Food selection and food quality in territorial males of a free-ranging population of white rhinoceros (*Ceratotherium simum simum*) in South Africa

B. Kiefer[1], U. Ganslosser[2], P. Kretzschmar[2], E. Kienzle[1]

[1]Institute of Animal Physiology, Physiological Chemistry and Animal Nutrition, Faculty of Veterinary Science, Ludwig-Maximilians-Universität, Veterinär Str. 13, 80539 München, Germany

[2]Zoological Institute I, Friedrich-Alexander University of Erlangen-Nürnberg, Staudtstr. 5, 91058 Erlangen, Germany;

Running head: Food selection of white rhinos

Corresponding author:

Britta Kiefer, Institute of Physiology, Physiological Chemistry and Animal Nutrition, Faculty of Veterinary Science, Ludwig-Maximilians-Universität, Veterinär Str. 13, 80539 München, Germany, (breitmaulnashorn@gmx.de);

FAX: ++49/89/21803208

In Fidgett, A. (ed.) European zoo nutrition II. Fürth, Filander Verlag 2002

Abstract

As part of a larger, multi-disciplinary approach to white rhino (*Ceratotherum simum simum*) behaviour, ecology and nutrition, a study was conducted on the foraging and ranging behaviour of three territorial males on a game ranch in Northern Transvaal, South Africa. Animal tracks representing the distance covered between midnight and early morning were followed, feeding sites identified, ingested grass species determined, and quantitative samples of ingested grass taken. Grass samples and additional grass and hay samples fed to white rhino at a German zoo were analysed for nutrient content. Food selection of free-ranging rhinos did not correspond to the frequency of occurrence of the individual grass species in their territory as determined by transect plots. The nutrient content of the diets selected by the three animals were very similar. There was no evident correlation between the distance travelled between feeding sites and the nutrient composition of selected diets. The mineral contents of the natural forages were noticeably lower than those of the zoo forages. This is in accord with similar reports from the literature on mineral contents of African and European forages. The relevance of this finding for captive mineral supplementation regimes should be further investigated.

Keywords: megaherbivore, grass analyses, minerals, protein,

Introduction

Food selection in free-ranging animals poses some serious difficulties for adaptive behaviour: Balancing multiple nutrients and minerals, according to the organism's current physiological needs, and avoiding toxic and anti-nutrient contents. This led to the concept of the nutritional niche, a multi-facetted set of environmental adaptations as dynamic as the ecological niche itself (Hume 1995). Optimal foraging theory as outlined e.g. by Stephens and Krebs (1986) allows predictions about the way an animal copes with this task. Profound knowledge of these decisions and adaptations in free-ranging animals is an important precondition for a better nutrition of zoo-animals. As part of a larger, multi-disciplinary approach to white rhino (*Ceratotherium simum simum*) behaviour, ecology and nutrition, a study was conducted on the foraging and ranging behaviour of territorial males. The present publication aims to outline the foraging behaviour, and analyse nutrient, energy and mineral content of the selected diet.

Methods

This project consisted of two parts, a field study on free-ranging animals and a feeding trail with captive white rhinos.

Field study

The first part the field study was conducted during February and March 1999 on a private game farm in South Africa (Northwest Transvaal). The vegetation of two territories of male white rhinos (animals A and G) was analysed by transect measurements. A total of 143 transect plots were placed in a distance of 0.8 minutes longitude and 0.8 minutes latitude to each other over the study area. At each plot all grass species were recorded, which allowed an analysis of the frequency of their occurrence. The frequency of occurrence of grass species within a territory was calculated from the number of transect plots it was present in relation to the total number of plots To characterise the habitat of a male territory, measurements on transect plots located within the territory established by Kretzschmar (2002) were used.

The tracks of three territorial males (A, B, G) were followed with the aid of an experienced tracker and the distance the animal walked was measured using a GPS. It usually represents the time from midnight until the late morning.

