

First approximation of food preferences and the chemical composition of the diet of the desert-dwelling black rhinoceros, *Diceros bicornis* L.

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ABSTRACT

Food preferences of black rhino inhabiting an area of extreme aridity in Damaraland SWA/Namibia were examined using a transect survey method. A wide variety of plant species were browsed by rhino in this region. Of the 103 species of plants encountered, 74 were used and the selection indices showed a moderate degree of selectivity on the part of browsing rhino. The chemical composition of a selected number of plants favoured by rhino contained moderately high levels of soluble tannins but these chemical deterrents apparently had no effect on the feeding preferences of these animals.

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1 INTRODUCTION

The hooklipped or black rhinoceros, *Diceros bicornis* Linn. (1758) was originally widely distributed in the southern African subregion. In South West Africa/Namibia their distribution extended from the Kunene river southwards along the escarpment to the Orange river and eastwards past Gobabis at 22° (Joubert and Eloff 1971). Early hunters and explorers eliminated a large proportion of the original population, leaving isolated but viable breeding populations in the arid terrain of the north west regions. From 1970 to 1972, 43 rhino were removed from the population still surviving in Damaraland and taken to the Etosha National Park in an attempt to protect the species (Hofmeyr et al. 1975). The estimated number of rhino now remaining in the arid desert habitat of the Skeleton Coast, Kaokoland and Damaraland is about 60; their distribution covers more than 20 000 km². Western Damaraland supports the majority of the present population which ranges over this very rugged and arid terrain, an area entirely unsuitable for conventional farming and where the human population is very small. More recently the illegal trade in rhino horn which has escalated throughout the world has caused an 85% decrease in the population world wide in only 14 years (Bradley Martin 1984). The International Union for the Conservation of Nature (IUCN) has recommended that these South West Africa/Namibia rhino receive priority conservation status within the arid habitat in which they live. Negotiations for the proclamation of areas to protect these rhino are presently underway.

The purpose of this investigation was to examine the diet of the rhino within the arid northwestern portion of SWA/Namibia (Plate 1). Several extensive studies on rhino diet have been carried out elsewhere in Africa (Goddard 1968, 1970, Joubert 1971, Hall-Martin et al.

1982, Mukinya 1977, Schenkel and Schenkel-Hullinger 1969), but in view of the extreme aridity prevailing in this region results from elsewhere cannot be directly applied here. Food availability and food preferences during the dry season plus the possible role of water, protein, fat, crude fibre, ash and tannin content, which may influence these preferences, were examined. The area under investigation is situated in the southernmost region of the distribution of the rhino population. (Fig. 1). It was hoped that this investigation would contribute information towards formulating priorities for the conservation and management of the Damaraland rhino.

2 PROCEDURE

2.1 The Study Area

The study area is situated east of the Skeleton Coast Park and west of the inhabited farmlands in Damaraland (Plate 2). The annual rainfall is less than 100 mm and periodic droughts may last for three of four years. Open gravel plains are interspersed with outcrops of granite boulder islands and transected by sandy riverbeds, which sustain the main food plants of the rhino. These tributaries run into hot dry valleys surrounded by rugged shale, schist, quartzite and mar-

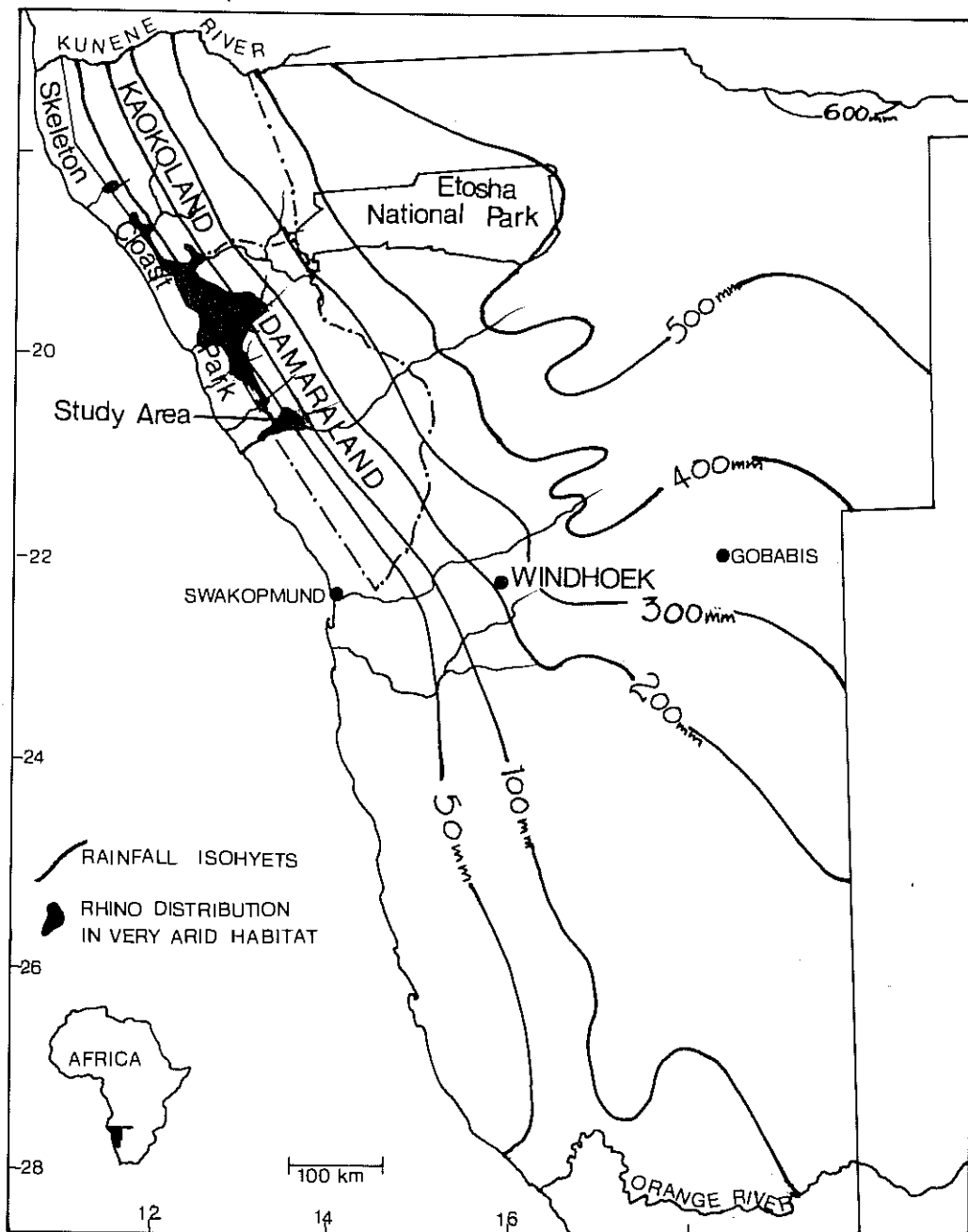


FIGURE 1: Position of the study area in relation to the distribution of black rhino in Damaraland and Kaokoland.

ble ridges which form the Ugab river valley (Hodgson 1972). Annual rains to the east of the study area result in flooding of the riverbeds and support growth of permanent vegetation in these riverbeds. Isolated waterholes and the succulent flora in the mountains of the study area are maintained by scattered and irregular, local showers which occur from January to March.

2.2 Animal Observations

The movements of each rhino we studied were plotted on a map. Observations were sometimes by direct sightings. When direct sightings were not possible because of the vast and rugged nature of the terrain, fresh and recognisable foot impressions of the rhino spoor that were clearly visible on the substrate were considered to be sufficient evidence of their presence. These spoor were measured and compared with an identification file of the spoor sizes and photographs of the rhino in the area and their positions were plotted on a map. Seasonal movements of individuals were then recorded and an estimate of their home ranges determined. Seventeen direct sightings were recorded during the 576 hours spent monitoring the home range. Thirteen of these sightings were cow and calf

pairs, three were cow and bull pairs and a lone bull was recorded once.

2.3 Food Preference

A list of plants definitely eaten by rhino was compiled from direct observations and verified by specimens collected for identification. These observations were facilitated by the paucity of other large herbivores in the study area and the characteristic damage inflicted on plants by feeding rhino. The home range was monitored each month to determine the routes most often used by the animals. It was found that they tended to re-use routes to feed and that fresh tracks were usually present on each monitoring visit. This led to the selection of six feeding routes. Each one represented a variation in the vegetation types which were frequently used and they were titled ROUTES A,B,C,D,E & F.

