128	11,1	2,253	15,2
Cucumis sp.			1,096	13,2	0.322	3.2		
Diospyros lycioides					0,546	5,4		
Forsskaolea candida			0,463	5,6				
Psoralea obtusifolia			0.292	3,5				
Ziziphus mucronata			1,251	15,1	2,741	27,0		
Others	2,393	9,1	0,922	11,1	0.173	1,7	1,443	9,8
Monocots†	1,354	5,2	0,191	2,3	0,287	2,8	7,581	51,3
Aristida congesta							14	3,1
Cynodon dactylon							16	3,6
Enneapogon brachystachyus							35	7,8
Enneapogon scaber							15	3,3
Eragrostis nindensis							14	3,1
Eragrostis porosa							19	4,3
Stipagrostis uniplumis							27	6,0
Others							90	20,1

* Fragment count (Monocotyledon species)
** Number of species: Wet season = 16, cool dry season = 21, transition period = 13, hot dry season = 11.
† Number of species: Wet season = 26, cool dry season = 27, transition period = 12, hot dry season = 23.

4 DISCUSSION

4.1 Differential fragmentation

Differential fragmentation is when the leaves of some species are consistently broken down into smaller fragments during mastication than the leaves of other species. Should this occur, it would result in under-representation of certain species due to a greater proportion of their fragments passing through the sieves. Dirschl (1962) proved that differential fragmentation did not occur in analyses of pronghorn rumen, but it is not known whether it occurred in the present study because the amounts of material retained by the sieves in all samples was insufficient to allow statistical comparison. It seems unlikely, however, because the limited feeding periods of the rock hyrax (Sale 1965a) result in the animals not masticating their food finely. For an animal of its size, the rock hyrax has remarkably coarse stomach contents.

4.2 Principal foods

Principal foods are regarded as plant groups or species which are eaten in proportions of 10,0 per cent or more. The principal foods for the four seasons are represented graphically in Figs 1 and 2. Species with values of 10,0 per cent or more in any one of the four seasons are represented throughout, irrespective of their subsequent proportions.

The data represented in Figs 1 and 2 are also arranged in contingency tables (Tables 9 and 10) in which all food categories other than principal foods were combined under "Others", to enable statistical comparison of the results. χ^2-tests for k independent samples (Siegel 1956) were conducted to determine whether overall significant differences exist between the seasonal proportions of the principal foods. In both cases the observed χ^2 was significant: For Sandmodder $\chi^2 = 153,85$ at $p < 0,01$ and for Warmfontein $\chi^2 = 263,51$ at $p < 0,01$. The proportions for each individual season were then compared with each adjacent season in a χ^2-test for two independent samples to determine whether principal foods change significantly from one season to the next. The results of these analyses are described separately for each study area below.

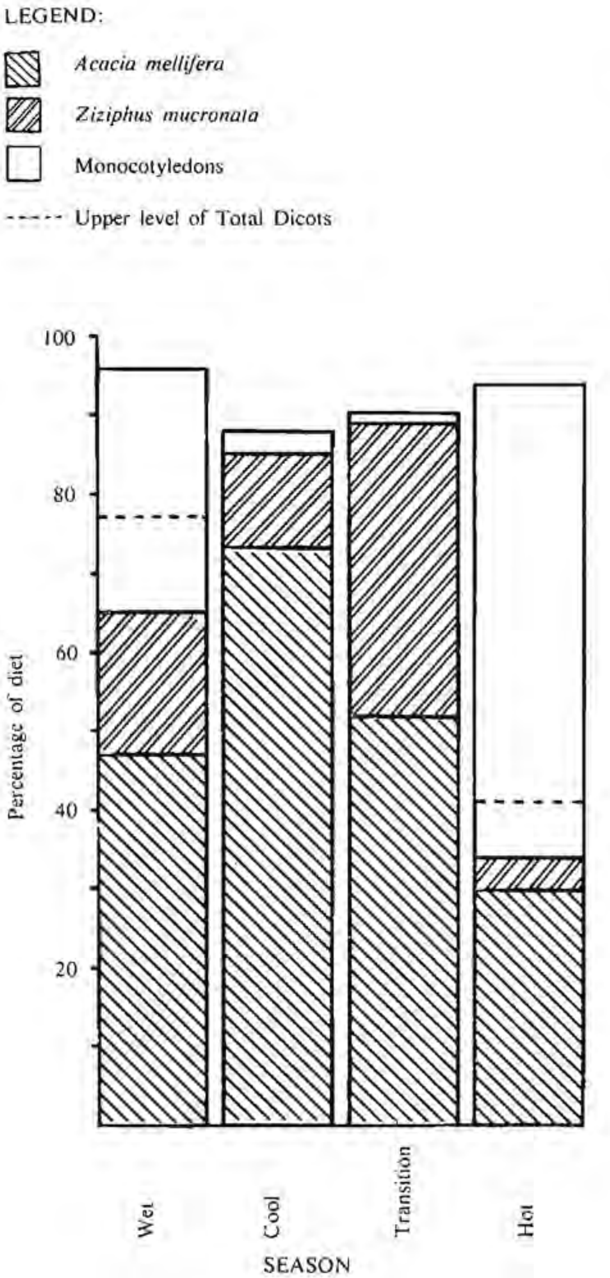


FIGURE 1: Principal foods of the rock hyrax at Sandmodder.

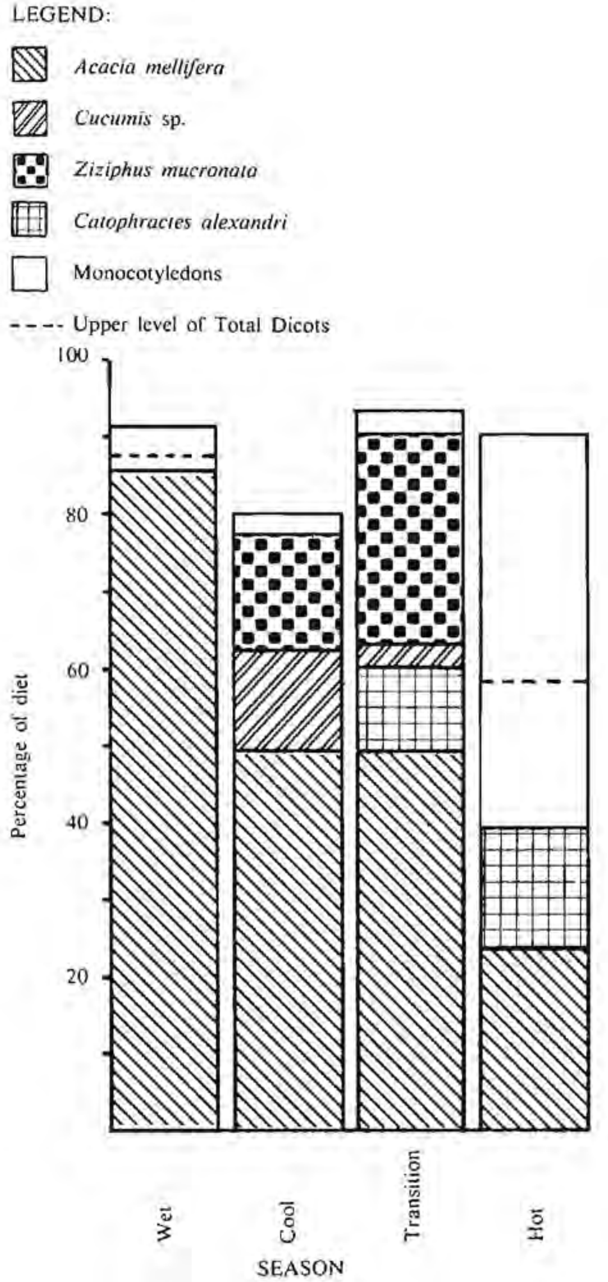


FIGURE 2: Principal foods of the rock hyrax at Warmfontein.

TABLE 9: Contingency table of the percentages of principal foods eaten by rock hyrax at Sandmodder.

Food category	Wet season	Cool dry season	Transition period	Hot dry season	Total	Expected proportions (all columns)
Monocotyledons	30,8	2,8	1,8	60,6	96,0	24,0
Acacia mellifera	46,8	73,7	52,2	29,7	202,4	50,6
Ziziphus mucronata	18,6	11,7	36,3	4,1	70,7	17,7
Others	3,8	11,8	9,7	5,6	30,9	7,7
Total	100,0	100,0	100,0	100,0	400,0	

$\chi^2 = 153{,}85$ (df = 9: P < 0,01).

TABLE 10: Contingency table of the percentages of principal foods eaten by rock hyrax at Warmfontein.

