Effects of browse availability and quality on black rhino (*Diceros bicornis michaeli* Groves 1967) diet in Nairobi National Park, Kenya

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Abstract

Investigations were conducted to study the effects of browse availability and quality on black rhinoceros (*Diceros bicornis michaeli* Groves 1967) diet in Nairobi National Park, Kenya, between September 1994 and February 1995. Line intercept method was used to assess availability of browse. The ratios of browsed crowns to the total crown were applied in the estimate of browse use. Proximate analysis and extraction methods were used, respectively, to appraise browse nutritional quality and phytochemical status of twelve species. Thirty-four plant species were identified as potential black rhino browse, whose availability differed significantly ($P < 0.001$). *Lippia javanica* (20.581 ± 3.101, $n = 544$) and *Lannea cornuta* (0.963 ± 0.529, $n = 544$) were the most and least available species, respectively. Only 32 species, however, were utilized, as *L. cornuta* and *Rhynchosia hirta* did not show any level of rhino feeding activity. Browse use was found to vary significantly ($P < 0.001$) during the study period. *Grewia similis* was most (20.564 ± 2.764, $n = 544$) and *Commelina africana* least (0.974 ± 0.974, $n = 544$) exploited, respectively. Differences in total alkaloids and phenols, crude fibre, crude protein and total ash contents among species investigated were highly significant ($P < 0.001$). Ether extract values were similar ($P = 0.0933$) across plant taxa. The study shows that the black rhino is a selective browser feeding on plants with low phenol and alkaloid contents and high fibre values. Of the nutritionally similar species, browsing was driven by availability. These findings suggest that a key habitat factor important in black rhinoceros conservation include diverse plant species with low levels of phenols and alkaloids.

Key words: availability, quality, rhino diet, use

Résumé

On a mené des recherches pour étudier les effets de la disponibilité et de la qualité des feuillages sur le régime alimentaire du rhinocéros noir (*Diceros bicornis michaeli* Groves 1997), au Parc National de Nairobi, au Kenya, entre septembre 1994 et février 1995. On a utilisé la méthode de line intercept pour évaluer la disponibilité des feuillages. On a rapporté le taux de couronnes mangées au nombre total de couronnes pour estimer le broutage. On a utilisé les méthodes d'analyse rapprochée et d'extraction respectivement pour connaître la qualité nutritionnelle du feuillage et le statut phytochimique de douze espèces. On a identifié trente-quatre espèces végétales comme pouvant être consommées par les rhinos noirs, et leur disponibilité différait significativement ($P < 0{,}001$). *Lippia javanica* (20,581 + 3,101 $n = 544$) et *Lannea cornuta* (0,963 + 0,529 $n = 544$) étaient respectivement l'espèce la plus et la moins disponible. Seules 32 espèces étaient utilisées cependant car ni *L.cornuta* ni *Rhynchosia hirta* ne présentaient de signe de broutage par les rhinos. On a découvert que le broutage variait significativement ($P < 0{,}001$) pendant la durée de l'étude. L'espèce la plus exploitée était *Grewia similis* (20,564 + 2,764 $n = 544$), la moins exploitée étant *Commelina africana* (0,974 + 0,974 $n = 544$). Parmi les espèces analysées, les différences entre les contenus totaux en alcaloïdes et phénols, en fibre brute, en protéine brute et en résidu de combustion étaient hautement significatives ($P < 0{,}001$). Les valeurs d'extrait d'éther étaient

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similaires parmi les taxons végétaux ($P = 0{,}0933$). L'étude montre que le rhino noir se nourrit de façon sélective des feuillages des plantes qui ont des contenus en phénols et en alcaloïdes bas et de fortes valeurs en fibres. Parmi les espèces de qualités nutritionnelles semblables, le choix dépendait de la disponibilité. Ces découvertes suggèrent qu'un facteur-clé de l'habitat, important pour la conservation du rhinocéros noir, est la présence de diverses espèces végétales avec un faible taux de phénols et d'alcaloïdes.