During January 1985, the driest month before the rains fell, each of the six feeding Routes was studied by first locating rhino tracks and indications of feeding having taken place or by location of one or more feeding rhino. Thereafter the following sampling method was employed. After selecting a route, all the



PLATE 1: Large male black rhino in excellent condition feeding on *Euphorbia virosa*, a plant possessing strong chemical defenses against herbivores.

species of plants available within a circle of 20 m diameter from a designated point, together with the number of individuals within each plant species, were recorded to assess the availability of the various species. The feeding track was then followed for 200 m to a second circle where the above estimate of availability was repeated. While following the 200 m route exactly along the track taken by the rhino, the number of bites (Hall-Martin et al. 1982) from each plant species browsed by the rhino was recorded on a pocket tape recorder. Availability of species along this track was not recorded. The entire procedure was repeated six times on each Route A,B,C,D,E and F. A total of 36 feeding tracks and their 72 'availability' circles was studied. Eventually a list of all the plant species together with the number of bites taken from the browsed plants was compiled (Table 1). Because of the difficulties experienced in differentiating between the two species *Merremia querichii* and *M. bipinnatifartita* during the collection of field data, these two species have been combined in this report as *Merremia* spp. both species were equally well favoured and all parts of the plant were eaten.

Hills' N_2 values: - ($N_2 = 1/CP_1^2 + P_1 + \dots P_n^2$) (Hill 1973) were calculated for the number of bites taken and for the number of plants available on the six

portions of each route. These N values provided an indication of the diversity of available forage and the diversity of plants eaten.

2.4 Analytical Procedures

The 19 plant species collected for analyses were selected during the preliminary monitoring of Routes and observations of feeding behaviour. They represent some of the plants browsed by the rhino within the investigation area. All samples were placed in plastic bags immediately after collection in the field and were kept at 4°C prior to air shipment to the University of Cape Town within 48 hours. They were frozen on arrival at the laboratory and stored for later analyses. All samples were replicated three times and the following analyses performed.

2.4.1 Proximate Analysis

Water content was determined by oven-drying to a constant weight at 60°C. The plant samples were then coarsely ground in a Wiley mill and sub-samples received further grinding in a mortar and pestle. Total ash determinations were made by heating samples to 450°C for 3 hours in a muffle furnace. Crude fibre,



PLATE 2: A *Euphorbia virosa* severely damaged by browsing rhino.

protein and crude fat determinations were carried out by using standard A.O.A.C. methods (A.O.A.C. 1975), while soluble carbohydrates were estimated by difference. The energy content of each plant food was calculated from the results obtained from the proximate analysis (Durrin and Passmore 1976).

2.4.2 Determination of Tannin/Polyphenols

Plant material was stored frozen without drying. When required for analyses, the samples were thawed and each was cut into small pieces. A thoroughly mixed sub-sample of 3-5g was then homogenised in

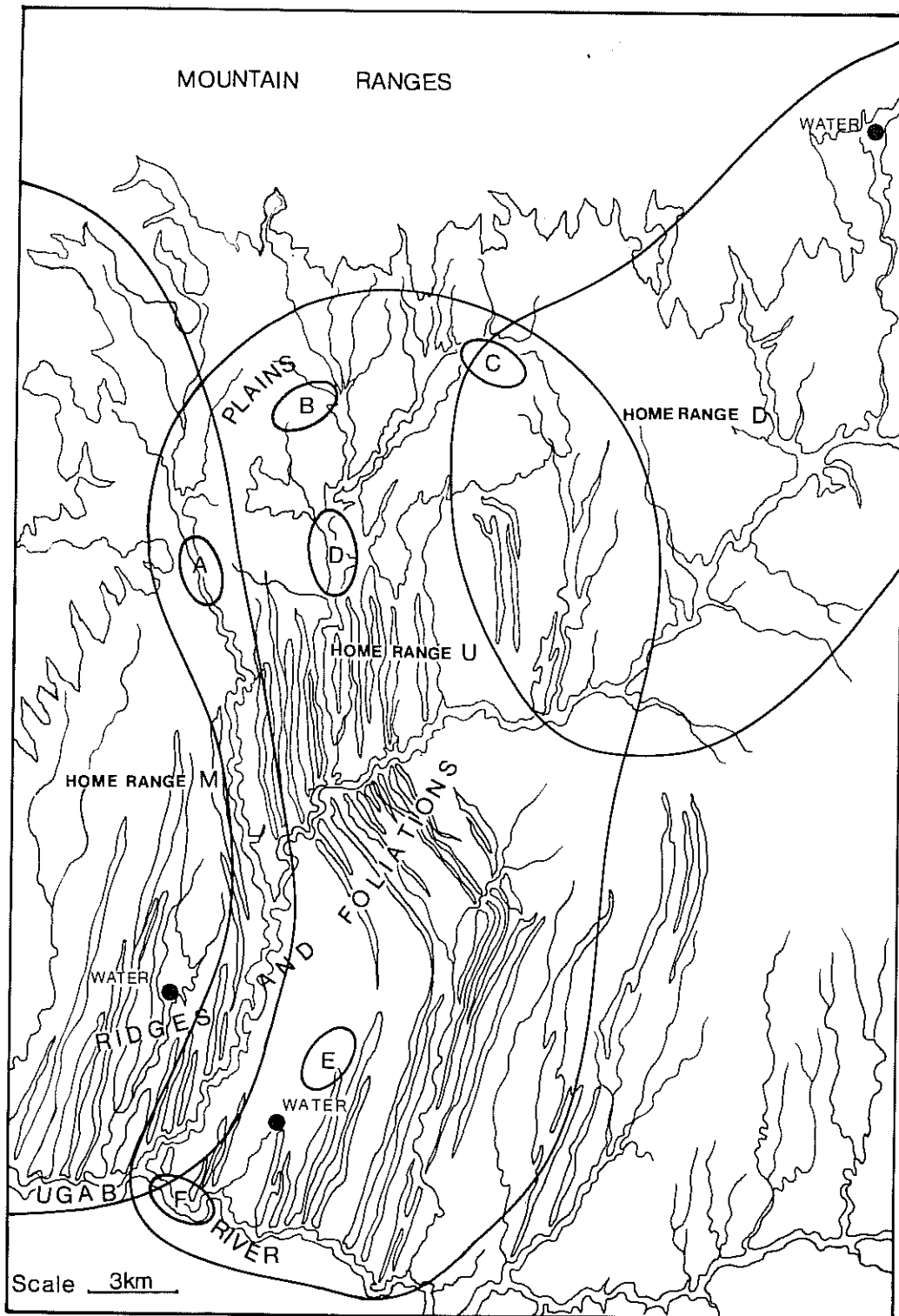


FIGURE 2: Estimated size and position of the three home ranges "D", "M", and "U" (map from Hodgson 1972). See text for explanation.