At each feeding site along the track, all plant species were identified and recorded. Afterwards they were classified into six classes of grazing value (depending on production of grazeable plant material) and into three classes of palatability (depending on nutritive value, fibre content, unpalatable chemical substances and moisture content) according to Van Oudtshoorn (1992). Grass next to the feeding site was collected in the same quantity and the same height as grass had been removed at the feeding site by the animal. Because different parts of grass have different chemical compositions (Field 1976), this technique was necessary to conduct an accurate investigation of the nutritive value of the rhino's food in their natural habitat. The grass samples from one track were pooled for nutritional analyses. Each rhino was tracked twice (A1, A2, B1, B2, G1 ,G2).

Captive study

The second part of the project involved feeding trials with five white rhinos at the zoo of Erfurt, Germany. The rhinos were fed grass and hay. Each diet was given for a period of 15 days and food samples were collected daily. All samples were pooled for each diet.

Analyses

All food samples were subjected to nutritional analyses of the crude nutrients by Weender Analysis (Naumann and Bassler 1988), and of the cell wall constituents (Van Soest 1967) and the gross energy (bomb calorimetry). In all forage samples the macroelements and in the grass samples from Africa also the trace elements were analysed. Phosphorus levels were determined by a colorimetric method, potassium, calcium and sodium by flame photometry, chlorine by using an electronic Eppendorf Chloridmeter and magnesium, copper, zinc and iron by atomic absorption spectrophotometry.

Results

The rhinos were followed over a distance of 890-5180 m. Between 6-26 feeding sites were found per track and on average there was a distance of 148-518 m between the feeding sites. An average between 74g and 483g grass (fresh weight) was eaten per feeding site (Table 1).

It is noticeable that track A1 with the lowest grass intake per feeding site (Table 1) contains the highest concentration of crude protein (Table 3).

A total of 13 grass species were recognised as rhinos food on all six tracks. At the feeding sites (n=73), mostly only one grass species was eaten (n=45), often two (n=21) and rarely three (n=3) or four (n=4).

The frequencies with which the different grass species were eaten were not equal between the males. The food selection of the rhinos did not correspond to the frequency of occurrence of the individual plant species in their territory (Table 2).

The contents of the organic matter (OM), crude fat (CFat), crude fibre (CF), nitrogen free extracts (NfE), gross energy (GE), neutral detergent fibre (NDF), lignin (ADL) and most of the minerals of the samples from the tracks are very similar (Table 3 and 4), although they consisted of three to ten different grass species. Only the crude protein (CP) and dry matter (DM) content showed differences (Table 3).

The mineral contents of the natural forage from the field study were noticeably lower than those of the forages of the zoo study (Table 5). Other results of nutrient analyses of the zoo diets are published elsewhere (Kiefer et al., in press).

Discussion

To investigate diet selection behaviour of animals, it is necessary to know what components are available to the animal (Stephens and Krebs 1986, Manly and McDonald 1993). Adult male white rhinos are strictly territorial (Owen-Smith 1973). The grass species composition of the diet selected by a territorial animal must be compared to the grass species composition of the home range of this animal for a usage-availability study (Johnson 1980). The results from of the investigated males show that the frequency of ingesting a plant species does not correspond to its frequency of occurrence (Table 2). For instance, *Brachiaria nigropedata* (Black-footed signal grass) was chosen seven times for foraging at track A1 (the second most common food resource for animal A) even though it is not common in its territory (occurring only at 9 % of all transect points). Noticeably, this grass has a very high grazing value and a very high palatability value according to Van Oudthoorn (1992). The high proportion of this grass species in the sample A1 may be responsible for the high protein content of this sample (Table 3). It is possible that this animal was selecting his food plants for high protein content on this track (CP 6.5 % DM). The sample A1 also contained a high level of moisture (48 % DM) and a low level of lignin (ADL 6.3 % DM). All three features indicate a relatively young vegetation stage and high nutritive value of this grass sample.

The low amount of grass taken per feeding site and the high overall protein content of the ingested forage at track A1 could indicate that the animal ate less at the feeding sites but more selective for protein. Regarding all six feeding tracks, however, the relationship between the amount of grass taken per feeding site and protein content is not evident. For more detailed conclusions, a broader sample size is necessary. One could assume an overall compromise in selectivity: in a short-term perspective, an animal might select for high protein content. In a more long-term perspective, a balance between all nutritive demands (energy, nutrients, minerals, avoidance of anti-nutrients) might result in sufficient levels of all nutrients.