Introduction

Ecological and chemical factors that influence diet selection by herbivores are important for development of conservation programmes such as breeding, translocation and introductions. This has led to an increase in attention on the factors affecting foraging behaviour in herbivores (Gartlan *et al.*, 1980; Holechek, Martin & Pieper, 1982). Food searching, intake and digestion influence optimal foraging, thus animals will use strategies that enable them to maximize benefit at minimum cost (Owen-Smith, 1994). For both hind-gut and rumen fermenters, energy and protein requirements per unit weight diminish with increasing size, so that larger species can survive on lower quality food (Bell, 1970, 1971; Janis, 1976). This places the large perissodactyl (e.g. the rhino) at the lowest level of requirements in a food quality continuum among African ungulates. However, two constraints may favour selectivity and diversity in rhino diet. First, high dietary diversity may be necessary for intake of essential nutrients, particularly of full complement of amino acids (Gartlan *et al.*, 1980). Second, the inability of perissodactyls to benefit from bacterial degradation of toxins should favour evolution of a more diverse diet (Freeland & Janzen, 1978). In perissodactyls, toxins enter the body before they make contact with microflora. Although other mechanisms of detoxification exist, one way of nullifying the effects of dose-dependent plant toxins is to ingest subtoxic levels of a range of compounds, by selecting food from a wide variety of plants containing different chemical profiles (Rhoades & Cates, 1976).

The black rhino is endangered in all its range, despite legislation taken to protect it (Cumming, Du Toit & Smart, 1990). Once, the species occupied most of the sub-Saharan Africa and numbered hundreds of thousands. Even by the turn of the 19th century, large, nearly contiguous populations of black rhino were spread across much of central, eastern and southern Africa (Ashley, Don & Western, 1990). More recently, there has been a dramatic decline, with numbers dropping from an estimated 65 000 in 1970 to about 3800 in 1987 (Ashley *et al.*, 1990). This represents a 95% decline in those 18 years alone. During the same period, Zimbabwe, Republic of South Africa and Namibia recorded stable populations. Where the decline occurred, it was largely due to commercial poaching for horn.

Efforts to rehabilitate the rhino populations in Kenya have focused on increasing security and the creation of sanctuaries (Brett, 1993). Usually these are small fenced areas with correspondingly small populations. Although little is known about the minimum habitat that can be managed effectively to sustain a viable rhino population, food availability and quality are major factors that determine habitat suitability. Therefore, in one such sanctuary, the Nairobi National Park, an assessment was made of the relative availability, utilization, nutritional quality and phytochemical status of plants previously identified as black rhino diet. We tested the hypothesis that browse utilization by this perissodactyl is dependent on vegetation quality and not quantity.

Materials and methods

The study area

The Nairobi National Park is the oldest legislated conservation area in East Africa, having been gazetted in 1946. It occupies an area of 114.8 km^2 and is situated 8 km south of the city between 2°18′ to 2°20′ S and 36°23′ to 36°28′ E. The park is fenced on all boundaries, except for about 20 km to the south along the Athi river. Due to seasonal changes in resources there is a tendency for seasonal migration in and out of the park by a number of ungulates. This section allows for movement of animals to and from the adjoining Kitengela conservation area. Recently, farming and fencing activities have increased in the Kitengela area, making dispersal of wildlife difficult and increasing human–wildlife conflict.

Annual mean maximum and minimum temperatures for the park are 25.3°C and 13.6°C, respectively. Rainfall is variable, with alternating dry and wet seasons. Usually the long rains occur between March and May (mean 150 mm), while the short ones occur between November and December (mean 90 mm).

The park presents a gently undulating gradient from high elevations around woodland areas in the north-west (1790 m) to mosaic grasslands of lowland plains in the south-east (1508 m). Several perennial rivers traverse the park along the north-eastern axis. The major vegetation communities includes a deciduous forest, riverine thorn forests, shrubs and grasslands. Detailed descriptions of vegetation and geology of this park have been made (Smith & Verdicourt, 1962; Hurxthal, 1979).