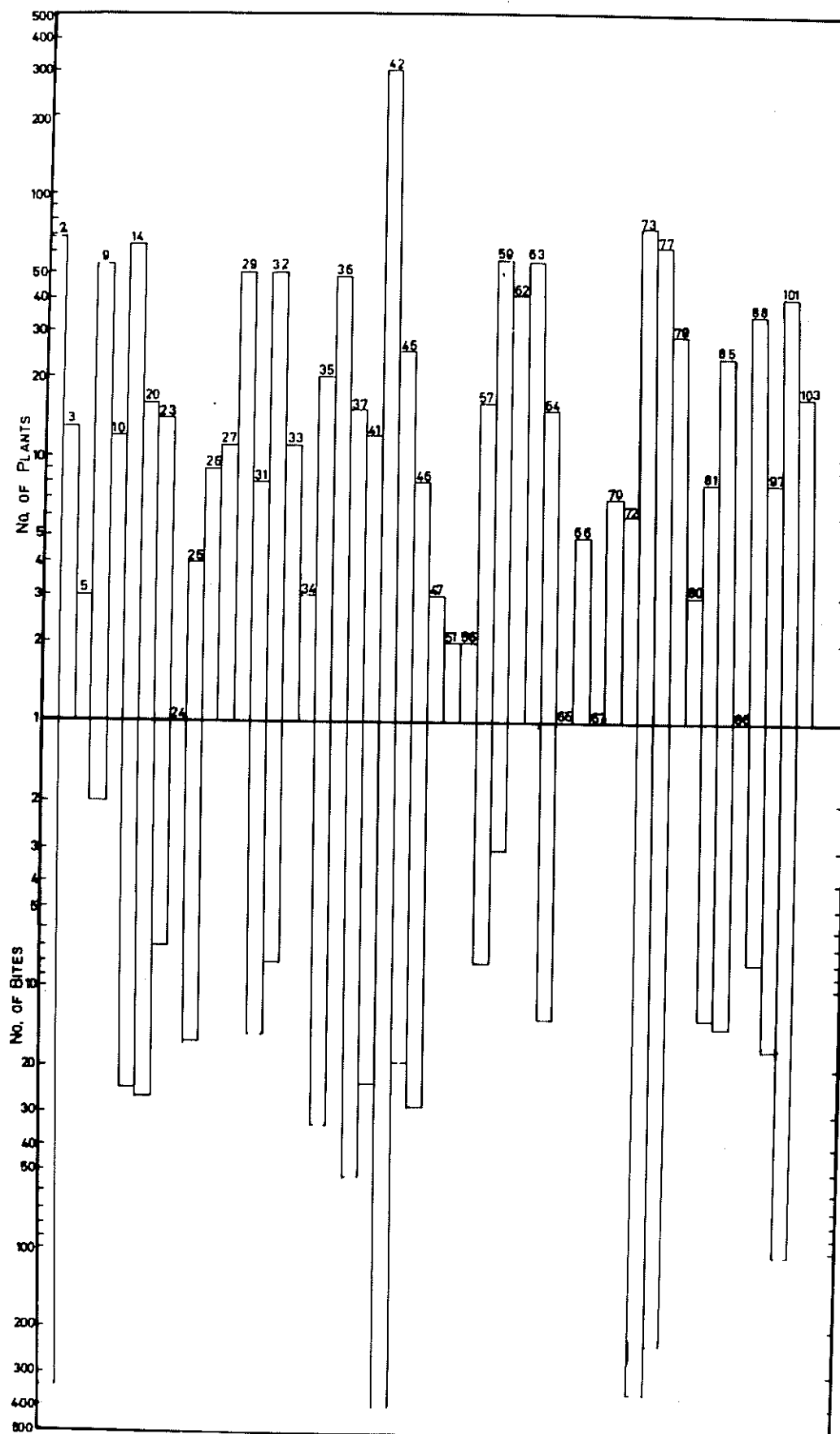


FIGURE 3: ROUTE A — Graphic presentation on semi-log scale of the abundance of various plant species plotted opposite their usage by the black rhino. The number above each bar denotes a particular plant species listed in Table 1.

50-100 ml of pure (98%) methanol using a high-speed blender. The methanol was decanted and extraction completed by washing the residue three times in boiling pure methanol (70°C) and then twice in boiling 50% methanol (80°C). Each wash lasted approximately 5 min. The pure and 50% extracts were pooled and filtered through Whatman No. 1 cellulose filter paper (in a few cases vacuum filtration using GF/C filters was necessary). The final volume was then measured and the extract refrigerated until analysed.

Soluble tannins were determined using Folin-Denis reagent, as outlined by Allen (1974). Dillutions of a freshly prepared aqueous solution of tannic acid (0.1 mg ml⁻¹) were used to construct a standard curve. After addition of Folin-Denis reagent and Na CO solution, samples and standards were kept at 25°C for 20 min and the absorbance measured at 760 nm. The tannin content of the plants has been expressed as a percentage of the wet weight.

2.4.3 Faecal Calcium and Phosphorus

The levels of calcium and phosphorus in rhinoceros faeces were determined to estimate the nutritional status of the animals with respect to these two important minerals (Belonje 1978). Calcium was analysed by the standard atomic absorption technique and phosphorus by the method description by Hanson (1950).

3 RESULTS AND DISCUSSIONS

3.1 Home Ranges

Three home ranges, covering an area of circa 2000 km², overlap in the area chosen for the study. The central and most heavily utilised range 'U' (circa 500 km²) was selected for the feeding investigation (Fig. 2). This home range was monitored each month for six months during the dry season which was the critical time. The period just preceeding and during full moon was chosen to facilitate sightings of rhino at waterholes. Five rhino used Home Range 'U'; a mature cow with a calf of nearly a year old, a younger cow which gave birth to a calf nearly halfway through the dry period and a mature bull. The overlapping home range 'M' accommodated three animals one of which was a mature bull, the remaining two were seen once but were not sexed. Home range 'D' which overlapped from the east, accommodated four rhino consisting of two mature bulls, a sub-adult cow and one of unknown sex.

3.2 Route Descriptions

ROUTE A

This route traversed a dry watercourse with scattered vegetation occupying the sandy riverbed which ran between broken shale ridges. Throughout the dry season 48 species of plants were recorded; rhino fed upon 25

of these species during the time of the investigation (Fig. 3). The two *Merremia* species were the most favoured, *Blepharis gigantea*, *Gossypium anomolum* and *Acacia reficiens* were fairly abundant and equally favoured.

ROUTE B

Route B traversed sparsely vegetated gravel plains with granite boulder outcrops. Rhino tended to feed on these plains during the early hours of the day and during the cool evenings and nights. Throughout the dry season 34 species of plants were noted; the rhino fed upon 22 of these species (Fig. 4). *Adenolobus pechuellii* was the most abundant species and the species most frequently consumed. *Merremia* spp. and *Calicorema capitata* were somewhat less abundant and together with *Acacia reficiens*, were the next most preferred food items. *Boscia foetida* was fairly abundant but was not highly favoured; *Sterculia africana* was very scarce but well favoured; 50% of the available *Welwitschia mirabilis* showed signs of browsing.

ROUTE C

This route was a winding path climbing steeply up an extremely rocky gulley on which the vegetation became increasingly sparse as the route progressed up the edge of an ancient, heavily eroded crater. On this route 35 plant species were noted of which 23 were eaten by rhino (Fig. 5). *Petalidium variable* and *Commiphora kraeuseliana* were the most abundant species and showed about 50% usage, whereas *Euphorbia virosa* was most frequently eaten although it was only 30% as abundant. The most common plant species recorded in the 'availability' circles were poorly represented (7%) among the species browsed by the rhino.

ROUTE D

Route D traversed a dry, sandy riverbed bordered by fairly well vegetated banks and was the most frequently used feeding route, situated approximately 20 km from the dry-season waterpoint. Forty-six species were recorded, of which 35 were eaten by the rhino (Fig. 6). Six species were particularly abundant: of these *Stipagrotis damarensis*, *Petalidium variable*, *Calicorema capitata* and the two *Merremia* species were frequently eaten but the other common species were not. Instead the less common species, e.g. *Blepharis gigantea*, *Acacia reficiens*, *Terminalia prunioides* and *Gossypium anomolum*, constituted the species more frequently eaten by the rhino. A well worn pathway and a large number of dung middens on this route indicated a high intensity of usage by rhino in the dry season.

ROUTE E

This route traversed extremely rocky and arid terrain where the vegetation was very sparse. The route was