Malcolm (1981) noted that in addition to selection of protein and energy, large ungulates also appear to be able to select for minerals such as sodium and calcium. Comparing the concentrations of the nutritional components of the grass samples between the tracks, most of them show similar values (Table 3 and 4). Ben-Sahar (1993) and Ben-Sahar and Malcolm (1992), determined the chemical composition (N, P, K, Ca, Mg, Fe, Zn, Cu, moisture, fibre) of ten different grass species in an area of South Africa near to our study site. Ben-Sahar (1993) supported the statement of Georgiadis and McNaughton (1990) that some grass species were characterised by high levels of a particular element and no single species accumulated high levels of all nutrients. The ranges of nutritive values between the tracks of this study are smaller than the ranges of nutritive values between the ten different grass species (Ben-Sahar 1993), because our track samples always consisted of several grass species.

The amounts of the macroelements in the South African grass are notably lower than in the forage of the zoo study (Table 5). This situation persists if the concentrations of all measured elements (marco and trace elements) from South African grass are compared to the conventional amounts for German forage published by the German Agriculture Society (DLG 1973, 1995). Tropical forages are of lower quality than temperate ones and often chronically deficient in mineral elements (McDowell 1985). The mean amounts of the minerals calcium (2.4 g/kg DM) and phosphorus (1 g/kg DM) in the South African grass are half of the amounts of these minerals in the forage from the zoo study (Table 5). Dietary calcium to phosphorus ratios ranging from 1:1 and 2:1 are best for proper absorption and metabolism, even though higher ratios can be handled (Robbins 1993). In the field study the ratios range between 1.9 and 3.6 and in the zoo study between 2.6 and 3, so no health problems due to the dietary calcium to phosphorus ratios should be expected. Ben-Sahar (1993) found similarly low values of Ca (1.7-4.0 g/kg DM) and P (4.0-0.9 g/kg DM) in the ten South African grass species. Grass from the Serengeti National Park in Tanzania, also showed low amounts of Ca (3.4-4.1 g/kg DM) and P (2.8-4.2

g/kg DM)(McNaughton 1988). The concentration of sodium in African grass with an average of 0.3 g/kg DM was ten times lower than the German forages (Table 5). The chlorine level was also lower in South African grass. Musalia et al. (1989) also found low sodium levels (0.2 g/kg DM) in grass commonly consumed by goats in western Kenya; the authors expect this to be a limiting factor of animal production in this area. The low sodium content of many plants could be an important defence that could reduce animal populations (Robbins 1993). Ungulates in Africa tend to meet their sodium requirements by geophagia at salt licks, at eroded termite mounts, or by consuming brackish water (Jarman 1972, McNaughton 1988), and white rhinos are no exception (Owen-Smith 1973 and 1988). At the game farm from this investigation salt licks were offered to all animal but no consumption by rhinos was directly observed. Potassium content also was considerably lower in the samples from South Africa compared to those from German (8.5 g/kg DM). Ben-Sahar (1993) reports potassium values of 4.8-14.9 g/kg DM in grass from South Africa. McNaughton (1988) presents, in grass from Kenya, values around 20 g/kg DM and Field (1976), for Uganda, values of eight different grass species between 2.7 and 28.4 g/kg DM. Magnesium content in South African grass samples, with a mean of 0.8 g/kg DM, is only about half the value common in grass in Germany (DLG 1995, Table 5). Musalia et al. (1989) and McNaughton (1988) found, for grasses from Kenya, about twice the amount of Mg than we did at our study site.

The results of our study demonstrate that white rhinos are capable of selecting not only at the level of feeding habitat (Owen-Smith 1973) but also at the level of particular of grass species. The difference in mineral content of the native forages and those used in a German captive feeding regime could suggest that a particular supplementation with marcominerals, e.g. calcium and phosphorus, is not as warranted as is commonly perceived within the zoo community.

Conclusions

1. Feeding tracks of male, territorial white rhino bulls on a game farm in South Africa varied considerably in length, amount of food taken, selectivity on the level of plant species.
2. Whereas one particularly long trail showed the animal to crop mostly small amounts of high-protein-content plants, all feeding trails taken together demonstrate an even distribution of nutrients, energy and minerals.
3. Mineral content of the plants consumed was considerably lower than that of plants fed to white rhino in a German zoo. This is in accord with similar reports from the literature on mineral contents of African and European forages. The relevance of this finding for

captive mineral supplementation regimes should be further investigated.