Browse availability

The line intersect method was used to estimate browse availability (Cain & Castro, 1959; Keeslaw, 1979; Greig-Smith, 1983; Cox, 1985; Krebs, 1989). Before data collection, reconnaissance surveys were done for the various vegetation types to select suitable sites for laying sampling plots. Eight plots were systematically selected within the four major vegetation communities excluding the deciduous forest. In selecting the sampling plots, those areas that were most representative of the vegetation and were known rhino home ranges (Waweru, 1985) were chosen. In each plot, a baseline measuring 100 m was set across the slope gradients and at least 30 m from road or track. Five line transects were set perpendicular to the baseline at 25 m intervals. Since black rhino browse at a maximum height of 2 m (Oloo, Brett & Young, 1994), dicotyledonous plants (herbs, shrubs or trees) below this height whose crown touched our transect were identified and profile recorded. Identification and nomenclature of plants followed those of Agnew (1974) and Beentje (1994). For each plant, distance from the baseline, crown depth and crown diameter were measured.

Species frequency, cover and density were determined per plot, following the methods of Mueller-Dombois & Ellenberg (1974) and Cox (1985). Percentage frequency of occurrence, cover and density for each species per transect and their relative values were then determined. Species importance value indices (IVIs) were obtained from the sum of their relative frequencies, relative cover and relative densities. Each species IVI was expressed as a proportion of 300 before arcsine transformation (availability index $(Pa') = \arcsin \sqrt{pa}$, where $pa = \mathrm{IVI}/300$; Zar 1984) and used as an indication of species availability (availability indices)).

Browse utilization

Forage utilization is one of the oldest approaches used in evaluating a herbivore's diet (Neu, Byers & Peek, 1974). The advantages of this procedure include speed and the fact that it provides information on where and to what degree a range is being used (Holechek *et al.*, 1982). Black rhino feeding is distinct as it clips off browse (twigs and shoots) to leave a scissor-like cut stump (Ritchie, 1963; Oloo *et al.*, 1994). Browse use was measured by the relevé method (Mueller-Dombois & Ellenberg, 1974). This involved visually appraising the percentage of the total crown browsed and was done on vegetation along the described transects. Species utilization index was obtained by arcsine transforming the relative browse utilization values.

Plant quality studies

Proximate and phytochemical analyses were made on twelve plant species previously listed as common in black rhino diets (Waweru, 1985; Ellen *et al.*, 1990; Oloo *et al.*, 1994). Twelve species were sampled from each of the eight plots by clipping the entire twig or shoot, and packing it in a polythene bag prior to analysis. Each sample was oven dried (105°C) before milling. Of the fine homogenous powder, an aliquot of 2 g was used for nutritional quality studies. Total ash, crude fibre, crude protein and crude ether extracts were estimated using standardized methods (Fonnesbeck, 1977; Kenya Bureau of Standards, 1978). Phytochemical studies involved determination of total phenol and alkaloid values as described by Hassanali (1994).

Statistical analyses

All results were arcsine transformed (Zar, 1984) before analysis. To test whether the black rhino food plants were equally available in the park, all browse species were replicated in all plots. Therefore a zero availability value was assigned to browse species in any plot where they were absent. One-way analysis of variance (ANOVA) was used to determine browse differences in availability, utilization, phytochemical and nutritional qualities. Statistically different means were separated using Tukey's multiple range test (Snedecor & Cochran, 1980). Correlation and regression analyses were used to measure associations and relationships between browse utilization, their quantity and quality, respectively. All analysis were carried out using the Statgraf computer program (STSC, 1986).

Results

A total of 34 plant species in the study area was identified as potentially available to black rhino as forage between September 1993 and February 1994. During this period, their availability differed significantly ($P < 0.001$). Availability indices ranged from 0.96 ± 0.96 for *Lannea cornuta*, to 20.58 ± 3.10 for *Lippia javanica* (Table 1). Only six species recorded a value greater than 10.