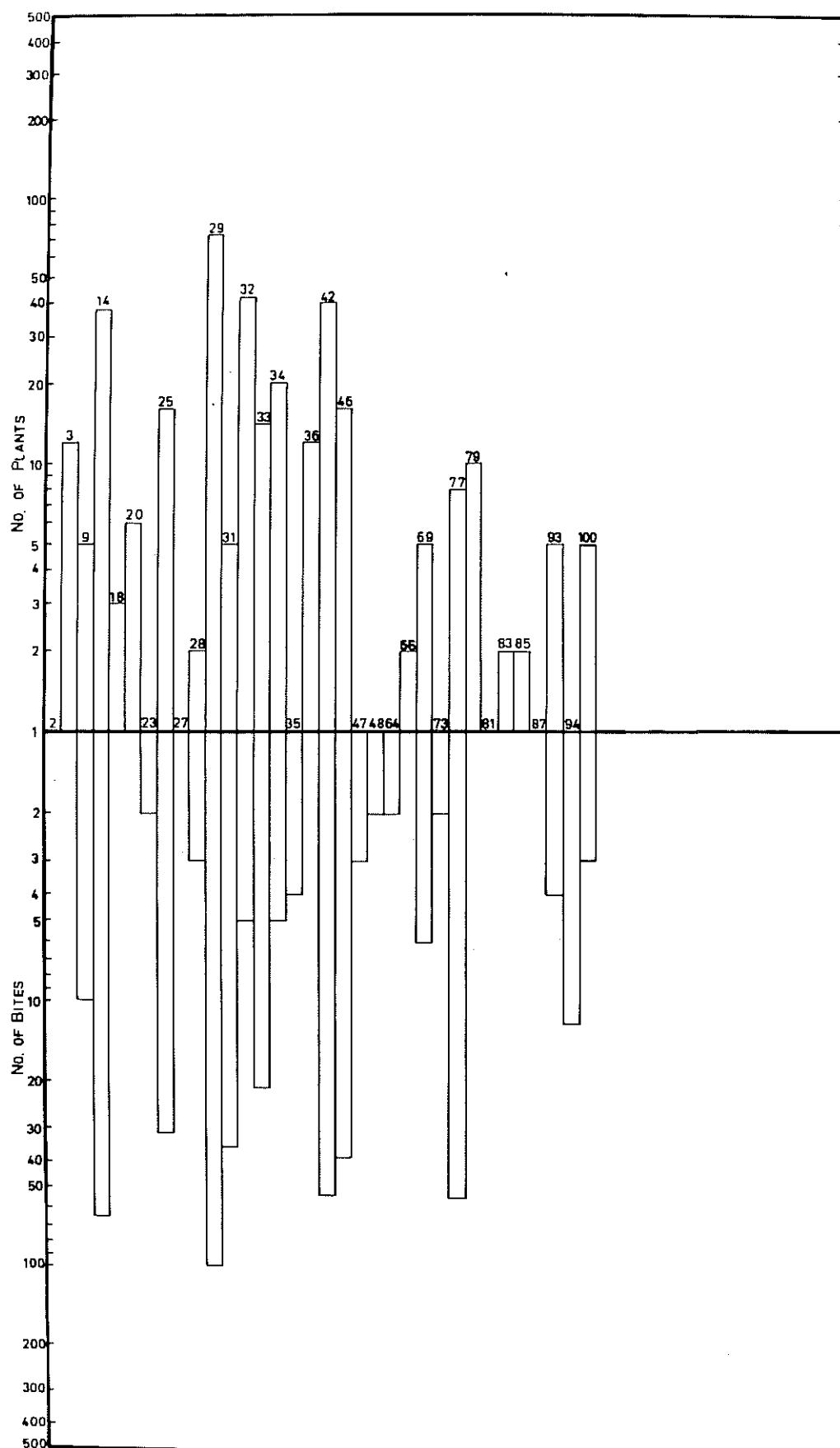


FIGURE 4: ROUTE B — Graphic presentation on semi-log scale of the abundance of various plant species plotted opposite their usage by the black rhino. The number above each bar denotes a particular plant species listed in Table 1.

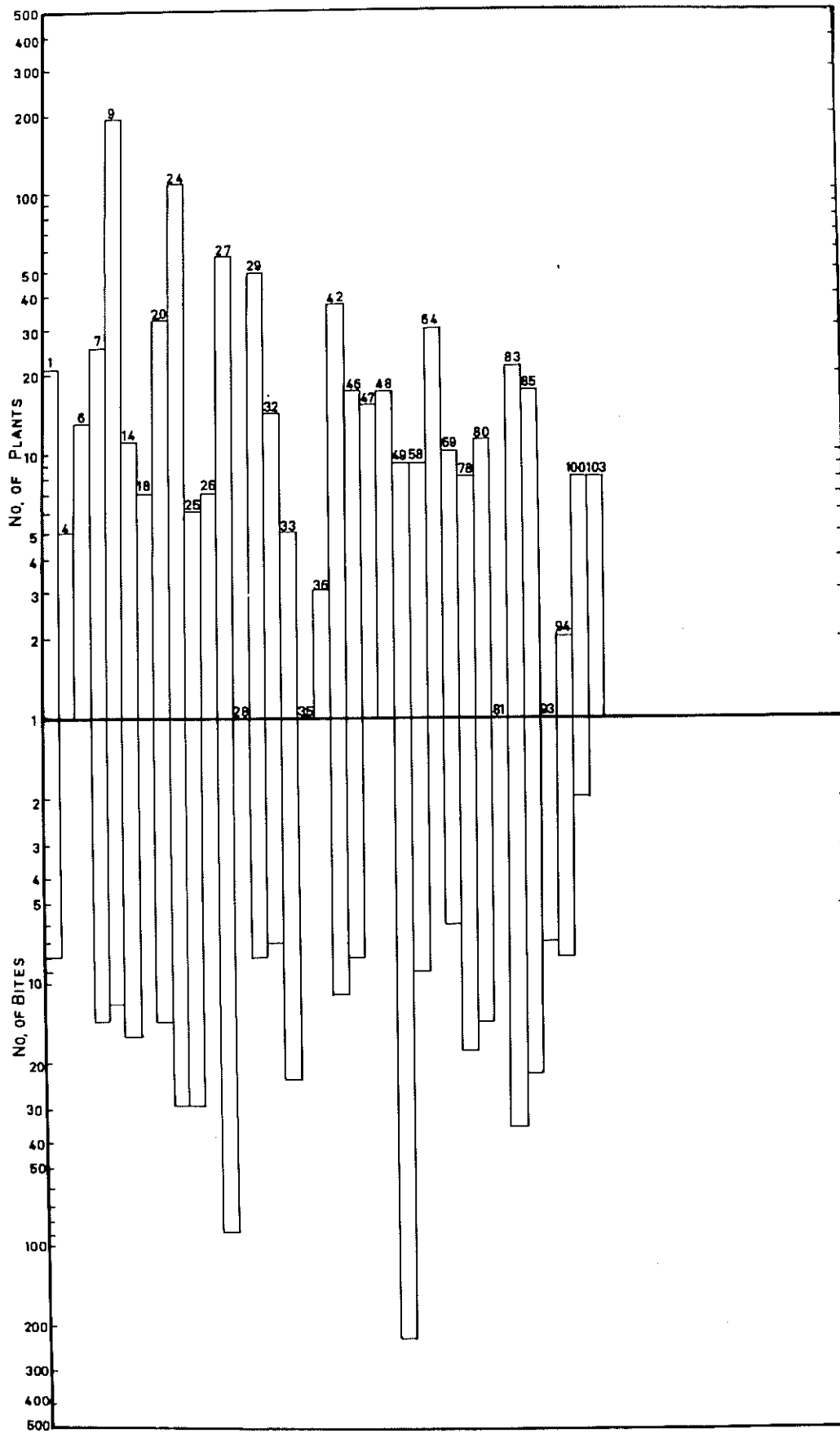


FIGURE 5: ROUTE C — Graphic presentation on semi-log scale of the abundance of various plant species plotted opposite their usage by the black rhino. The number above each bar denotes a particular plant species listed in Table 1.