Food category	Wet season	Cool dry season	Transition period	Hot dry season	Total	Expected proportions (all columns)
Monocotyledons	5,2	2,3	2,8	51,3	61,6	15,4
Acacia mellifera	85,7	49,2	48,8	23,7	207,4	51,9
Catophractes alexandri	0,0	0,0	11,1	15,2	26,3	6,6
Cucumis sp.	0,0	13,2	3,2	0,0	16,4	4,1
Ziziphus mucronata	0,0	15,1	27,0	0,0	42,1	10,5
Others	9,1	20,2	7,1	9,8	46,2	11,6
Total	100,0	100,0	100,0	100,0	400,0	

$\chi^2 = 263{,}51$ (df = 15: p < 0,01).

4.2.1 Sandmodder

The results of the tests for Sandmodder are summarised in Table 11 which shows significant differences between the relative proportions of principal foods for all seasons. It is thus concluded that the changes in the percentage of any principal food from one season to the next are significant.

TABLE 11: Results of a series of χ^2-tests comparing the principal food proportions in the diet of the rock hyrax at Sandmodder, showing significant differences between the seasons.

Test combination	df	χ^2	p
Wet: Cool dry	3	35,003	< 0,01
Cool dry: Transition	3	16,699	< 0,01
Transition: Hot dry	3	88,338	< 0,01
Hot dry: Wet	3	23,099	< 0,01

4.2.1.1 *Acacia mellifera*

Observation indicated that *Acacia mellifera* starts to lose its leaves during the cool dry season. Some individuals of the species experience regrowth during the transition period but lose their leaves again during the hot dry season. This explains the decline in the percentage of the species in the diet of the rock hyrax from the cool dry season to the hot dry season. It seems that, in the hot dry season, *Acacia mellifera* is simply displaced by other species which are either unavailable or unpalatable in other seasons.

4.2.1.2 *Ziziphus mucronata*

This species also loses its leaves during the cool dry season (hence the decline in the percentage in the diet in this season) but exhibits fairly strong regrowth in the transition period at Sandmodder. (Most of the *Ziziphus mucronata* plants at Sandmodder actually grow in the river-bed and their roots probably reach down into or very close to the water table). This explains the increased percentage of *Ziziphus mucronata* in the diet of the rock hyrax in this season, when the percentage of *Acacia mellifera* is declining. During the hot dry season *Ziziphus mucronata* loses some of its leaves again and thus declines in the diet.

4.2.1.3 Monocotyledons

The dotted lines across the Monocotyledon bars in Fig. 1 denote the percentage of "Total Monocots" (upper level of "Total Dicots"). The area immediately below the dotted line therefore represents the unclassified Monocotyledon material.

The percentage of Monocotyledons declines in the cool dry season and the transition period because the grass becomes dry and unpalatable. The following explanation is suggested for the unexpected increase in the hot dry season: Scattered rain showers usually occur in the latter part of the hot dry season (arbitrarily defined as mid-October to end of January in this study) just before the commencement of the "continuous" wet period. These scattered showers are possibly sufficient to allow regrowth of some of the perennial grasses such as *Eragrostis nindensis* and *Enneapogon brachystachyus*, which are known to sprout after only 10 mm of rain, but insufficient to start the general growing season for woody plants, resulting in an interim period with adverse browsing conditions and favourable grazing conditions. To illustrate this explanation, selected rainfall data for 1975 and 1976 from Na-Os (a rainfall station close to Sandmodder at 27° 12'S; 18° 59'E) are presented, together with corresponding per centages of total Monocotyledons in the diet, in Table 12.

TABLE 12: Selected monthly rainfall data (mm) for 1975 and 1976 from Na-Os and selected percentages of total Monocotyledons in the diet of the rock hyrax for corresponding months at Sandmodder.

Month	Rainfall	Percentage total Monocots
1975:		
January	21,2	–
February	15,5	–
March	113,5	53,2
April	4,6	5,1
November	7,5	3,4
December	35,5	75,3
1976:		
January	223,2	60,9
February	129,0	5,1
March	151,5	29,1
April	73,5	17,6

Observations made during regular visits to the study area at the time indicated that the rainfall recorded by the end of February 1975 (which included two single showers of 17,5 mm and 15,5 mm) did not result in the general commencement of the growing season although some of the grasses had sprouted. Stomach contents were unavailable for January and February 1975 but Moncotyledons comprised over 50 per cent of the diet in March, declining to 5,1 per cent in April *before* the grass dried out. The 1976 wet season was above average and commenced earlier, on 9 January when 50,5 mm was recorded. The 35,5 mm of rain which fell during December 1975 was sufficient to allow a growth of grass but insufficient to allow general commencement of the growing season. Similarly, the percentage of Monocotyledons in the diet remained high in January but declined in February, March and April when the growing season was in full swing.

Sale (1965a) found that in the Great Rift Valley and other lowland habitat in Kenya *Procavia habessinica* and *Heterohyrax brucei* do not eat grass to any appreciable extent at all while Mount Kenya hyrax (*Procavia johnstoni mackinderi*) are enabled to feed extensively from the coarse tussock grasses found in alpine habitat by the abundance of open water. Working in koppie habitat in the Serengeti National Park, Tanzania, Turner and Watson (1965) found that overlap in the diets of the sympatrically occurring *Procavia johnstoni matschiei* and *Heterohyrax brucei* is small, the former feeding exclusively on grass, the latter a browser. Hoeck (1975), however, refutes this in an extensive study in the same locality and found that *Procavia johnstoni* grazed only in the wet season and occupies an almost identical niche to *Heterohyrax brucei* in the dry season. In both species, the amount of grass eaten increases in the wet season, although *Heterohyrax brucei* remains mainly a browser. Hoeck (1975) attributes the switch to grasses to the increase in nutrients in new shoots of grasses, which supports the explanation given above to a degree.

4.2.2 Warmfontein

The results of the χ^2-tests for two independent samples for the Warmfontein data are presented in Table 13 which also shows significant differences between all sets of principal food proportions.

TABLE 13: Results of a series of χ^2 tests comparing the principal food proportions in the diet of the rock hyrax at Warmfontein, showing significant differences between the seasons.

Test combination	df	χ^2	p
Wet: Cool dry	4	43,368	< 0,01
Cool dry: Transition	5	37,163	< 0,01
Transition: Hot dry	5	83,344	< 0,01
Hot dry: Wet	3	87,912	< 0,01

4.2.2.1 *Acacia mellifera*

The decline in the percentage of this species in the diet of the hyrax from the cool dry season to the hot dry season is again attributed to loss of leaves although it appears, in this case, that the regrowth of leaves in the transition period has the effect of maintaining the percentage of *Acacia mellifera* at the same level as during the cool dry season.

4.2.2.2 *Ziziphus mucronata*

This species is eaten during the cool dry season when the proportion of *Acacia mellifera* in the diet declines. Its percentage presumably increases during the transition period because of regrowth, the same trend as was found at Sandmodder. In the hot dry season *Ziziphus mucronata* disappears entirely from the diet at Warmfontein probably due to loss of leaves (there is less of this species at Warmfontein than at Sandmodder and it would be more difficult for hyrax to obtain leaves from it in the hot dry season at Warmfontein).

4.2.2.3 *Cucumis* sp.

Rock hyrax eat mostly the fruits of this species, apparently not during the wet season, when the plant grows, but during the cool dry season after the fruits have ripened. As the dry seasons progress, however, the fruits dry out and break up which explains why a smaller percentage is eaten in the transition period and why *Cucumis* sp. disappears from the diet in the hot dry season.

4.2.2.4 *Catophractes alexandri*

Catophractes alexandri is not eaten during the wet season or cool dry season but is eaten in increasing proportions from the transition period onwards, apparently as a replacement for the declining percentages of *Acacia mellifera* and *Ziziphus mucronata*.

TABLE 14: Selected monthly rainfall data (mm) for 1975 and 1976 and selected percentages of total Monocotyledons in the diet of the rock hyrax for corresponding months at Warmfontein.

Month	Rainfall	Percentage total Monocots
1975:		
January	7,0	–
February	18.0	–
March	120,2	0,1
April	6,0	9,0
November	0,0	21.7
December	36,0	33,5
1976:		
January	196,6	37,1
February	137,0	6,3
March	130,5	2,4
April	37,0	2,8

4.2.2.5 Monocotyledons

The seasonal fluctuation of the percentage of Monocotyledons in the diet follows the same pattern as at Sandmodder, except that it is much lower in the wet season. The same explanation is suggested, namely that the scattered showers at the end of the hot dry season allow regrowth of grass (which is preferred) but not of woody plants. Selected rainfall data for 1975 and 1976 from Warmfontein, together with the corresponding percentages of total Monocotyledons are presented in Table 14 to illustrate the explanation.