Of the 34 plant species, only 32 showed signs of black rhino feeding activity (Table 1). The two species not browsed were *L. cornuta* and *Rhynchosia hirta*. Black rhinos' use of the 32 food plants differed markedly ($P < 0.001$) during the study. While *Grewia similis* showed the highest utilization index (20.56 ± 2.76), *Commelina africana* showed the lowest (0.97 ± 0.97, $n = 16$) (Table 1). Browse utilization also varied significantly ($r = 0.569$, $P < 0.001$, $n = 544$) with availability. The least available, *Lannea cornuta*, was not consumed at all. *Grewia similis* and *Hibiscus fuscus*, the most utilized forage species, showed availability indices greater than 10. *Acacia brevispica* with a utilization index (9.5) similar to that of *L. javanica* (8.2) was only one-fifth as available as the latter (Table 1).

For the twelve plant species analysed for qualitative status, differences in their fibre, protein, alkaloid, and phenol contents were highly significant ($P < 0.001$). Differences in ether extract values observed were, however, not statistically significant ($P = 1.920 \pm 1.55$). *Psidia arabica* had the highest recorded values of total alkaloid (5.29 ± 0.11) and crude protein (21.92 ± 1.55), while the highest phenols and crude fibre levels were, respectively, found in *Acacia drepanolobium* (7.65 ± 0.36) and *Phyllanthus fischeri* (43.78 ± 0.66) (Table 2). The lowest concentrations of total alkaloid (2.16 ± 0.03) and crude fibre (8.81 ± 1.92) were recorded in *Achyranthers aspera*, while the lowest values for both total phenols (2.83 ± 0.16) and crude protein (16.5 ± 0.23) were from *Phyllanthus fischeri* (Table 2).

Browse utilization was highly correlated with increasing plant fibre contents ($r = 0.333$, $P < 0.02$, $n = 48$; Table 3). Utilization was, however, lower in plants with high alkaloids ($r = -0.3733$, $P < 0.009$, $n = 48$), phenols ($r = -0.4065$, $P < 0.004$, $n = 48$; Fig. 1), ether extracts ($r = -0.2890$, $P < 0.046$, $n = 48$) and protein ($r = -0.2393$, $P < 0.101$, $n = 48$) concentrations. Plants with high crude fibre content generally had a low content of phenols, alkaloids, ether extracts and protein (Fig. 2), whereas those with high alkaloids had high phenols ($P = 0.001$), protein ($P = 0.003$) and ether ($P = 0.035$) extracts (Table 3). However, plant phenol levels had no significant association with protein or ether extract values.

Discussion

During this study, 34 plant species (21 woody and 13 herbage) belonging to 27 genera within 20 families, were identified as available browse for black rhinos in Nairobi National Park. However, only 32 species (20 woody and 12 herbs) showed actual browsing by black rhinos. Earlier studies in the same site had recorded 47 plant species (28 woody, 16 herbs and 3 grasses) and 52 species (34 woody species, 8 herbs and 10 grasses), respectively, as black rhino food plants (Waweru, 1985; Muya, 1993). Elsewhere in Kenya, over 103 plant species from 37 families were recorded in rhino diet (Oloo *et al.*, 1994). In Luangwa Valley, Zambia, black rhinos were found to feed on 220 different species (99 woody, 102 herbs and 25 grasses) (Leader-Williams, 1985). These findings show that black rhino has a high dietary diversity and concur with earlier ones (Goddard, 1968, 1970; Mukinya, 1973, 1977; Hall-Martin, Erasmus & Botha, 1982). Relatively fewer species of rhino food plants were, however, recorded here in comparison to previous studies. Of the 34 plant species we collected, only 20 were earlier recorded (Waweru, 1985; Muya, 1993) as rhino browse in this habitat. Possible reason for such differences may be attributed to sampling methods. In this study, the indirect approach of assessing cut stumps we used and thus no grasses were sampled. Other studies used direct observations (Muya, 1993) and faecal analysis (Waweru, 1985). That fourteen rhino plant foods not recorded by earlier workers in this habitat were identified here would suggest that a combination of techniques is necessary for a comprehensive study of rhino diet.