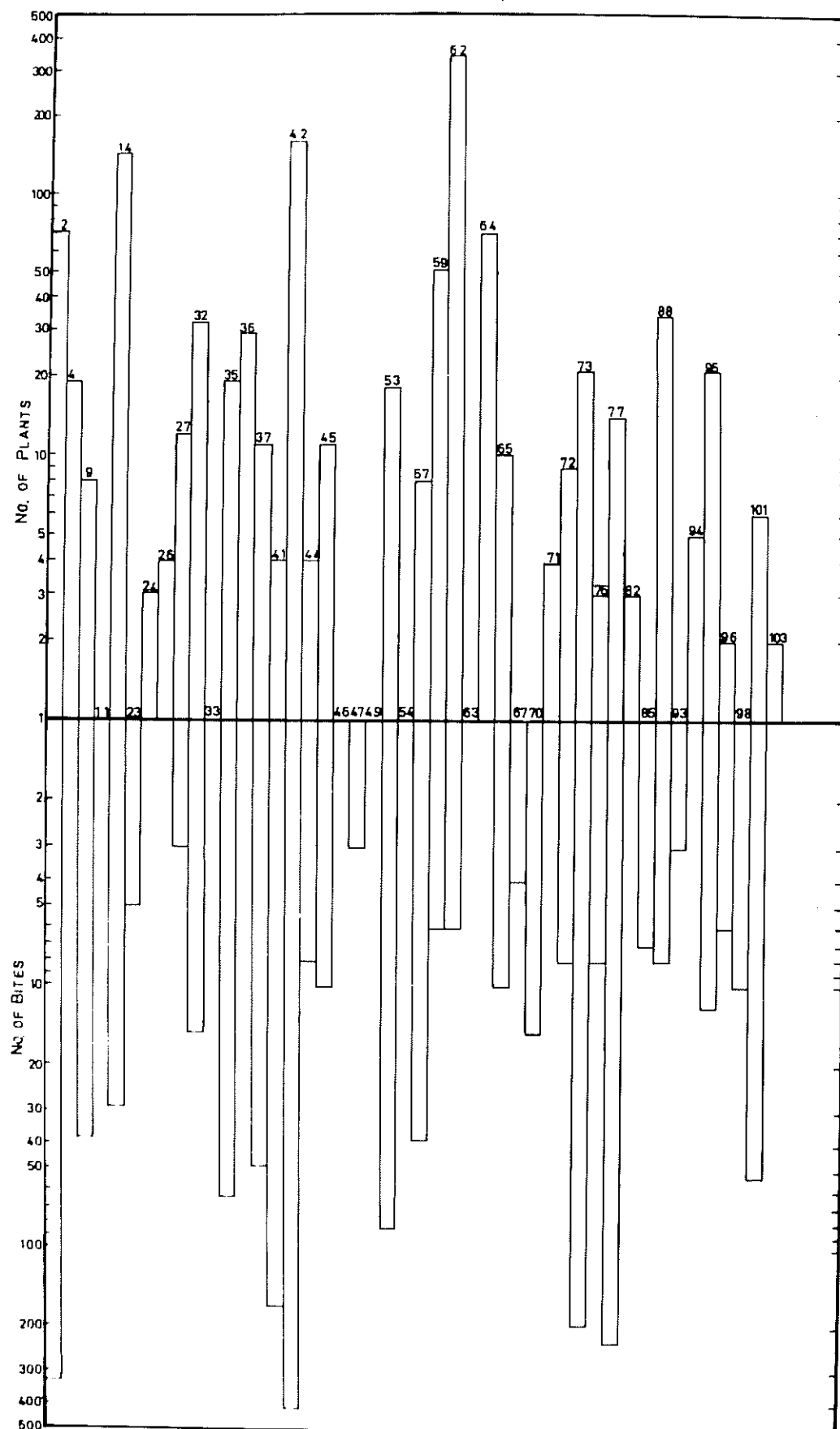


FIGURE 6: ROUTE D — Graphic presentation on semi-log scale of the abundance of various plant species plotted opposite their usage by the black rhino. The number above each bar denotes a particular plant species listed in Table 1.

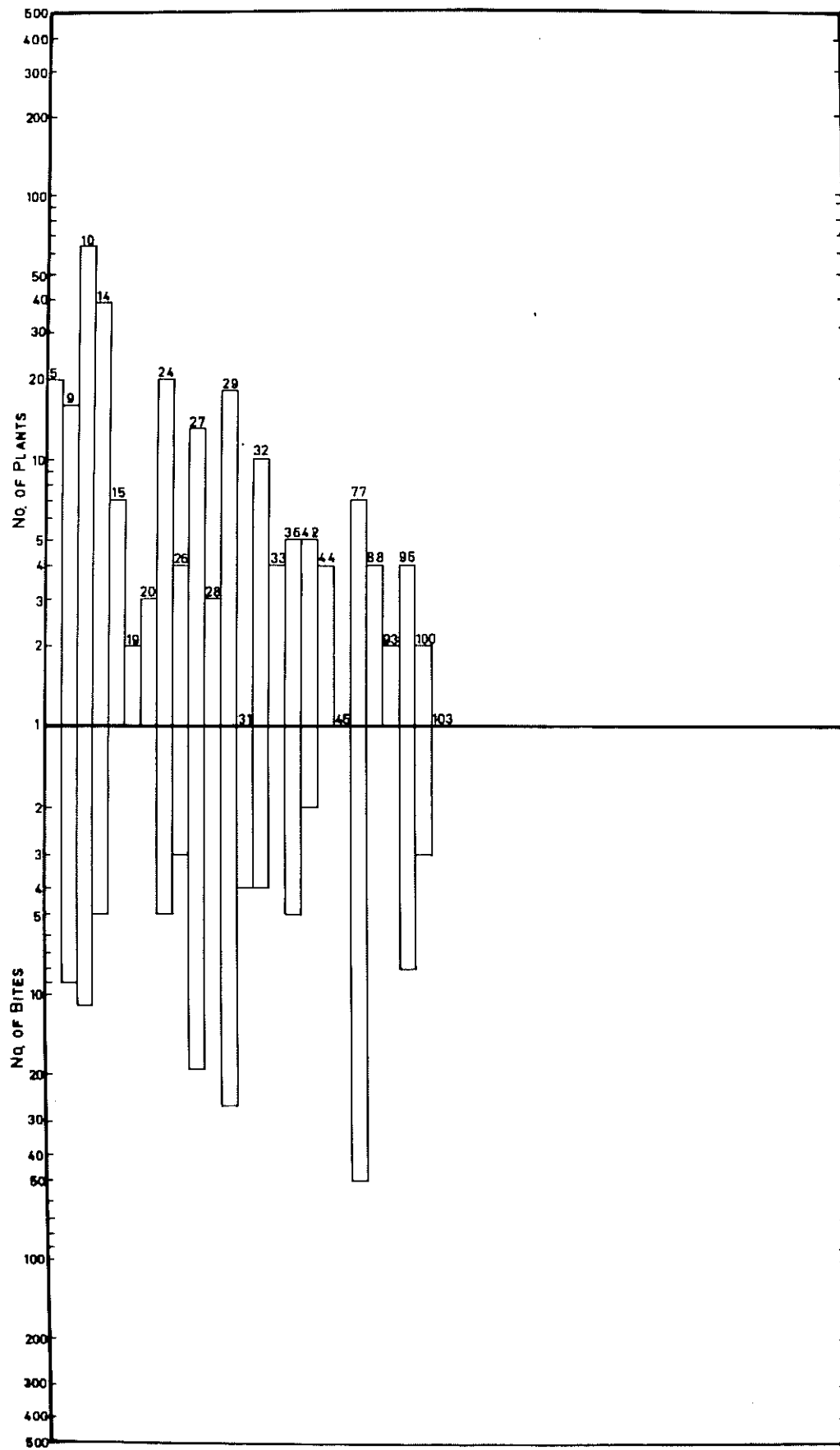


FIGURE 7: ROUTE E — Graphic presentation on semi-log scale of the abundance of various plant species plotted opposite their usage by the black rhino. The number above each bar denotes a particular plant species listed in Table 1.

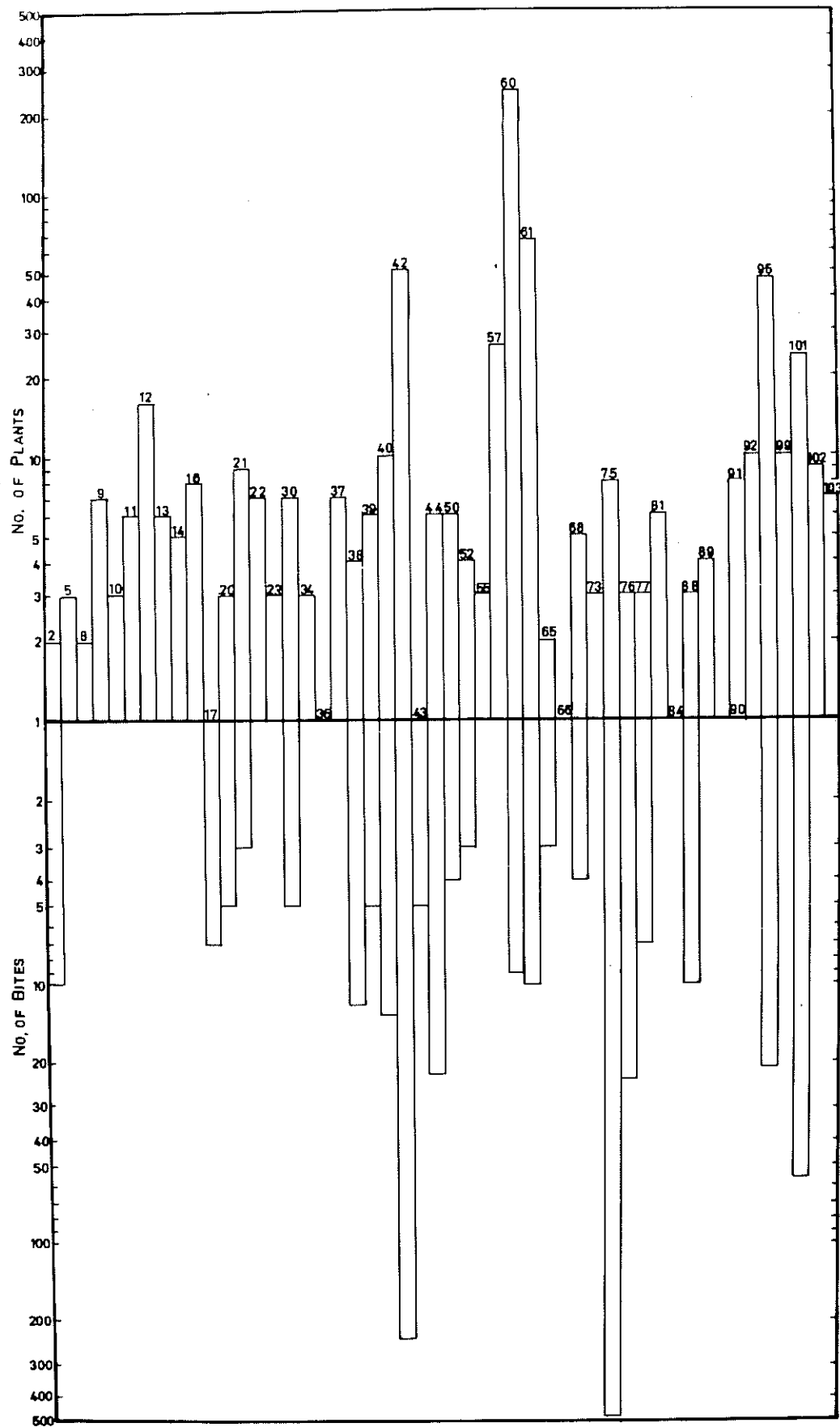


FIGURE 8: ROUTE F — Graphic presentation on semi-log scale of the abundance of various plant species plotted opposite their usage by the black rhino. The number above each bar denotes a particular plant species listed in Table 1.