The 1975 wet season commenced in early March and was preceded by a fall of 18,0 mm in February but the percentage of Monocotyledons in March is low because the stomach content samples for March were collected almost three weeks after the wet season had commenced, by which time the animals had probably already started feeding on the fresh browse. The 21,7 per cent Monocotyledons in the diet in November 1975

TABLE 15: Relative proportions of Monocotyledon species in rock hyrax stomach content samples from Sandmodder.

Species	Wet season		Cool dry season		Transition period		Hot dry season	
	Count*	Per cent	Count	Per cent	Count	Per cent	Count	Per cent
Anthephora pubescens	52	11.3	1	0,4	–	–	–	–
Aristida adscenionis	–	–	–	–	–	–	4	1.3
Aristida congesta	35	7,6	7	3,0	7	4,1	18	6,0
Aristida engleri	1	0,2	–	–	–	–	5	1,7
Asthenatherum glaucum	6	1,3	–	–	–	–	–	–
Cenchrus ciliaris	–	–	14	5,9	–	–	13	4,3
Chloris virgata	8	1,7	1	0,4	–	–	9	3,0
Cynodon dactylon	8	1,7	10	4,2	104	61,2	50	16,7
Cyperus longus	3	0,7	2	0,8	–	–	–	–
Dactyloctenium aegyptium	–	–	–	–	–	–	2	0,7
Digitaria eriantha	11	2,4	–	–	–	–	–	–
Enneapogon brachystachyus	35	7,6	9	3.8	9	5.3	28	9.3
Enneapogon cenchroides	–	–	–	–	–	–	14	4.7
Enneapogon scaber	135	29,3	87	36,7	25	14,7	11	3,7
Eragrostis biflora	1	0,2	–	–	–	–	–	–
Eragrostis echinochloidea	3	0,7	12	5,1	10	5.9	–	–
Eragrostis nindensis	20	4,3	3	1.3	–	–	17	5.7
Eragrostis porosa	–	–	3	1,3	5	2,9	–	–
Eragrostis rotifer	10	2,2	3	1.3	–	–	–	–
Eragrostis trichophora	17	3.7	1	0,4	4	2,4	54	18.0
Heteropogon contortus	4	0,9	6	2,5	–	–	–	–
Leucophrys mesocoma	4	0,9	2	0,8	–	–	–	–
Rhynchelytrum villosum	–	–	4	1,7	–	–	–	–
Schmidtia kalahariensis	3	0,7	3	1,3	–	–	–	–
Setaria appendiculata	12	2,6	11	4,6	–	–	–	–
Setaria verticillata	29	6,3	2	0,8	–	–	–	–
Stipagrostis ciliata	12	2.6	–	–	–	–	5	1,7
Stipagrostis hirtigluma	–	–	5	2,1	–		36	12,0
Stipagrostis hochstetterana	23	5,0	4	1,7	–	–	8	2,7
Stipagrostis uniplumis	2	0,4	13	5,5	–	–	7	2,3
Trachyandra arvensis	8	1,7	30	12,7	3	1,8	13	4,3
Tragus berteronianus	15	3,3	1	0,4	–	–		–
Triraphis ramosissima	–	–	3	1,3	2	1,2		–
Unknown	3	0,7	–	–	1	0,6	6	2,0
Total	460	100.0	237	100.0	170	100.1	300	100,1

* Fragment count

is contradictory to the pattern in Table 14 as no rain fell at Warmfontein in that month. The 1976 wet season, which was preceded by showers totalling 36,0 mm in December 1975 (and correspondingly high percentages of Monocotyledons in December and January), commenced on 9 January when 60,0 mm was recorded. This was followed by the same characteristic decline in the percentage of Monocotyledons from February onwards. The relevance of these remarks to the findings of Sale (1965a), Turner and Watson (1965) and Hoeck (1975) is the same as for Sandmodder.

4.3 Utilisation of Monocotyledons

The utilisation of Monocotyledons is an important feature of the diet because it relates to the loss of livestock grazing attributable to the rock hyrax. The various Monocotyledon species eaten are listed as fragment counts and percentages relative to Monocotyledons as a group in Tables 15 and 16. A large number of grasses are utilised at all times, even when the total percentage of Monocotyledons in the diet is low. Many

TABLE 16: Relative proportions of Monocotyledon species in rock hyrax stomach content samples from Warmfontein.

Species	Wet season		Cool dry season		Transition period		Hot dry season	
	Count*	Per cent	Count	Per cent	Count	Per cent	Count	Per cent
Anthephora pubescens	26	7,5	–	–	–	–	–	–
Aristida adscensionis	3	0,9	4	5,6	–	–	–	–
Aristida congesta	15	4,3	–	–	11	11,5	14	6.1
Aristida engleri	–	–	1	1,4	–	–	–	–
Asthenatherum glaucum	10	2,9	–	–	3	3,1	10	4,3
Cenchrus ciliaris	–	–	5	6,9	–	–	1	0,4
Chloris virgata	–	–	–	–	–	–	3	1,3
Cynodon dactylon	5	1,4	2	2,8	31	32,3	16	7,0
Digitaria eriantha	–	–	2	2,8	–	–	6	2,6
Enneapogon brachystachyus	42	12,0	4	5,6	13	13,5	35	15,3
Enneapogon cenchroides	–	–	2	2,8	–	–	–	–
Enneapogon scaber	21	6,0	21	29,1	16	16,7	15	6.5
Eragrostis echinochloidea	9	2,6	8	11,1	2	2,1	7	3.0
Eragrostis nindensis	9	2,6	–	–	–	–	14	6.1
Eragrostis porosa	3	0,9	1	1,4	–	–	19	8,3
Eragrostis rotifer	6	1,7	–	–	–	–	–	–
Eragrostis trichophora	16	4,6	5	6,9	7	7,3	–	–
Heteropogon contortus	5	1,4	–	–	–	–	3	1,3
Leucophrys mesocoma	25	7,2	2	2,8	–	–	10	4,3
Panicum arbusculum	–	–	3	4,2	2	2,1	2	0,9
Rhynchelytrum villosum	9	2,3	–	–	–	–	–	–
Schmidtia kalahariensis	19	5,3	–	–	2	2,1	3	1,3
Setaria appendiculata	16	4,6	–	–	–	–	–	–
Setaria verticillata	12	3,4	–	–	–	–	3	1,3
Stipagrostis ciliata	26	7,5	3	4,2	–	–	8	3,5
Stipagrostis hirtigluma	6	1,7	6	8,3	1	1,0	5	2,2
Stipagrostis hochstetterana	10	2,9	–	–	–	–	10	4,3
Stipagrostis namaquensis	2	0,6	–	–	–	–	4	1,7
Stipagrostis uniplumis	40	11,5	1	1,4	–	–	27	11,7
Trachyandra arvensis	6	1,7	1	1,4	7	7,3	1	0,4
Tragus berteronianus	5	1,4	–	–	1	1,0	11	4,8
Triraphis ramosissima	2	0,6	–	–	–	–	–	–
Unknown	2	0,6	1	1,4	–	–	3	1,3
Total	349	100,1	72	100,1	96	100,0	230	99,9

* Fragment count

of the species are eaten in small proportions indicating that the animals are largely non-selective in their grazing.

The principal Monocotyledon species utilised by the rock hyrax (i.e. those species which constitute 10,0 per cent or more *of the Monocotyledons*) are presented in Figs 3 and 4. The higher the percentage comprised by principal species, the lower is the diversity of species utilised. From Figs 3 and 4 it is evident that diversity decreases from the wet season to the transition period but increases again in the hot dry season. This pattern conforms to the pattern described above for the total amounts of Monocotyledons in the diet: The availability of grasses declines as the dry period progresses with the result that there are fewer species with nutritious green leaves than in the wet season. The scattered thunder showers which preceded the 1976 wet season could similarly account for the return of diversity to wet season levels during the interim period before commencement of the growing season because a greater number of species would then be desirable.