Black rhino food plants recorded were not uniformly available in the habitat. This difference in availability was highly significant ($P < 0.001$). *Lippia javanica* showed the highest availability index and *L. cornuta*

Table 1 Mean (±SEM, $n = 16$) availability and utilization indices of black rhino food plants in Nairobi National Park between September 1994 and February 1995

	Mean values	
Browse species	Availability	Utilization
Launea cornuta (Oliv. & Hiern) C. Jeffrey	0.96 ± 0.96 a	0.00 ± 0.00 a
Ochna ovata F. Hoffm.	1.08 ± 0.72 a	1.26 ± 0.26 a
Commiphora africana (A. Rich) Engl.	1.17 ± 0.80 a	2.49 ± 1.81 a
Tephrosia villosa (L.) Pers.	1.18 ± 0.83 a	1.18 ± 0.89 a
Leonotis nepetifolia R. Br.	1.36 ± 0.62 a	4.53 ± 2.07 a
Acacia xanthophloea Benth.	1.78 ± 0.95 a	3.29 ± 2.28 a
Carissa edulis (Forsk.) Vahl	1.86 ± 1.27 a	2.05 ± 1.41 a
Balanites aegyptiaca (L.) Del.	2.13 ± 1.04 a	4.18 ± 2.87 a
Rhus natalensis Krauss	2.16 ± 2.16 a	3.02 ± 1.36 a
Maytenus senegalensis (Lam.) Exell	2.17 ± 0.98 a	3.98 ± 1.80 a
Lantana camara L	2.26 ± 1.55 a	1.85 ± 1.27 a
Acacia senegal (L.) Willd.	2.32 ± 1.58 a	3.67 ± 2.51 a
Acalypha fruticosa Forsk.	2.41 ± 0.98 a	5.64 ± 2.20 b
Cordia ovalis DC	2.54 ± 0.91 a	5.31 ± 1.93 b
Achyranthers aspera L.	3.12 ± 1.22 b	5.90 ± 2.31 b
Rhynchosia hirta (Andrews) Meikle & Verde.	3.47 ± 1.17 c	0.00 ± 0.00 a
Commelina africana L.	3.77 ± 1.28 c	0.97 ± 0.97 a
Scutia myrtina (Burm. f.) Kurz	3.86 ± 1.30 c	6.77 ± 2.26 b
Sida spp.	4.54 ± 1.32 d	5.05 ± 2.13 b
Acacia brevispica Harms	4.55 ± 1.49 d	9.53 ± 3.08 b
Indigoferra arrecta A. Rich	4.84 ± 2.52 d	3.05 ± 1.64 a
Acacia mellifera (Vahl) Benth.	5.52 ± 2.25 d	3.91 ± 1.80 a
Acacia drepanolobium Sjøstedt	5.99 ± 3.48 d	4.53 ± 2.27 b
Hibiscus aponuerus Sprague & Hutch.	6.03 ± 1.11 d	8.03 ± 3.24 b
Phyllanthus fischeri Pax	6.15 ± 1.81 d	10.15 ± 2.69 c
Croton dichogamus Pax	7.79 ± 3.18 d	4.56 ± 1.81 b
Barleria grandicalyx Lindau	8.64 ± 1.33 d	8.20 ± 2.00 b
Psidia arabica J & S	8.81 ± 3.30 d	1.74 ± 0.73 a
Ocimum kilimandscharicum Guerke	10.25 ± 2.27 e	3.11 ± 1.34 a
Hibiscus fuscus Garcke	10.62 ± 1.57 e	15.23 ± 3.67 d
Solanum incanum L.	13.41 ± 1.17 f	3.51 ± 1.45 a
Grewia similis K. Schum.	13.76 ± 2.07 g	20.56 ± 2.76 e
Aspilia mossambicensis (Oliv.) Wild.	14.52 ± 4.26 h	6.42 ± 1.82 b
Lippia javanica (Burm. f.) Spreng	20.58 ± 3.10 i	8.17 ± 1.27 b