Acknowledgements

We want to thank DAAD and Zebra Foundation for their financial support.

References

Ben-Sahar R. 1993: Patterns of nutrient contents in grasses of a semi-arid savanna. Afr J Ecol 31:343-347.

Ben-Sahar R, Malcolm JC. 1992: The relationships between soil factors, grass nutrients and the foraging behaviour of wildebeest and zebra. Oecologia 90:422-428.

DLG. 1973. Futterwerttabellen-Mineralstoffgehalte in Futtermitteln. Arbeiten der DLG Bd. 62, Dokumentationsstelle der Universität Hohenheim, 2. Aufl. Frankfurt/Main, Germany: DLG-Verlag.

DLG. 1995. Futterwerttabellen für Pferde. 3. Aufl., Frankfurt/Main, Germany: DLG-Verlag.

Field CR. 1976: Palatability factors and nutritive value of the food of buffaloes in Uganda. E Afr Wildl J14:181-201.

Georgiadis NJ, McNaughton SJ. 1990. Elemental and fibre contents of savanna grasses: variation with grazing, soil type, season and species. J Appl Ecol 27:623-634.

Hume JD. 1995: General concepts of nutrition and nutritional ecology. In: Ganslosser U, Hodges JK, Kaumanns W, editors. Resource and captive propagation. Fuerth, Germany: Filander-Verlag. 90-98.

Jarman PJ. 1972: The use of drinking sites, wallows and salt licks by herbivores in the flooded Middle Zambezi Valley. E Afr Wildl J 10:193-209.

Johnson DH. 1980. The comparison of usage and availability measurement for evaluating resource preference. Ecology 61:65-71.

Kiefer B, Wichert B, Ganslosser U, Kretzschmar P, Kienzle E. Digestibility trials in the zoo compared to field studies of white rhinoceros. Proc Int Symp Elephant and Rhino Res, June 7-11, 2001, Vienna. (in press)

Kretzschmar P. 2002. Ecological, endocrinological and ethological investigations of female male choice in free-ranging white rhinoceros. [dissertation] Zoological Institute I, Friedrich-Alexander University of Erlangen-Nürnberg, Germany.

Malcolm C. 1981. Large herbivores and food quality. Symp Brit Ecol Soc 2:345-368.

Manly BFJ, McDonald DL. 1993. Resource selection by animals: statistical design and analysis for field studies. London: Chapman & Hall.

McDowell LR. 1985. Nutrition of grazing ruminants in warm climates. New York: Academic Press.

McNaughton SJ. 1988. Mineral nutrition and spatial concentrations of African ungulates. Nature 334:343-345.

Musalia LM, Semenye PP, Fitzhugh HA. 1989. Mineral status of dual-purpose goats and forage in western Kenya. Small Rum Res 2:1-9.

Naumann C, Bassler R, editors. 1988. Die chemische Untersuchung von Futtermitteln. Band III Methodenbuch. Darmstadt, Germany: Naumann-Neudamm.

Owen-Smith N. 1973. The behavioural ecology of the White Rhinoceros. [dissertation] University of Wisconsin.

Owen-Smith N. 1988. Megaherbivores: The influence of very large body size on ecology. Cambridge: Cambridge University Press.

Robbins CT. 1993. Wildlife feeding and nutrition. London/San Diego: Academic Press.

Stephens DW, Krebs J. 1986. Foraging theory. Princeton: Princeton University Press.

Van Oudtshoorn FP. 1992. Guide to grasses of South Africa. Cape Town, RSA: Briza Publikasies Cc.

Van Soest PJ. 1967. Development of a comprehensive system of feed analysis and its application to forages. J Anim Sci 26:119-125.

Table 1. Tracking data: length of the tracking distance in meter (m), number of feeding sites and amounts of the ingested grass (g) of fresh weight.

animal	track	tracking distance (m)	feeding sites per track (n)	average tracking dist. per feeding site (m)	grass samples fresh weight (g)	average grass amount (g) per feeding site
A	A 1	4230	26	163	1930	74
	A 2	890	6	148	2900	483
B	B 1	2230	14	159	4250	304
	B 2	1700	9	189	2870	319
G	G 1	3010	8	376	1940	243
	G 2	5180	10	518	2120	212

Table 2. Frequency of feeding (total number) and frequency of occurrence (in percent) of the grass species and their classification by Van Oudthoorn (1992) in the territories of animal A and G.