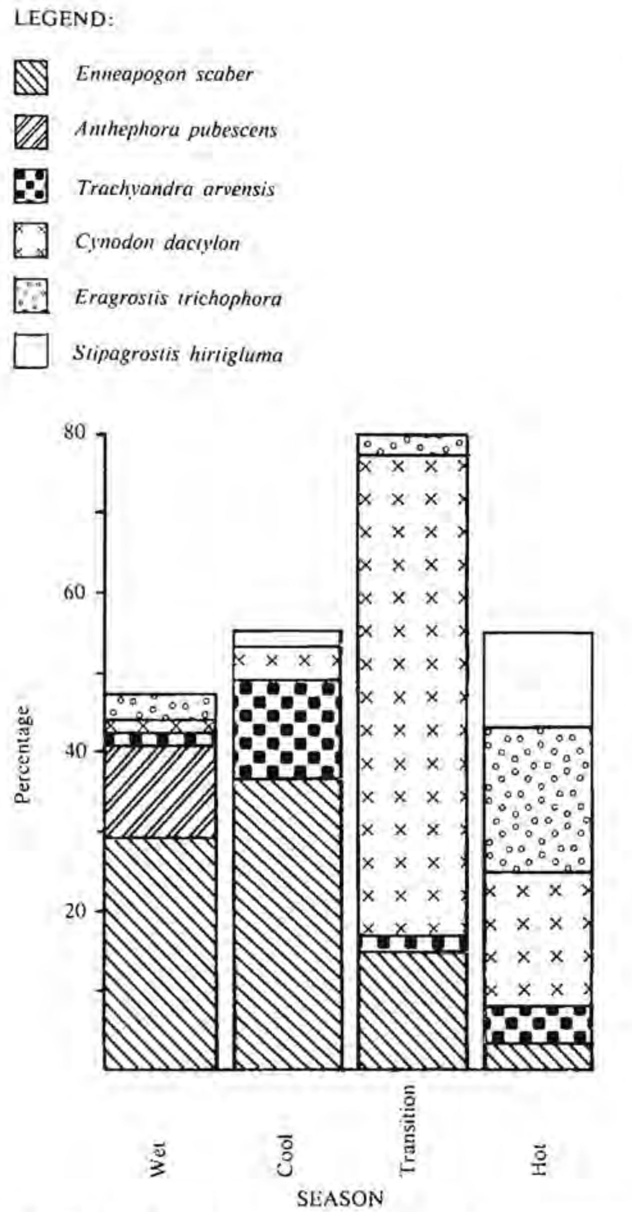


FIGURE 3: Relative percentages of the principal Monocotyledons utilised by the rock hyrax at Sandmodder.

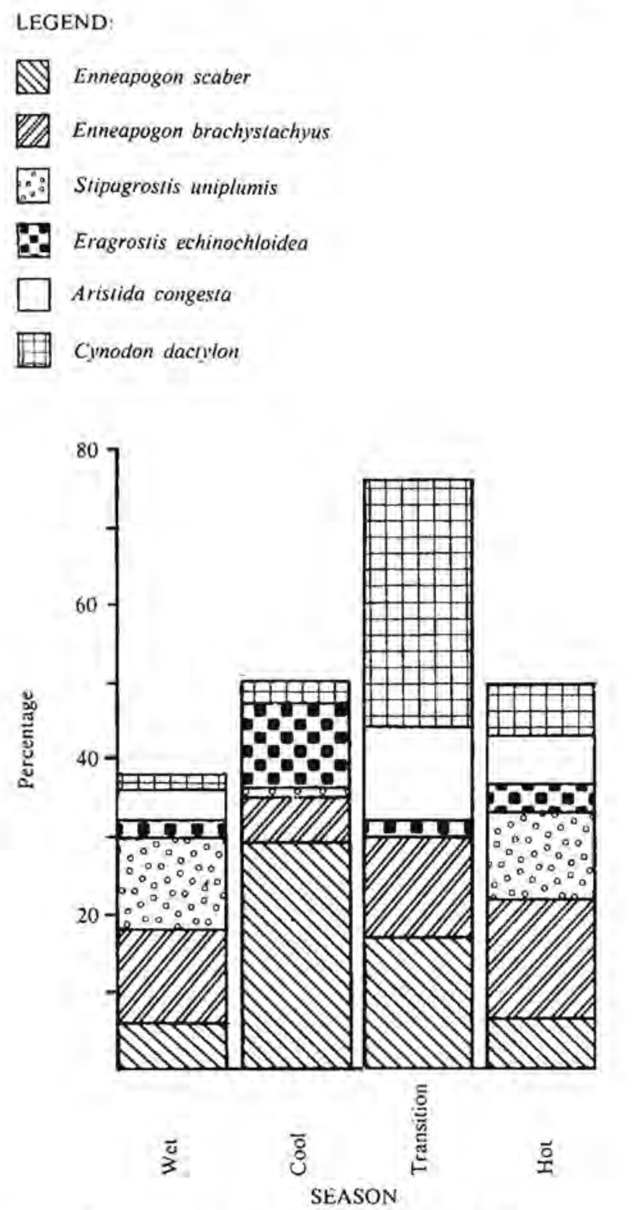
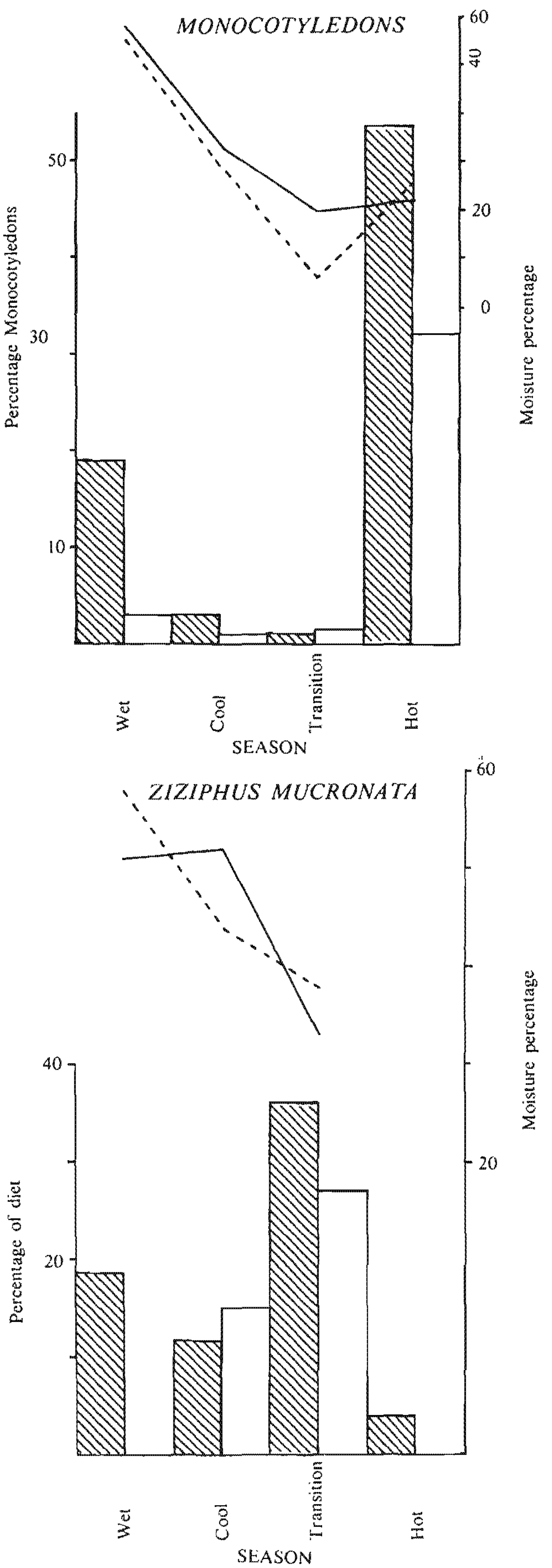


FIGURE 4: Relative percentages of the principal Monocotyledons utilised by the rock hyrax at Warmfontein.

Two of the principal species in Figs 3 and 4 are common to both study areas, namely *Cynodon dactylon* and *Enneapogon scaber*. At both study areas the percentage of *Cynodon dactylon* increases considerably from the wet season to the transition period and then declines again in the hot dry season. It is suggested that its percentage is low in the wet season and the immediately preceding period because of the number of other green grasses available, but is high in the transition period because it grows in moist areas and remains green long after other grasses have dried out. The percentage of *Enneapogon scaber* is highest in the cool dry season at both study areas and then declines through the rest of the dry period. The only possible explanation is that, due to its high availability, a higher actual number of plants of the species remain nutritious after the wet season than other species, but that the latter are preferred in the wet season and at the end of the hot dry season.