heavily used by rhino because this pathway provided direct access to water from the feeding grounds (ROUTES A,B,C,D). The rhino tended to forage over the rugged terrain on the return trip from the water to the favoured feeding ground. This route showed the lowest diversity of plant species available, 25, of which only 14 were eaten (Fig. 7). *Commiphora virgata* and *Adenolobus pechuelii* were nearly equally available and each equally well browsed. The tree *Acacia reficiens* grows as a stunted shrub because of continual browsing by rhino but was not readily available.

ROUTE F

This route traversed a major river course with intermittent patches of open water and relatively abundant vegetation, separated by open stretches of sand where vegetation was limited. The route was situated within easy reach of the waterpoint on Route E, but was infrequently used by rhino during the investigation period. This was possibly due to the presence of humans in the area where vehicles frequently traversed the riverbed. On Route F, 50 species were recorded of which 25 were eaten (Fig. 8). The reed *Phragmites australis* was the most abundant plant species but was only eaten in localised patches. The survey technique showed a low abundance of *Acacia albida*, because of

the large areas occupied by the tree canopies. It was, however, well browsed. The creeper forbs of the two *Merremia* species were again fairly well represented and well used.

3.3 Food Preferences

The plants available in the area as well as those consumed by the rhino have been listed alphabetically according to family (Table 1). Genus and species names have been included wherever possible. The list of species consumed also indicates food preferences, expressed as number of bites divided by availability, during the period of this investigation. These preferences included unexpected species such as *Euphorbia virosa* (Plate 3) even though this species was not well represented on the study routes. *Euphorbia virosa* grows in the study area on steep slopes covered by rocky scree difficult to traverse but evidence of rhino having fed upon these plants was abundant. A rhino cow was observed (R. Loutit, pers. comm.) feeding on one such plant for an hour and a half. The remains of the plant were examined after the rhino had left and measurements were taken. The diameter of the basal cover of the plant measured 178 cm. and the height of the branches from ground level was 165 cm. The lower sections of 68 branches which remained indicated that



PLATE 3: Study area in the dry season.

TABLE 1: List of all species encountered in the six routes (A–F) and their associated availability circles. Families are ordered alphabetically and genera are listed alphabetically within families. For each route an index of usage (number of bites taken along track/number of plants in 'availability' circles) was calculated. A '0' indicates no bites were taken; a '+' indicates bites were recorded on track but plant was not recorded in circles; a blank indicates neither bites nor plants were noted. ID No. refer to this study only.

PLANTS	ROUTES						ID No.
	A	B	C	D	E	F	
ACANTHACEAE							
<i>Barleria rogersii</i>			0.38				1
<i>Blepharis gigantea</i>	4.88	0		4.54	0	5.00	2
<i>B. bossii</i>	0	0					3
<i>Monechma arenicola</i>			0	0.05			4
<i>M. divaricatum</i>	0				0	0	5
<i>Petalidium</i> Sp. nov			0				6
<i>P. canescens</i>				0.56			7
<i>P. halimoides</i>						0	8
<i>P. pilosi-bracteolatum</i>	0				0.17	0	9
<i>P. variabile</i>	0.04	2.00	0.06	0.19	0.56	0	10
<i>Ruellia diversifolia</i>				+		0.17	11
AIZOACEAE							
<i>Sesuvium sesuvioides</i>						0	12
AMARANTHACEAE							
<i>Arthraerua leubnitziae</i>						0	13
<i>Calicorema capitata</i>	0.38	1.71	1.45	0.20	0.13	0	14
<i>Leucosphaera bainesii</i>					0		15
ASTERACEAE							
<i>Calostephane marlothiana</i>						0	16
<i>Epaltes gariepina</i>						+	17
<i>Helichrysium herniarioides</i>		0	0				18
<i>H. roseo-niveum</i>					0		19
<i>Osteospermum microcarpum</i>	1.62	0	0.44		0	1.67	20
spp. septentrionale							
<i>Pechuel-Loeschae leubnitziae</i>						0.33	21
<i>Pluchea dioscoridis</i>						0	22
BORAGINACEAE							
<i>Trichodesma africanum</i>	0.50	+		+		0	23
BURSERACEAE							
<i>Commiphora kraeuseliana</i>	0		0.26	0	0.25		24
<i>C. pyracanthoides</i>	4.00	2.63	4.83				25
<i>C. saxicola</i>	0		0	0	0.75		26
<i>C. virgata</i>	0	0	1.57	0.75	1.46		27
<i>C. wildii</i>		1.50	0		0		28
CAESALPINIACEAE							
<i>Adenolobus pechuelii</i>	0	1.36	0.17		1.44		29
<i>Colophospermum mopane</i>						0.71	30
<i>Parkinsonia africana</i>	1.88	7.00			4.00		31
CAPPARACEAE							
<i>Boscia foetida</i>	0.16	0.10	0.50	0.47	0.40		32
<i>Cadaba schroepellii</i>	0	1.5	4.6	0	0		33
<i>Cleome foliosa</i>	0	0.75				0	34
<i>Maerua juncea</i>	1.65	+	0	3.32			35
<i>M. schinzii</i>	0	0	0	0	1.00	0	36
CELASTRACEAE							
<i>Maytenus senegalensis</i>	3.47			4.36		0	37
CHENOPODIACEAE							
<i>Atriplex vestita</i>						3.00	38
<i>Salsola aphylla</i>						0.83	39
<i>Suaeda plumosa</i>						1.30	40
COMBRETACEAE							
<i>Terminalia prunioides</i>	1.92			41.50			41
CONVOLVULACEAE							
<i>Merremia bipinnatifidita</i> and <i>M. guerichii</i>	1.32	1.32	0.31	2.61	0.40	4.61	42
CYPERACEAE							
<i>Juncellus laevigatus</i>						+	43
<i>Scirpus dioicus</i>				2.00	0	3.67	44

PLANTS	ROUTES						ID No.
	A	B	C	D	E	F	
EBENACEAE							
<i>Euclea pseudebenus</i>	0.76			0.89	0		45
EUPHORBIACEAE							
<i>Euphorbia damarana</i>	3.50	2.38	0.47	0			46
<i>Euphorbia sp. nov.</i>	0	+	0	+			47
<i>E. phylloclada</i>		+	0				48
<i>E. virosa</i>			24.89	0			49
<i>Ricinus communis</i>						0.67	50
FABACEAE							
<i>Crotalaria damarensis</i>	0						51
<i>C. platysepala</i>						0.75	52
<i>Indigofera guerrana</i>				4.56			53
<i>Otoptera burchellii</i>				+			54
<i>Psoralea obtusifolia</i>						0	55
<i>Rhynchosia candida</i>	0						56
<i>Sesbania pachycarpa subsp. dinterana</i>	0.50			4.75		0	57
GERANIACEAE							
<i>Sarcocaulon mossamedense</i>	0.05		1.00				58
GRAMINEAE							
<i>Centropodia mossamedense</i>				0.12			59
<i>Phragmites australis</i>						0.04	60
<i>Sporobolus consimilis</i>						0.15	61
<i>Stipagrostis damarensis</i>	0			0.18			62
<i>S. hochstetterana</i>	0			0			63
<i>S. uniplumis</i>	0.87	2.00	0	0.01			64
var. <i>uniplumis</i>							
HELIOTROPIACEAE							
<i>Cordia sinensis</i>	0			9.00		1.50	65
<i>Heliotropium tuberulosum</i>	0	0				0	66
HYDROPHYLLACEAE							
<i>Codon schenkii</i>	0			4.00			67
JUNCACEAE							
<i>Juncus rigidus</i>						0.80	68
LILIACEAE							
<i>Protasprargus sp.</i>		1.20	0.60				69
LOASACEAE							
<i>Kissenia capensis</i>	0			+			70
LORANTHACEAE							
<i>Plicosepalus sp.</i>				0			71
<i>Tapinanthus oleifolius</i>	1.17			0.89			72
MALVACEAE							
<i>Gossypium anomalum</i>	4.71	2.00		9.24		0	73
MESEMBRYANTHEMACEAE							
<i>Psilocaulon salicornioides</i>						0	74
MIMOSACEAE							
<i>Acacia albida</i>						59.88	75
<i>A. erioloba</i>				2.67		7.67	76
<i>A. reficiens</i>	3.62	6.75		16.29	7.14	2.33	77
<i>Elephantorrhiza suffruticosa</i>			2.25				78
MOLLUGINACEAE							
<i>Gisekia africana</i>	0	0					79
NYCTAGINACEAE							
<i>Boerhavia deserticola</i>	0		1.27				80
<i>Phaeoptilum spinosum</i>	1.63	0	0			0	81
PEDALIACEAE							
<i>Sesamum marlothii</i>				0			82