Means with different letters between columns are significantly ($P < 0.05$) different.

the least (Table 1). The use of browse materials also differed significantly during this study (Table 1). *Grewia similis*, although showing only the third highest availability index, was the most utilized, while *L. javanica* (the most available) was only moderately browsed. Nonetheless, *L. cornuta* was not only least available, but was also not browsed at all. Utilization varied positively and significantly ($r = 0.5689$, $P < 0.001$, $n = 544$) with availability. This relationship was expected since black rhinos are confronted with a 'cost' and 'benefits' situation of extreme selection of browse species for utilization against their availability, and they have to integrate successfully this relationship in order to survive. The 'benefits' accrued from selectivity might be too expensive energetically to sustain, especially in cases where food resources are not widely available and therefore, browse species which are more available tend to be utilized more (Morris, 1990).

Table 2 Mean (±SEM, $n = 4$) of total alkaloids, phenols, crude fibre and crude protein contents of twelve black rhino browse species in Nairobi National Park

	Mean values			
Browse species	Total alkaloids	Total phenols	Crude fibre	Crude protein
Achyranthers aspera	2.16 ± 0.03 a	3.46 ± 0.16 a	8.81 ± 1.92 e	16.87 ± 0.43 b
Grewia similis	2.16 ± 0.09 a	2.93 ± 0.19 a	38.51 ± 0.66 d	17.34 ± 0.28 b
Phyllanthus fischeri	2.25 ± 0.03 a	2.83 ± 0.16 a	43.78 ± 0.66 g	16.50 ± 0.23 a
Scutia myrtina	2.37 ± 0.10 a	2.96 ± 0.13 a	34.72 ± 1.30 c	17.99 ± 0.66 c
Rhus natalensis	2.60 ± 0.08 b	4.81 ± 0.29 b	32.14 ± 2.20 b	17.98 ± 0.66 c
Maytenus senegalensis	3.02 ± 0.15 c	6.53 ± 0.27 d	32.07 ± 2.00 b	16.87 ± 1.04 b
Acacia drepanolobium	3.58 ± 0.11 d	7.65 ± 0.36 e	41.36 ± 2.50 f	18.05 ± 2.03 c
Lippia javanica	4.06 ± 0.06 e	6.51 ± 0.21 d	32.00 ± 0.30 b	17.28 ± 0.43 b
Solanum incanum	4.25 ± 0.11 f	7.06 ± 0.23 d	32.50 ± 0.97 b	20.97 ± 0.59 d
Aspilia mossambicensis	4.55 ± 0.16 f	2.91 ± 0.17 a	34.59 ± 3.35 c	17.30 ± 0.03 b
Carissa edulis	5.22 ± 0.11 g	7.46 ± 0.22 d	31.38 ± 0.88 b	17.45 ± 0.14 b
Psidia arabica	5.29 ± 0.11 g	6.29 ± 0.32 c	29.91 ± 1.49 a	21.92 ± 1.55 e

Means with different letters between columns are significantly ($P < 0.05$) different.

Table 3 Correlation matrix between utilization, availability and quality of the twelve selected black rhino browse species ($n = 48$). Value shown are correlation coefficients. * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

	Availability	Alkaloid	Phenols	Ether extracts	Fibre	Protein
Utilization	0.5640***	−0.3733**	−0.4065**	−0.2890*	0.3331*	−0.2393
Alkaloid			0.6015***	0.3058*	−0.4823***	0.4153**
Phenols				0.2750	−0.3978**	0.2795
Ether extracts					−0.5272***	−0.0127
Fibre						−0.3907**