4.4 Moisture content of forage species

Sale (1965a) mentioned a colony of Mount Kenya hyrax (*Procavia johnstoni mackinderi*) which had access to water but apparently did not drink, while two other species he studied in the Great Rift Valley did not have access to surface water. Louw, Louw and Retief (1972) stated that the renal efficiency of the rock hyrax is high, but not spectacularly high and that the animal is unable to exist indefinitely without free water on a dry diet. Louw (1971) and Louw *et al.* (1972) concluded that the success of the rock hyrax in hot arid environments can be attributed to its avoidance of temperature extremes by retiring to rock shelters and expressed the opinion that it could exist comfortably without access to surface water provided it utilised succulent plants and dew. In the Groot Karas Mountains dew or fog is rare outside the wet season and succulents do not occur in significant amounts in the



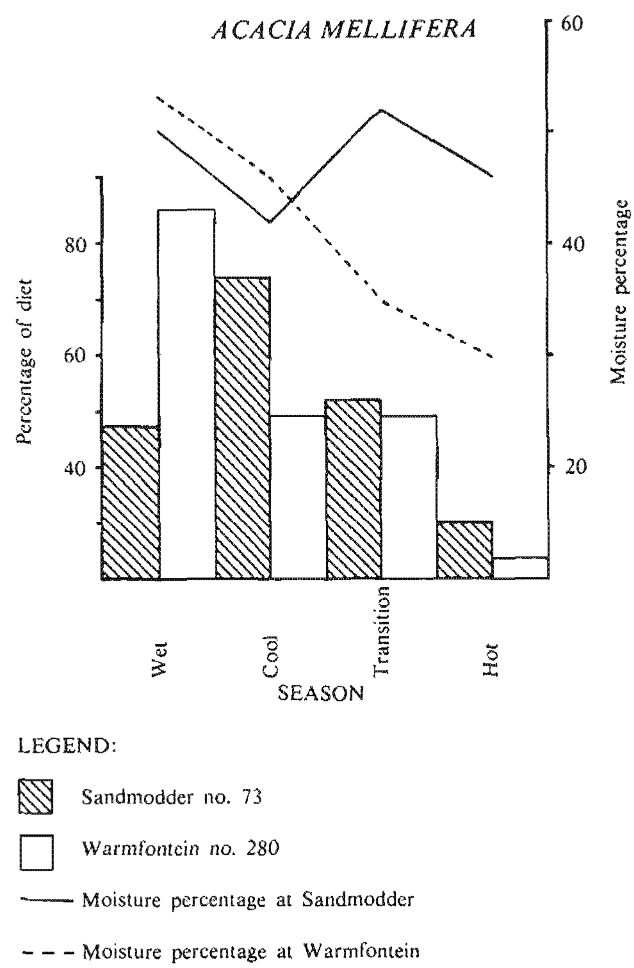


FIGURE 5: Percentages of principal foods in the diet of the rock hyrax compared with seasonal changes in their moisture percentages at two study areas in southern South West Afrca.

study areas. Although surface water is available in places, rock hyrax were not observed drinking and they must therefore obtain a proportion of their water requirements from their food.

Hanse (1962) stated that to many rock hyrax populations in the Karoo open water is unavailable and assumed that the selection of certain food species (not specified) is primarily for water. Coe (1962) stated that *Procavia johnstoni mackinderi* shows preferences for grasses, mosses and other higher plants with succulent leaves. According to Sale (1965a) Mount Kenya hyrax prefer food species containing the most water. A captive individual of this species did not drink when fed on high moisture content *Sonchus* sp. but did drink when fed on lucerne hay (Sale 1966). According to Hoeck (1975) *Procavia* and *Heterohyrax* switch to browse in the dry season because of the lack of nutrients in the grasses.

In this study an attempt was made to determine whether moisture content is a primary factor in the selection of food species or not. The moisture percentages of as many plant species as possible were therefore determined in each season and those of the principal foods are compared graphically with their corresponding percentages in the diet in Figs 5 and 6. Where more than one sample was available for a given species in a given season, the mean moisture percentage was used. The moisture percentage of Monocotyledons as a group was determined by calculating the mean for those species utilised in each season. As there was only one moisture percentage value available for *Cucumis* sp., those of a closely related species, *C. sagittatus*, were used in Fig 6.

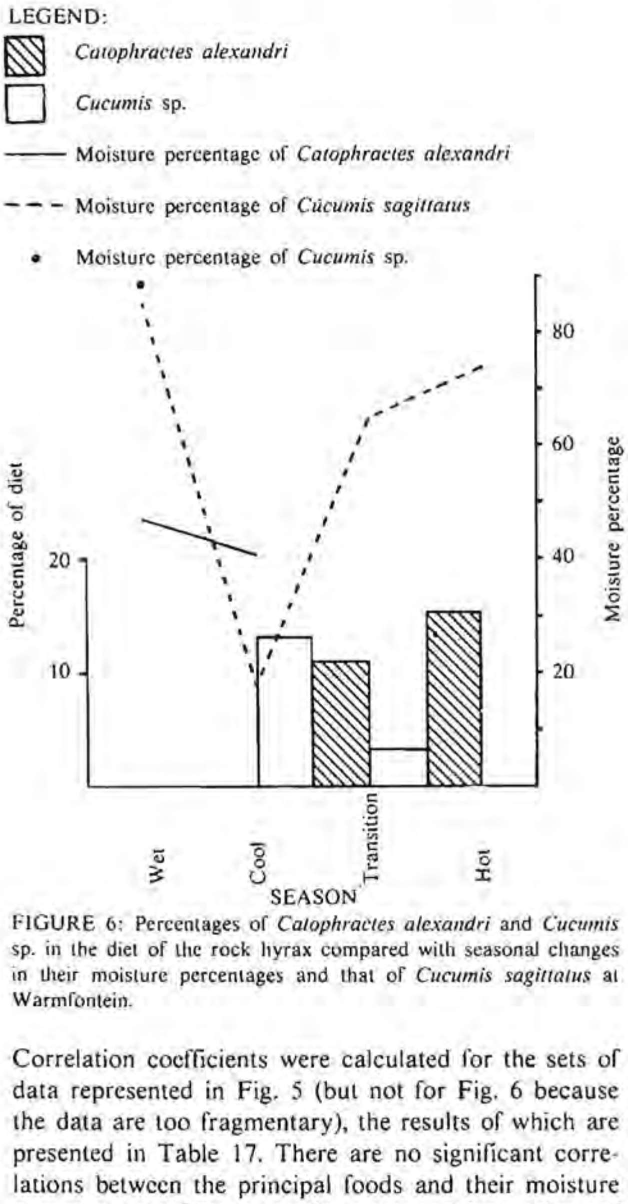


FIGURE 6: Percentages of *Catophractes alexandri* and *Cucumis* sp. in the diet of the rock hyrax compared with seasonal changes in their moisture percentages and that of *Cucumis sagittatus* at Warmfontein.

Correlation coefficients were calculated for the sets of data represented in Fig. 5 (but not for Fig. 6 because the data are too fragmentary), the results of which are presented in Table 17. There are no significant correlations between the principal foods and their moisture percentages which proves that seasonal fluctuations of the species concerned are not primarily governed by moisture content.

TABLE 17: Correlation coefficients calculated from the seasonal percentages of principal foods in the diet of rock hyrax and their corresponding moisture percentages at two study areas in southern South West Africa.

Food category	r	t	df	p
Sandmodder:				
Monocotyledons	−0,116	−0,17	2	> 0,05
Acacia mellifera	−0,406	−0,63	2	> 0,05
Ziziphus mucronata	−0,974	−4,31	1	> 0,05
Warmfontein:				
Monocotyledons	−0,104	−0,15	2	> 0.05
Acacia mellifera	0,903	2,96	2	> 0.05
Ziziphus mucronata	−0,987	−6,13	1	> 0.05

It is possible, however, that the selection of a food species *within* a given season may be governed primarily by moisture content. This can only be determined by considering those species which are not selected as well. Contingency tables were thus drawn up of the number of utilised and non-utilised species with moisture percentages of 50 per cent or less on the one hand, and 51 per cent or more on the other hand, the hypothesis being that a greater proportion of the utilised species are in the latter group than non-utilised species. Since the hypothesis is directional, tests for significance were only necessary for those tables which conformed to it. The wet season (105 species), cool dry season (109 species), and hot dry season (60 species) configurations were all the opposite of the hypothesis and a χ^2-test for significance was therefore conducted only on the dry season table (58 species). No significant difference was found: $\chi^2 = 0{,}777$; $p > 0{,}05$.

4.5 Diversity of the diet

Turner and Watson (1965), Sale (1965a) and Hoeck (1975) have all drawn attention to the diversity of the diet of various hyrax species in East Africa. The number of species utilised in each season in the present study is presented in Table 18. In all cases the number of species utilised is high in the wet season, reaches a minimum in the transition period and increases again in the hot dry season. It is postulated that as environmental conditions become more adverse for plant life, the number of palatable or nutritious species declines, resulting in a smaller spectrum being utilised by the rock hyrax. The unexpected increase in diversity in the hot dry season is attributed to the above average 1976 wet season which commenced in January, a month arbitrarily assigned to the hot dry season.