PLANTS	ROUTES						ID No.
	A	B	C	D	E	F	
PERIPLOCACEAE							
<i>Curroia decidua</i>		0	1.67				83
<i>Ectadium virgatum</i>						0	84
PLUMBAGINACEAE							
<i>Dyerophytum africanum</i>	0.58	0	1.29	7.00			85
RHAMNACEAE							
<i>Ziziphus mucronata</i>	0						86
RUBIACEAE							
<i>Kohautia lasiocarpa</i>		0					87
SALVADORACEAE							
<i>Salvadora persica</i>	0.23			0.24	0	3.33	88
SOLANACEAE							
<i>Datura innoxia</i>						0	89
<i>Lycium decumbens</i>						+	90
<i>Nicotiana glauca</i>						0	91
<i>Solanum nigrum</i>						0	92
STERCULIACEAE							
<i>Hermannia amabilis</i>		0.80	+	+	0		93
<i>Sterculia africana</i>		12.00	4.00	0			94
TAMARICACEAE							
<i>Tamarix usneoides</i>				0.57	2.00	0.45	95
TILIACEAE							
<i>Grewia flava</i>				3.00			96
<i>G. bicolor</i>	2.12						97
<i>G. tenax</i>				+			98
VAHLIACEAE							
<i>Vahlia capensis</i>						0	99
WELWITSCHIACEAE							
<i>Welwitschia mirabilis</i>		0.60	0.25		1.50		100
ZYGOPHYLLACEAE							
<i>Tribulus zeyheri</i>	2.51			8.83		2.75	101
<i>Zygophyllum simplex</i>						0	102
<i>Z. stapffii</i>	0		0	0	0	0	103

more than half of these had been consumed. The rhino had fed heavily on every plant of this species which was accessible to them in that locality. *Boscia foetida* and *Maerua schinzii* were neglected when other vegetation was available. They were however well browsed during a prolonged period of drought in 1979/80/81.

Petalidium variable was also neglected during the study period but, again, they were well browsed during the prolonged drought of 1979/80/81. *Sterculia africana* was scarce but browse evidence recorded during the monitoring of home ranges, showed that in dry rocky areas this tree was often reduced to a stump through continuous feeding. The plant showed very good recovery after rains fell. *Blepharis gigantea* was browsed and *Welwitschia mirabilis* was lightly browsed wherever they were available. During this investigation all parts of *W. mirabilis* were eaten throughout the dry period but freshly chewed and matted sections of leaves were found discarded on pathways leading to water.

During the preliminary monitoring of the Routes it was observed that *Commiphora* species were favoured

in the less vegetated areas (Routes B,C and E). The results show that *Commiphora pyracanthoides* was fairly well favoured during this study although it was not included as a food plant by Joubert (1971). This may have been due to the availability of other vegetation in the higher rainfall area where the latter study was carried out.

3.4 Nutritional Value

The nutritional values of eleven species of food plants used by rhino are listed in Table 2. Water content varied considerably but did not appear to markedly influence selection. The plants with the highest water content were *Euphorbia virosa* and *Merremia* spp.

The ash content of *Salvadora persica* was found to be unusually high which may serve as a deterrent to herbivory. Nevertheless, rhino and other herbivores have been observed to feed on this plant but not to any great extent. Several plant species consumed by the rhino were found to have a high crude fibre content. In particular the values for *Commiphora virgata*, *Sterculia africana* and *Euphorbia damarana* were very

TABLE 2: Proximate analysis of thirteen species of plants browsed by rhino and of rhino dung

Plant	Water Content (%)	Ash (% dry wt)	Crude Fibre (% dry wt)	Protein (% dry wt)	Crude Fat (% dry wt)	Carbohydrate (% dry wt)	Energy value (kJ. g ⁻¹ dry wt)
<i>Blepharis gigantea</i>	46.0	11.9	20.7	5.9	1.2	60.4	15.8
<i>Boscia foetida</i>	37.2	8.8	23.1	17.9	1.3	48.9	17.1
<i>Cadaba schroepelli</i>	39.4	13.0	16.7	15.2	2.0	53.1	16.3
<i>Commiphora virgata</i>	13.7	5.8	49.8	2.1	0.7	41.6	16.3
<i>Euphorbia damarana</i>	38.6	4.1	34.8	2.8	24.2	34.1	22.0
<i>Euphorbia virosa</i>	80.4	11.2	27.1	3.3	6.3	52.1	16.8
<i>Merremia spp.</i>	76.0	13.2	23.4	13.1	1.7	48.6	16.3
<i>Phragmites australis</i>	64.4	10.1	28.0	10.1	1.5	50.3	16.3
<i>Salvadora persica</i>	64.3	41.3	9.6	8.4	0.5	40.2	10.7
<i>Sterculia africana</i>	54.1	12.9	32.5	4.0	0.6	50.0	15.5
<i>Welwitschia mirabilis</i>	58.5	14.5	19.1	10.7	1.1	54.6	15.5
<i>W. mirabilis seeds</i>	3.8	9.4	18.1	11.8	0.8	59.9	16.3
Dung	4.5	6.1	45.4	5.8	5.7	37.0	16.0

high. This is reflected in the high crude fibre content found in the dung samples and agree with the results obtained by Hall-Martin et al (1982) during the dry period of their investigation. *Welwitschia mirabilis* has a relatively high water and fibre content which may account for the leaves being chewed and then discarded. *Euphorbia damarana*, which has a high crude fibre value (34.8%), was also chewed by the rhino and then discarded.

Crude fat values for *Euphorbia damarana* and *E. virosa* were also unusually high. The analytical procedure used, namely ether extraction, does not reflect true lipid content and the high values are probably due to the high latex content of these plants. The high crude fat values also found in the dung samples suggest that this component may not be fully utilised by the rhino.

3.5 Soluble Tannins

The soluble tannin content of the browsed plants that were investigated varied from 0.15% to 4.06% on a wet mass basis (Table 3). Harbourn (1982) is of the opinion that tannin content is a key factor in determining the choice of food plants but cites a threshold value of at least 0.2% tannin on a dry mass basis to be effective in this regard. If the values in Table 3 are converted to a dry mass basis then all the plants that were investigated exceed this threshold value. It can be concluded therefore that, within the group of plants selected for analysis, the tannin content was moderately high and represents a potential defense against herbivory. * Other means of defense were also evident. These included the formidable spines and highly irritating latex of *Euphorbia virosa* which surprisingly (see Cooper and Owen-Smith 1986) did not deter the rhino from feeding heavily on this plant (Plate 1). The lower face and muzzle of one rhino observed feeding in *E. virosa* was covered with this white latex (R. Braby pers. comm.) (Plate 1). In fact, it was a favoured plant in spite of causing severe skin irritation to the person

TABLE 3: Soluble tannins in seventeen species of plants browsed by rhino and in rhino dung.