			ANIMAL A		ANIMAL G	
Grass species	graz. value	palatability	frequency of feeding	frequency of occurence	frequency of feeding	frequency of occurence
Aristida spp.	very low	unpalatable	5	79	1	74
Brachiaria nigropedata	very high	very palatable	7	9	-	15
Digitaria eriantha	high	palatable	2	12	4	63
Enneapogon cenchroides	medium	palatable	3	3	5	15
Enneapogon scoparius	very low	palatable	2	39	-	41
Eragrostis rigidor	low	unpalatable	-	93	6	89
Heteropogon contortus	medium	palatable	4	15	1	19
Melinis repens	low	palatable	8	57	-	63
Panicum coloratum	very high	palatable	2	21	2	22
Panicum maximum	very high	very palatable	-	39	2	56
Schmidtia pappophoroides	high	palatable	2	94	-	67
Tragus berteronianus	low	palatable	5	79	-	44
Urochloa mosambicensis	high	palatable	4	61	1	48

Table 3. Composition of dry matter (DM as percent of fresh weight) and organic matter (OM), crude fat (CFat), crude fibre (CF), crude protein (CP), nitrogen free extracts (NfE), acid detergent lignin (ADL) and neutral detergent fibre (NDF) in percent of DM and the gross energy (GE) in MJ per kg DM of the grass samples from the feeding tracks.

Track	DM (% FW)	OM (% DM)	CFat (% DM)	CF (% DM)	CP (% DM)	NfE (% DM)	GE (MJ/kg DM)	ADL (% DM)	NDF (% DM)
A 1	48.1	91.8	1.1	35.8	6.5	48.4	18.3	6.3	74.7
A 2	65.4	92.2	1.1	37.1	4.1	49.9	18.4	6.6	75.4
B 1	49.4	90.9	0.9	34.9	5.6	49.4	18.1	6.2	73.5
B 2	64.9	92.0	1.0	34.9	4.2	51.9	18.3	7.5	75.1
G 1	55.3	90.9	1.4	35.2	3.5	50.8	18.2	6.7	73.3
G 2	68.0	92.6	1.1	35.4	4.1	52.0	18.6	7.5	75.7
mean	58.5	91.7	1.1	35.6	4.7	50.4	18.3	6.8	74.6
SD	8.7	0.7	0.2	0.8	1.1	1.4	0.2	0.6	1.0

Table 4: mineral content of the grass samples from the feeding tracks in dry matter

Track	Ca (g/kg)	P (g/kg)	Ca : P	Na (g/kg)	Cl (g/kg)	K (g/kg)	Mg (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Zn (mg/kg)
A 1	2.3	1.1	2.2	0.3	3.9	10.8	1086	6	156	25
A 2	2.7	1.0	2.8	0.3	1.5	7.0	542	4	213	18
B 1	2.2	1.2	1.9	0.2	3.0	9.9	1071	4	209	35
B 2	1.9	1.0	2.0	0.3	4.3	7.1	566	4	220	27
G 1	3.7	1.0	3.6	0.2	3.4	8.8	748	4	172	16
G 2	1.8	1.0	1.8	0.4	4.9	7.4	947	4	91	16
mean	2.4	1.0	2.4	0.3	3.5	8.5	827	4	177	23
SD	0.7	0.1	-	0.1	1.2	1.6	243. 7	1	49	8

Table 5. Average mineral contents of the grass samples from the field study and of the two forages from the zoo study

Forage composition	Ca (g/kg DM)	P (g/kg DM)	Ca : P	Na (g/kg DM)	Cl (g/kg DM)	K (g/kg DM)	Mg (g/kg DM)
Grass field	2.44	1.03	2.36	0.27	3.5	8.5	0.83
Grass zoo	5.97	2.33	2.56	3.81	4.66	12.17	2.08
Hay zoo	5.87	1.93	3.04	2.49	11.42	22.62	1.36