TABLE 18: Numbers of plant species utilised by rock hyrax at two study areas in southern South West Africa.

Season	Sandmodder No. 73			Warmfontein No. 280		
	M*	D*	Total	M	D	Total
Wet	25	19	44	26	16	42
Cool dry	25	19	44	17	21	38
Transition	9	6	15	12	13	25
Hot dry	17	8	25	23	11	34

* M = Monocotyledon species; D = Dicotyledon species.

In an attempt to find statistical evidence for this explanation, the total number of species utilised was compared graphically with the "climatic adversity index" described in an earlier paper (Lensing and Le Roux 1982), a parameter reflecting adversity of environmental conditions for the maintenance of plant growth (Fig 7) which is calculated as follows:

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

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

Tx = Mean daily maximum temperature for the month recorded at Keetmanshoop

The C values in Fig. 7 are the averages for all months in each of the seasons. Correlation coefficients were calculated from the data but neither were significant: For Sandmodder $r = -0{,}981$ ($t = -2{,}78$; $df = 2$; $p > 0{,}05$) while for Warmfontein $r = -0{,}895$ ($t = -2{,}83$; $df = 2$; $p > 0{,}05$). It is possible that, if data for a longer continuum of time had been available, significant negative correlations would have been shown to exist.

LEGEND:

—— Number of species at Sandmodder no. 73

- - - Number of species at Warmfontein no. 280

—·— Climatic adversity for Na-Os

······· Climatic adversity for Warmfontein

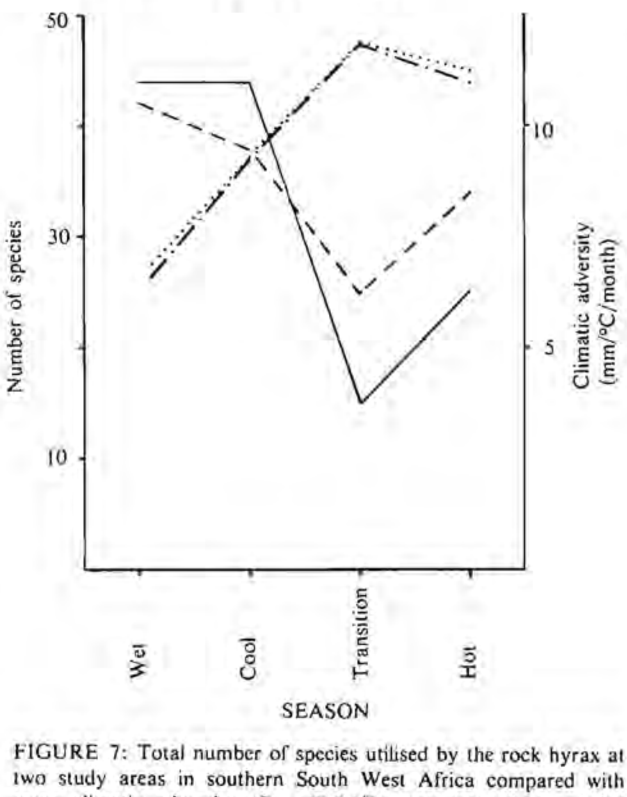


FIGURE 7: Total number of species utilised by the rock hyrax at two study areas in southern South West Africa compared with mean climatic adversity, C = (E-R)/Tx, calculated from rainfall recorded at Na-Os and Warmfontein.

4.6 Food preferences

To determine an animal's food preferences, the composition of its diet must be compared with the availability of the foods it selects (Petrides 1975). The relative availability (RA) of forage species as determined by Lensing and Le Roux (1982) for each season was compared with their corresponding percentages in the diet using a preference rating (PR) and Ivlev's Electivity Index (EI) (Petrides 1975). PR and EI are defined by the following formulae:

$$PR = \frac{\text{Percentage ingested}}{\text{Percentage available}}$$

Ratings greater than 1,00 calculated from this formula denote preferred species while ratings less than 1,00 denote neglected species. Unity denotes a neutral species.

$$EI = \frac{\text{Percentage ingested} - \text{percentage available}}{\text{Percentage ingested} + \text{percentage available}}$$

PR and EI were not calculated for species ingested in proportions of 3,0 per cent or less on the grounds that, because of sampling error in the determination of RA (Lensing and Le Roux 1982), calculations based on small percentages would be unreliable. In any case, such species would have a roughly neutral preference rating and would not be of any interest. Some of the species ingested in measurable proportions occurred so infrequently in the vegetation that they were not recorded in the availability surveys. Since a plant must be available to be ingested, these species were arbitrarily accorded a RA value of 0,1 per cent. Food preferences are presented in Tables 19 and 20. Highly preferred species with a PR greater than 100,0 are represented by ∞ while highly neglected or totally avoided (available but not utilised) species are represented by $1/\infty$.

4.6.1 Sandmodder

At Sandmodder Dicotyledons as a group are approximately neutral except in the hot dry season when they are neglected. *Acacia mellifera* is a preferred species throughout the year with a peak in the cool dry season. The PR of 35,00 determined for *Acacia erioloba* in the hot dry season is unreliable as only pods were recorded in the diet at this time. *Acacia erioloba* occurs infrequently along the Leeu River at Sandmodder and was not recorded in the relative availability surveys. *Acacia erioloba* pods are known to be nutritious (Palgrave 1977) and possibly hold some attraction for the rock hyrax in the hot dry season.

Monocotyledons are preferred throughout the year with a peak in the hot dry season which is probably due to the increase in the proportion of Monocotyledons in the diet at the end of the hot dry season, for which an explanation has been suggested above. Nearly all the grasses in Table 19 are highly preferred at the end of the hot dry season. Availability for the hot dry season was recorded in December 1975 before the grasses had started growing while the stomach content analyses results for January (when considerable rain was recorded) were arbitrarily included in the hot dry season. Monocotyledons were therefore probably more available in

TABLE 19: Food preferences (PR and EI)* of the rock hyrax at Sandmodder.

Category	Wet season		Cool dry season		Transition period		Hot dry season	
	PR	EI	PR	EI	PR	EI	PR	EI
Dicotyledons	0,70	−0,18	0,98	−0,01	0,99	−0,01	0,39	−0,43
Acacia erioloba	—	—	—	—	—	—	35,00	0,94
Acacia karroo	0,02	−0,96	0,08	−0,86	0,11	−0,80	0,09	−0,83
Acacia mellifera	6,59	0,74	13,65	0,86	8,16	0,78	8,03	0,78
Pappea capensis	1/∞**	−0,99	0,50	−0,81	1/∞	−1,00	1/∞	−1,00
Rhigozum obovatum	1/∞	−1,00	1/∞	−1,00	1/∞	−1,00	—	—
Ziziphus mucronata	0,45	−0,38	0,31	−0,53	1,11	0,05	0,08	−0,86
Monocotyledons	44,00	0,96	5,60	0,70	4,50	0,64	∞†	0,99
Anthephora pubescens	∞	1,00	—	—	—	—	—	—
Aristida congesta	—	—	—	—	—	—	36,00	0,95
Cynodon dactylon	—	—	—	—	—	—	∞	1,00
Enneapogon brachystachyus	—	—	—	—	—	—	56,00	0,96
Eragrostis nindensis	—	—	—	—	—	—	87,50	0,98
Eragrostis trichophora	—	—	—	—	—	—	∞	1,00
Stipagrostis hirtigluma	—	—	—	—	—	—	∞	1,00

* PR = Preference rating; EI = Electivity Index
** PR < 0,01 (highly neglected or totally avoided category)
† PR > 100,00 (highly preferred category)

TABLE 20: Food preferences (PR and EI)* of the rock hyrax at Warmfontein.