Since the most abundant browse (*L. javanica*) was only moderately used, browsing could not be explained by food availability alone but also by qualitative and possibly other factors. The importance of food availability to animal populations depends on, among other factors, the extent to which the animals can exploit it for their growth (Milton, 1979). Food selection by non-ruminant herbivores is closely related to positive nutritional factors such as protein and total non-structural carbohydrates than to negative ones such as phenols and alkaloids (McKey *et al.*, 1981; Bergeron & Jodoin, 1989). Since availability is an important factor in utilization, the rhino is expected to select widely available browse of high quality. The observations here were not fully consistent with this hypothesis as black rhino utilized significantly more plants which, although widely available, had high fibre contents, low concentrations of alkaloid and phenols, and irrespective of the protein values (Fig. 1 and Table 3). For instance, *G. similis* utilization was over two times greater than that of *L. javanica*, the most available species (Table 1). *Grewia* had higher fibre (index 38 cf 32), lower alkaloid (index 2 cf 4), lower phenols (index 3 cf 6.5) but similar protein values to *Lippia*, respectively (Table 2). Similar comparison can be made between *Grewia* and *P. arabica*, whose utilization was ten times lower. *Acacia brevispica* had an availability index five times lower than *Lippia* but similar level of utilization. These findings would suggest that low levels of phenols and alkaloids, or high fibre values, were a possible triggering mechanism to food selection by black rhinos in this habitat. Thus, plants with low levels of these

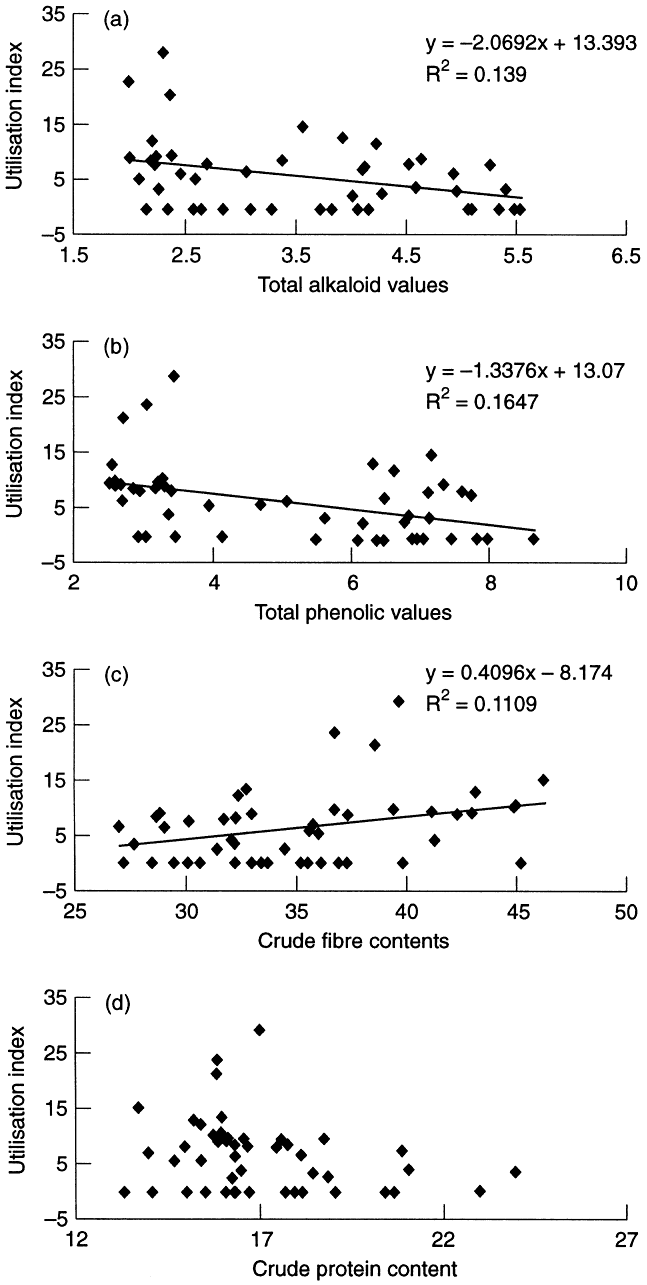

Fig 1 Scattergrams showing relationship between browse utilization and (a) total alkaloids, (b) total phenols, (c) crude fibre content and (d) crude protein

toxic compounds or high fibre content but also widely available, were selected.