Plant	Soluble tannins (% wet wt)
<i>Acacia albidu</i>	0.63
<i>Acacia erioloba</i>	2.23
<i>Acacia reficiens</i>	1.52
<i>Blepharis gigantea</i>	0.86
<i>Boscia foetida</i>	0.28
<i>Cadaba schroepelli</i>	0.15
<i>Calicorema capitata</i>	0.48
<i>Commiphora tenuipetiolata</i>	1.87
<i>Euphorbia damarana</i>	1.34
<i>Euphorbia virosa</i>	0.37
<i>Gossypium anomalum</i>	1.54
<i>Maerua juncea</i>	0.53
<i>Maerua schinzii</i>	0.63
<i>Merremia spp.</i>	0.25
<i>Phragmites australis</i>	0.29
<i>Salvadora persica</i>	0.29
<i>Welwitschia mirabilis</i>	1.69
<i>Welwitschia mirabilis seeds</i>	4.06
Dung	0.68

preparing a sample of this plant for analysis. It would appear then that rhino are able to overcome some major chemical and physical defenses of plants without any apparent harm. According to Cooper and Owen-Smith (1985), however, large mammalian herbivores are influenced not by soluble tannins but mainly by condensed tannins due to their dependence upon microbial fermentation of plant cell walls for part of their energy needs.

3.6 Calcium and Phosphorus

The calcium levels found in rhino dung varied from 2.05 - 6.51% (= 3.30; SE = \pm 0.26) on a dry mass basis. These values are considerably higher than the normal range reported for cattle (0.55 - 1.55%) by the

Regional Veterinary Laboratories in Windhoek. These high values may be a reflection of the high calcium content of the calcrete soils in the study area. Phosphorus levels measured in rhino faeces fell within the normal range reported for cattle and sheep. These results suggest that the rhino do not suffer any deficiency of these two important minerals.

4 CONCLUSION

Estimates of feeding preferences are subject to sampling errors (Owen-Smith and Cooper in press). Moreover, plant surveys in desert areas are notoriously difficult because of the sparse nature and patchy distribution of the vegetation. This proved to be the case in the present investigation and the results obtained

TABLE 4: Diversity (Hill's N_2 index) of the plants in the 'availability' circles and of bites taken along the tracks by browsing rhino for Route A–F.

Route	Hill's N_2	
	Plants in circles	Bites
A	12.919	6.577
B	10.527	8.395
C	9.829	5.899
D	8.634	8.064
E	8.912	6.032
F	6.332	3.182

can only be considered a first approximation. Nevertheless, the feeding track method used proved to be useful in establishing the major preferred food items in the diet of these desert-dwelling rhino. Gener-

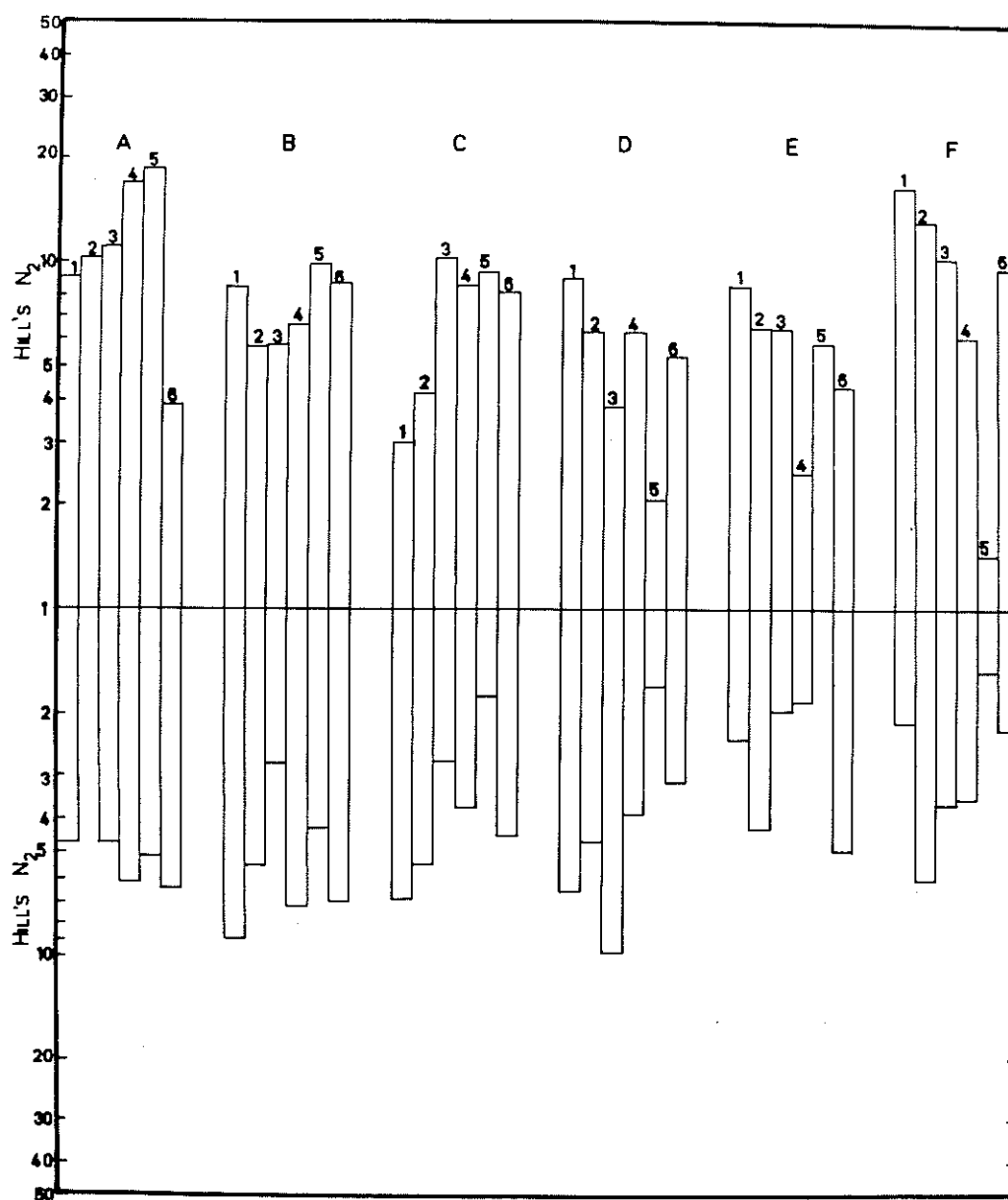


FIGURE 9: Diversity (Hill's N_2 index) of the plant species available (above the line) plotted opposite diversity of usage of these species (below the line) by the black rhino for each replicate (1–6) within each feeding Route, A, B, C, D, E, and F.

al observations supplemented the feeding track method and the total list of plants (74) browsed by the rhino in this unusual habitat should be of value in planning their future conservation.

In desert habitats the selection of food items may be guided by factors other than nutritional value, for example, water content of the plants (Harbourne 1982). Prior to the feeding track study, general observations on these rhino had been carried out. The tentative conclusion reached from these observations was that almost every plant was browsed by these animals and that they were feeding non-selectively. However, when the diversity of available forage was calculated for this study (Hill's N), it was found to be higher than the diversity of plants actually consumed in almost every instance (Fig. 9, Table 4). This result suggests that, at least during the time of this study, the rhino were feeding somewhat selectively from the plants available. The coefficient of variation was calculated from the mean and standard deviations obtained when the diversity values for the separate portions of each route were combined (Table 5). For four of the six routes, the coefficient of variation for the diversity of availability was greater than for the diversity of the plants consumed. These calculations again suggest that the rhino were being somewhat selective in their diet.

In view of the extreme aridity of the study area, comparisons with previous studies carried out in more mesic habitats (Goddard 1968, 1970; Joubert 1971, Hall-Martin et al. 1982, Mukinya 1977, Schenkel and Schenkel-Hullinger 1969) are not particularly rewarding. Nevertheless, several common conclusions can be drawn with these studies, namely that rhino feed on an usually wide variety of species and shift their feeding preferences according to circumstances. They are also able to use plants which, because of their formidable chemical defenses, are denied to most other herbivores. In fact, this is one of the major conclusions to be drawn from this study. The food plants in this desert region are sparsely distributed and rely heavily on chemical defense for their survival. They are also in many instances extremely fibrous. In spite of this the resident population of rhino used these plants successfully; they remained in good condition throughout the driest periods and their reproduction was normal.

TABLE 5: An indication of the between route section variability of plants and bites obtained by calculating the coefficient of variation from the means and standard deviations of Hill's N, diversity index value for sections 1-6 of each route (A-F).

Route	Plants		Bites
A	43 %	>	42 %
B	22 %	<	34 %
C	39 %	<	42 %
D	39 %	<	58 %
E	36 %	<	56 %
F	56 %	>	52 %
Mean	39 %	<	47 %

From the conservation viewpoint there were no indications of pressure on the habitat and a limited increase in their population should be encouraged. Competition with other large herbivores is probably minimal in view of the extreme aridity of the region and the inability of many other herbivores to overcome the chemical defenses of some of the more important food plants favoured by the rhino.

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