Category	Wet season		Cool dry season		Transition period		Hot dry season	
	PR	EI	PR	EI	PR	EI	PR	EI
Dicotyledons	1,04	0,02	1,07	0,03	1,02	0,01	0,49	−0,34
Acacia mellifera	1,30	0,13	0,98	−0,01	0,75	−0,14	0,33	−0,50
Boscia foetida	—	—	1/∞**	−1,00	1/∞	−1,00	—	—
Cadaba aphylla	—	—	1/∞	−1,00	1/∞	−1,00	1/∞	−1,00
Catophractes alexandri	0,27	−0,58	1/∞	−1,00	1,73	0,27	3,10	0,51
Cucumis sp.	—	—	—	—	32,00	0,94	—	—
Diospyros lycioides	—	—	—	—	54,00	0,96	—	—
Forsskaolea candida	—	—	∞†	1,00	—	—	—	—
Ozoroa namaensis	1/∞	−1,00	1/∞	−1,00	1/∞	−1,00	1/∞	−1,00
Parkinsonia africana	1/∞	−1,00	—	—	—	—	—	—
Rhigozum trichotomum	—	—	0,13	−0,77	0,05	−0,90	1/∞	−1,00
Ziziphus mucronata	—	—	∞	1,00	15,00	0,88	0,32	−0,52
Monocotyledons	0,58	−0,26	0,26	−0,58	0,62	−0,23	34,20	0,94
Aristida congesta	—	—	—	—	—	—	∞	1,00
Cynodon dactylon	—	—	—	—	—	—	36,00	0,95
Enneapogon brachystachyus	—	—	—	—	—	—	78,00	0,97
Enneapogon scaber	—	—	—	—	—	—	6,60	0,86
Eragrostis nindensis	—	—	—	—	—	—	∞	0,99
Eragrostis porosa	—	—	—	—	—	—	43,00	0,95
Stipagrostis uniplumis	—	—	—	—	—	—	20,00	0,94

* PR = Preference rating; EI = Electivity Index
** PR < 0,01 (highly neglected or totally avoided category)
† PR > 100,00 (highly preferred category)

January than was recorded in December and the PRs for the grass species in Table 19 are probably over-estimations.

4.6.2 Warmfontein

Dicotyledons as a group are approximately neutral throughout the year except in the hot dry season when they are neglected. *Acacia mellifera* (the most important food species from the point of view of availability and diet) is preferred in the wet season, approximately neutral in the cool dry season and transition period, but is neglected in the hot dry season. *Catophractes alexandri* is preferred in the hot dry season while both *Cucumis* sp and *Diospyros lycioides* are highly preferred in the transition period. In both cases, the fruits are eaten by rock hyrax. *Ziziphus mucronata* is highly preferred in the cool dry season and preferred during the transition period.

Monocotyledons as a group are neglected throughout the year except in the hot dry season when they are preferred. As at Sandmodder, this is probably due to the increase in Monocotyledons in the diet of the rock hyrax at the end of the hot dry season. As has been explained above for Sandmodder, the PRs listed for the various grass species are also probably over-estimations.

4.7 Evaluation of the rock hyrax problem

4.7.1 Herbage resource available to sheep

No published or unpublished information on the botanical composition of the diet of Karakul sheep in southern South West Africa could be obtained, but it is generally accepted that they feed mainly on perennial grasses such as *Stipagrostis* spp., *Anthephora pubescens, Cenchrus ciliaris* and *Panicum arbusculum* and dwarf shrubs such as *Barleria* spp., *Petalidium linifolium* and *Rhigozum trichotomum*. They are known to crop grass short and feed close to the ground and have not been observed to get up onto their hind legs to browse. The maximum reach of 17 Karakul ewes from the Neudamm Agricultural Research Station near Windhoek was determined by holding up their heads and measuring the distance from the ground to the lower lip. The mean for the 17 ewes was 94 cm.

Since the canopy volume (BV) used by Lensing and Le Roux (1982) in their formula for RA for trees and shrubs is based on the assumption of a roughly cubic shape, it was possible to determine which proportion, pro rata, of the total RA for each species was not beyond the reach of sheep by applying their maximum reach to the formula. By summing the RAs thus obtained and adding the total to the total RA for grasses and forbs, the total herbage resource available to sheep was determined and is expressed as a percentage of the total herbage resource in rock hyrax habitat in Table 21. The Table shows that most of the resource at Sandmodder is unavailable. Since the percentages in Table 21 were derived from the *maximum* reach of sheep and since Karakul sheep feed close to the ground, the proportion of the total herbage resource normally utilised by sheep is probably much smaller.

TABLE 21: Herbage resource available to sheep in rock hyrax habitat at two study areas in southern South West Africa expressed in units per ha and as percentages of the total herbage resource.

Season	Sandmodder No. 73		Warmfontein No. 280	
	U/ha	Per cent	U/ha	Per cent
Wet	42 617,8	29,3	12 981,0	62,5
Cool dry	22 532,8	26,3	6 336,2	60,0
Transition	16 926,0	26,4	4 474,3	44,9
Hot dry	19 294,5	25,6	5 216,3	50,2
Mean		26,9		54,4

4.7.2 Utilisation of the herbage resource available to sheep by rock hyrax

As the daily intake of the rock hyrax is unknown, it was not possible to determine how much of the herbage available to sheep is removed by hyrax. The percentages of the herbage resource available to sheep which is comprised by those species which are *subject to* utilisation by hyrax were therefore calculated and are presented in Table 22. It should be emphasised that most of the species utilised by hyrax are utilised in minute quantities and that a large proportion of the diet of the rock hyrax is obtained from species of which small proportions are available to sheep. For example, it was calculated that at Sandmodder rock hyrax obtain, on the average, 79 per cent of their diet from species which comprise 56 per cent of the herbage resource available to sheep in rock hyrax habitat.

TABLE 22: Proportions of the herbage resource available to sheep which is *subject to* utilisation by rock hyrax at two study areas in southern South West Africa expressed in units per ha and as percentages.

Season	Sandmodder No. 73		Warmfontein No. 280	
	U/ha	Per cent	U/ha	Per cent
Wet	40 036,6	93,9	11 174,5	86,1
Cool dry	19 637,8	87,2	3 667,7	57,9
Transition	12 440,1	73,5	2 907,1	65,0
Hot dry	17 194,4	89,1	4 268,7	81,8
Mean		85,9		72,7

4.7.3 Loss of potential agricultural yield

Rock hyrax habitat is easily recognisable on large scale aerial photographs because of the typical rock formations. All the available habitat (including estimated feeding zones) on the two study farms was marked out on aerial photographs and measured using a planimeter. It was found that 2,9 and 3,6 per cent of the total areas of the farms Sandmodder and Warmfontein, respectively, are hyrax habitat. The validity of the assumption that these percentages roughly approximate that proportion of the total herbage available to sheep which occurs in rock hyrax habitat is governed by the following mutually compensating factors:

1 Yield in hyrax habitat is higher than elsewhere because the watercourses and ravines have a higher water table and a higher density of trees and shrubs.
2 Much of the higher yield in hyrax habitat is out of the reach of sheep. In addition, these areas are the most inaccessible parts of the range and are probably frequented by sheep less often than more level terrain.

The proportion of the total potential yield of the farms which is subject to utilisation by hyrax was estimated by applying the mean percentages in Table 22 to the above percentages. For Sandmodder this proportion was determined at 2,5 per cent and for Warmfontein 2,6 per cent. It can safely be assumed that hyrax remove less than 50 per cent of the latter percentages per year which would reduce them to 1,2 and 1,3 per cent respectively. The fact that hyrax and sheep do not utilise exactly the same spectrum of species must, however, also be taken into account. It can then be estimated that not more than one per cent of the potential total yield of the two farms available to sheep is lost to the rock hyrax population annually. An average sheep farm with a stocking rate of one small animal unit per ha and a lambing percentage of about 120 per cent (De Klerk, pers. comm.)* will yield a gross annual income of R3,24 per ha at an average Karakul pelt price of R10,80. The value of the yield lost to hyrax will therefore be about 3,2 cents per ha per annum.

*Mr. J. N. De Klerk. Agriculture Division, Private Bag 13186, Windhoek, South West Africa.

5 CONCLUSIONS

The diet of the rock hyrax consists mainly of the leaves of shrubs and trees which is in agreement with what Sale (1965a) found for *Procavia habessinica* in lowland (0 – 3 500 m) Kenya. Grasses are only eaten in significant quantities at the end of the hot dry season and start of the wet season, the only time when individual grasses become principal foods. According to Coe (1962) *P. johnstoni mackinderi* mostly grazes and according to Turner and Watson (1965) it is solely a grazer at Serengeti. Hoeck (1975) refutes these findings, stating that the species grazes only in the wet season, but nevertheless classifies it as a grazer. The results of the present study indicate that *P. capensis* can be regarded as an intermediate feeder according to the classification of Hofmann and Stewart (1972). The diversity of the diet (Turner and Watson 1965, Sale 1965a and Hoeck 1975) has been substantiated by the present study.

Food species are primarily selected on the basis of factors other then moisture content, which confirms what Sale (1965a and 1966) and Hoeck (1975) found. As hyrax were not observed to drink it is concluded that the vegetation of the Groot Karas Mountains provides them with sufficient water.

In Koppie habitat in the Serengeti National Park Hoeck (1975) found that both the genera *Procavia* and *Heterohyrax* feed in proportion to availability with few preferences. In general the same situation exists in the Groot Karas Mountains and the rock hyrax can thus be described as an opportunistic feeder. This is supported by the differing food preferences of the two study areas which are ascribed to differences in the composition of the vegetation. Grasses as a group are preferred only at the end of the hot dry season. Only one individual grass, *Anthephora pubescens*, is preferred outside the hot dry season.