The apparent negative association between browse utilization and crude protein levels (Table 3), although not statistically significant, was unexpected. This may be explained by their selection for plants with low phenol and alkaloid levels, since such species had correspondingly low protein values (Table 3). It may also be that rhinos here were selecting only for high fibre browse. Such plants showed low protein contents (Table 3). The latter explanation may hold true here since hind gut fermenters are known to obtain optimum nutrient adequately from browse material high in fibre content (Janis, 1976) as long as the browse material is

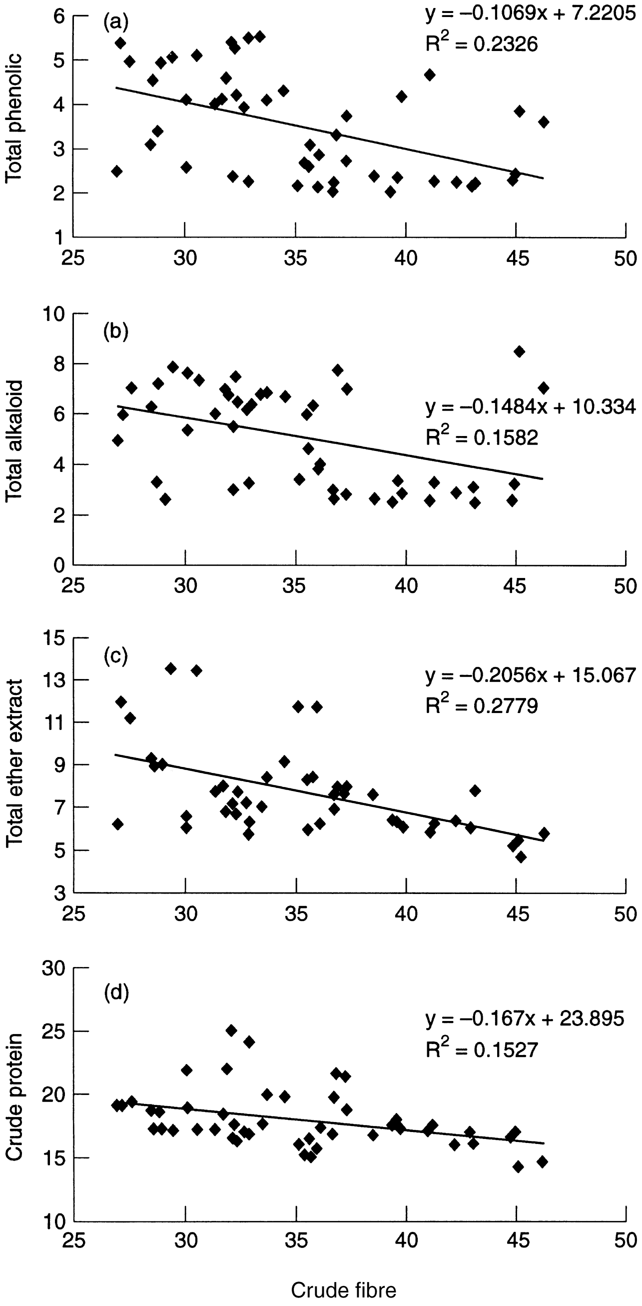

Fig 2 Scattergrams showing relationship between crude fibre content and (a) total phenols, (b) total alkaloids, (c) total ether extracts and (d) crude protein contents

widely distributed (Bell, 1982). Our findings are also in agreement with previous ones which showed that, owing to their inability to benefit from bacterial degradation of toxins, perissodactyls favour utilization of species low in total phenol and alkaloid levels (Freeland & Janzen, 1978).

This study has shown that the black rhino is a selective browser. However, they integrate the selection of browse material with availability in order to satisfy their nutritional requirements. Negative nutritional factors such as phenols and alkaloids were important in determining food selection. Such browse had high fibre contents. Positive nutritional factors such as crude protein and total ether extracts were not as important.

We suggest that areas with diverse browse materials low in total phenols and alkaloids are suitable for setting up sanctuaries in black rhino conservation programme in Kenya.

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