The feeding strategy provides an insight into the rock hyrax problem (sic) and if considered together with previously published information on herbage availability (Lensing and Le Roux 1982), indicates that not more than one per cent of the potential agricultural yield of the study areas is removed by hyrax. As the problem has been shown to be localised (Lensing and Joubert 1977), it is not considered a serious threat to the Karakul industry. The estimated value of the loss (3,2 cents per ha per year) is too low to justify population control because firstly, the cost of control should not exceed this figure and secondly, the entire loss will not be recovered by control.

6 ACKNOWLEDGEMENTS

The contents of this paper formed part of a thesis submitted to the University of Pretoria for the degree M.Sc. (Wildlife Management). To my study supervisors, Prof. J. du P. Bothma (Department of Zoology) and Prof. G. K. Theron (Department of Botany), I owe my gratitude for their valuable guidance, advice and criticism. My technical assistant, Mr. Friedl Burger and successive general assistants, Messrs. Willem Ulungu and Matias Ndjoura are thanked for their help with the field work and in the laboratory. The Regional Nature Conservators stationed at Keetmanshoop, particularly Messrs. Roelf de Bruine (Principal Nature Conservator), John Rose (Senior Nature Conservator) and Derek Clark (Nature Conservator) are thanked for assistance with field work and for providing a logistical base.

I wish to thank the then Director of Nature Conservation, the late Mr. B. J. G. de la Bat, for allowing me to submit the work as part of a thesis and the present Director, Mr. P. S. Swart, for allowing publication of this paper. The Assistant-Director (Research), Dr. E. Joubert, is thanked for his advice and criticism.

The Director and staff of the McGregor Museum in Kimberley, particularly Mesdames S. Mathew and D. Zietsman, conducted the actual analyses of aliquot samples. The then Department of Agricultural – Technical Services provided facilities for determining the surface area of hyrax habitat and provided the 17 Karakul ewes for measurement.

The sheep-farming community of southern South West Africa is thanked for their hospitability and many kindnesses and Messrs. M. J. Smit and A. P. van Niekerk, owners of the two study farms, are acknowledged for permission to work on their land.

To my wife, Emile, who typed the manuscript, and to my children, I owe much for support and encouragement.

7 REFERENCES

BAUMGARTNER, L. L. and MARTIN, A. C.
1939: Plant histology as an aid in squirrel food-habit studies. *J. Wildl. Manage.* 3:266–268.

BIGALKE, R.C.
1972: Observations on the behaviour and feeding habits of the springbok, *Antidorcas marsupialis*. *Zool. Afr.* 7:333–359.

CARLETON, W. M.
1966: Food habits of two sympatric Colorado squirrels. *J. Mamm.* 47:92–103.

CHAPMAN, R. F.
1957: Observations on the feeding of adults of the locust. *Brit. J. Anim. Behaviour* 2:60–65.

COE, M. J.
1962: Notes on the habits of the Mount Kenya hyrax (*Procavia johnstoni mackinderi* Thomas). *Proc. Zool. Soc. Lond.* 138:638–644.

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.
1962: Sieve mesh size related to analysis of antelope rumen contents. *J. Wildl. Manage.* 26:327–328.

DUSI, J. L.
1949: Methods for the determination of food habits by plant microtechniques and histology and their application to cottontail rabbit food habits. *J. Wildl. Manage.* 13: 295–299.

FIELD, C. R.
1970: A study of the feeding habits of the hippopotamus in 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.

HALL-MARTIN, A. J.
1974: Food selection by Transvaal Lowveld giraffe as determined by analysis of stomach contents. *J. Sth. Afr. Wildl. Mgmt. Ass.* 4:191–202.

HANSE, W. A.
1962: Inleidende studie van die dassie, *Procavia capensis*, sy verhouding tot die boerdery in Suid-Afrika en beheermetodes. *Verslag nr. 19 Departement van Natuurbewaring in Kaapprovinsie:* 108–121.

HEWSON, R.
1962: Food and feeding habits of the mountain hare *Lepus timidus scoticus* Hilzheimer. *Proc. Zool. Soc. Lond.* 139:515–526.

HOECK, H. N.
1975: Differential feeding behaviour of the sympatric hyraces *Procavia johnstoni* and *Heterohyrax brucei*. *Oecologia* (Berl.) 22:15–47.

HOFMANN, R. R. and STEWART, D. R. M.
1972: Grazer or browser: a classification based on the stomach structure and feeding habits of East African ruminants. *Mammalia* 36:226–240.

LENSING, J. E.
1980: Leaf blade epidermal anatomy of 39 monocotyledon species from southern South West Africa. *Madoqua* 12:71–122.

LENSING, J. E. and JOUBERT, E.
1977: Intensity distribution patterns for five species of problem animals in South West Africa. *Madoqua* 10: 131–141.

LENSING, J. E. and LE ROUX, C. J. G.
1982: Herbage availability inventories in rock hyrax habitat in southern South West Africa. *Madoqua* 13:45–57.

LIVERSIDGE, R.
1970: Identification of grazed grasses using epidermal characters. *Proc. Grassl. Soc. S. Afr.* 5: 153–156.
1972: Grasses grazed by springbok and sheep. *Proc. Grassl. Soc. S. Afr.* 7: 32–38.

LOUW, G. N.
1971: Water economy of certain Namib desert animals. *S. Afr. J. Sci.* 67:119–123.

LOUW E., LOUW G. N. and RETIEF, C. P.
1972: Thermolability, heat tolerance and renal function in the dassie or hyrax, *Procavia capensis*. *Zool. Afr.* 7: 451–469.

MARTIN, D. J.
1955: Features on plant cuticle. *Trans. Bot. Soc. Edinb.* 36: 278–287.

MILLAR, R. P.
1971: Reproduction in the rock hyrax (*Procavia capensis*). *Zool. Afr.* 6:243–261.
1972: Degradation of spermatozoa in the epididymus of a seasonally breeding mammal, the rock hyrax, *Procavia capensis*. *J. Reprod. Fert.* 30:447–450.
1973: An unusual light-shielding structure in the eye of the dassie, *Procavia capensis* Pallas (*Mammalia: Hyracoidea*) *Ann. Trans. Mus.* 28: 203–205.

MILLAR, R. P. and FAIRALL, N.
1976: Hypothalamic, pituitary and gonadal hormone production in relation to nutrition in the male hyrax (*Procavia capensis*). *J. Repord. Fert.* 47: 339–344.

MILLAR, R. P. and GLOVER, T. D.
1970: Seasonal changes in the reproductive tract of the male rock hyrax, *Procavia capensis*. *J. Reprod. Fert.* 23: 497–499.
1973: Regulation of seasonal sexual activity in an ascrotal mammal, the rock hyrax, *Procavia capensis*. *J. Reprod. Fert. Suppl.* 19:203–220.

PALGRAVE, K. C.
1977: *Trees of Southern Africa*. C. Struik, Cape Town.

PETRIDES, G. A.
1975: Principal foods versus preferred foods and their relations to stocking rate and range condition. *Biol. Conserv.* 7:161–169.

SALE, J. B.
1965a: The feeding behaviour of rock hyrax (genera *Procavia* and *Heterohyrax*) in Kenya. *E. Afr. Wildl. J.* 3: 1–13.
1965b: Hyrax feeding on a poisonous plant. *E. Afr. Wildl. J.* 3:127.
1966: The daily food consumption and mode of ingestion in the hyrax. *J. E. Afr. Nat. Hist. Soc.* 25:215–224.

SIEGEL, S.
1956: *Nonparametric statistics*. McGraw-Hill Book Company. New York.

SPARKS, D. R.
1968: Diet of black-tailed jackrabbits on sandhill rangeland in Colorado. *J. Range Manage.* 24:203–208.

THOMAS, A. D.
1946: The Cape dassie. *African Wildlife* 1:64–68.

TURKOWSKY, F. J.
1975: Dietary adaptability of the desert cottontail. *J. Wildl. Manage.* 39:748–756.

TURNER, M. I. M. and WATSON, R. M.
1965: An introductory study on the ecology of hyrax (*Dendrohyrax brucei* and *Procavia johnstoni*) in the Serengeti National Park. *E. Afr. Wildl. J.* 3:49–60.

WILSON, D.E., HIRST, S.M. and ELLIS, R. P.
1977: Determination of feeding preferences in wild ruminants from trocar samples. *J. Wildl. Manage.* 41:70–77.