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Dietary overlap between Boer goats and indigenous browsers in a South African savanna

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The winter diet of free ranging Boer goats in Valley Bushveld, KwaZulu-Natal, was determined by direct observations and compared with the diet of indigenous browsers (kudu, eland, giraffe, black rhinoceros) in order to determine which browsers are most compatible with goats for ensuring more efficient use of savanna vegetation. Goats were predominantly browsers during winter, spending 73% of their time eating woody plant forage. Principal woody plant species in the diet included *Rhus pentheri, Acacia nilotica, Acacia karroo, Euclea crispa* and *Ziziphus mucronata*. Succulents (*Aloe ferox* and *Aloe maculata*) were also readily eaten. Highly preferred species were *Capparis sepiaria, Phyllanthus verrucosus* and *Scolopia zeyheri*, while *Rhoicissus tridentata, Calpurnia aurea, Acacia ataxacantha, Euclea natalensis, Clerodendrum glabrum, Zanthoxylum capense and Hippobromus paucifolia* were strongly avoided. Goats fed between ground level and 1m, with an average feeding height of 0.67m. The diet and feeding height of kudu and goats and of black rhinoceros and goats overlapped to a large extent suggesting that they are potential competitors for food resources. Similarly, overlap in diet between giraffe and goats was extensive, but overlap in feeding height was small. The potential for competition appeared to be the least between goats and eland because, despite feeding at similar heights, they generally consumed different species. A mixed farming system which includes goats, eland and giraffe is proposed as a useful management tool for using savanna vegetation more efficiently.

Keywords: animal production, bush encroachment, competition

Introduction

Approximately 54% of KwaZulu-Natal is covered by the Savanna biome (Low and Rebelo 1998), in which encroachment by woody plants at the expense of the grass layer has occurred (Edwards 1967, Hoffman and O'Connor 1999) as a result of commercial livestock production systems with only one or two species of grazing animals. Bush encroachment is considered a major threat to livestock production because it alters habitat structure and decreases herbaceous production (Stuart-Hill 1987). Thus, the incorporation of browsers in a savanna system is proposed as a useful management tool for using the grass and woody components more efficiently (Smith 1999). Their use may increase animal production and retard woody plant expansion (Owen-Smith 1985).

An emerging notion is to integrate wildlife into livestock systems in order to increase production (Jarman and Sinclair 1979, Owen-Smith 1985, Coppock *et al.* 1986). However, wild herbivores and livestock may compete for scarce resources, especially in arid and semi-arid rangelands (Voeten and Prins 1999). A question arising is the compatibility of livestock and wildlife (Voeten 1999). Animals suggested to complement cattle in livestock enterprises include greater kudu (*Tragelaphus strepsiceros* Pallas), a browsing antelope of 180–300kg, eland (*Taurotragus oryx* Pallas), a 450–700kg predominantly browsing antelope, giraffe (*Giraffa camelopardalis* L.), a large browser (700–1 400kg), and black rhinoceros (*Diceros bicornis* L.), an 800–1 100kg browser. Boer goats, an alien domestic mixed feeder weighing 35–70kg, may complement grazers in livestock systems (Owen-Smith 1985), but little is known about their diet, especially in KwaZulu-Natal. Another option may be a combination of goats and indigenous browsers, but this would only be feasible if competition between them was not severe. Knowledge of the diet selection of goats and indigenous browsers is therefore required for ascertaining whether they complement or compete with one another.

In terms of the national goat population, KwaZulu-Natal ranks third (13%) after the Eastern Cape (50%) and Northern Province (15%) (De Villiers *et al.* 1998). Goats offer socio-economic advantages because of their minimal management requirements, wide-scale availability, low initial replacement and maintenance cost, production of meat and milk in sustainable quantities for household consumption, and ecological advantages of biological control of bush encroachment and their ability to survive and produce in harsh environments (Slippers *et al.* 1998). Goats thus provide a means of enhancing veld condition, improving the quality of life and increasing income.

This study investigated diet selection over the winter season only. This is a crucial period when the availability of food decreases in quantity and quality (Owen-Smith 1985) and competition is most likely to occur (Schoener 1982). The aims of this study were to determine the diet composition of free ranging Boer goats during winter and quantify the degree of dietary overlap of Boer goats with eland, kudu, giraffe and black rhinoceros in order to determine which indigenous browsers are most compatible with goats for ensuring more efficient use of savanna vegetation.

Procedure

Study area

The Boer goat study was undertaken in the 750ha Roodedraay farm (28°56'1"S, 30°00'E), situated approximately 15km from the town of Weenen in KwaZulu-Natal, South Africa. Mean annual rainfall is 656mm, with the dry season stretching from May to August. Mean annual minimum and maximum temperatures are 10.7°C and 23.7°C, respectively. Altitude ranges from 900–1 400m asl. Geological formations of the area consist of the Beaufort (sandstone) and Ecca (shale) series, while soil types include Mispah, Glenrosa, Hutton, Clovelly and Shortlands (Camp 1999a). Vegetation is classified as Valley Bushveld (Acocks 1953), which is dominated by *Acacia* species, although there is a diversity of broadleaved species.

The diet of Boer goats at Roodedraay was compared with the diets of eland, kudu, giraffe and black rhinoceros in the nearby Weenen Nature Reserve (WNR) (28°51'S, 30°00'E). Mean annual rainfall, measured at WNR, is 732mm (1981—1999) with a hot and humid wet season from September to April, and a cool to cold dry period over the rest of the year. Vegetation types of both study sites correspond to Valley Bushveld, although WNR also supports Mixed Thornveld and Dry Tall Grassveld on the higher plateaux (Camp 1999b). It was therefore feasible to compare directly the diets of the aforementioned species.

Data collection

Data collection follows the methodology for a study of the diets of greater kudu, eland, giraffe and black rhinoceros at WNR based on two winter periods (1998 and 1999) (Breebaart 2000). Details of the diets of indigenous browsers are presented elsewhere (Breebaart 2000).

Diet composition and feeding heights

Feeding observations of free ranging Boer goats were conducted from 07h00 to 15h45 daily except on weekends for a period of six weeks during winter (19 June–22 July 2000). A herd of 120 animals, consisting of adults, sub-adults and juveniles, was observed. Juvenile goats were six months to a year old, sub-adult goats were between a year and two years old, while adults were older than two years. All individuals were marked with coloured ear tags which aided rapid and accurate identification of age. Goats were penned nightly and released to roam freely during the day. The goats soon became habituated to the presence of an observer so that it was possible to observe animals from ranges of 1–5m with minimal disturbance.

Only foraging animals were observed and the most clearly visible animal was selected as a focal animal. If it did not feed within 60 seconds, a new focal animal was chosen. Each instance in which a focal animal fed on an individual woody plant was recorded as one feeding event. If an animal returned to a plant that it had previously browsed, this was not regarded as a separate, independent feeding event. Herbaceous plants grow in close proximity to each other and, therefore, when grasses and forbs (including creepers) were eaten, this was recorded as a single feeding event irrespective of the number of plants utilised. Time spent feeding was recorded with a stop watch. Each feeding event included the time when the focal animal took its first bite from a particular woody plant until it swallowed its last bolus. If the focal animal fed on herbaceous plants the feeding time included the total time that the animal's nose was in the sward. Such records did not, therefore, constitute feeding events on individual plants. The number of bites taken from each woody plant was recorded.

Once feeding began, the following were recorded: date, duration of observation, age (adult, sub-adult, or juvenile) of focal animal, plant species and plant part eaten, feeding height, and height of plant species. Plant nomenclature followed Arnold and De Wet (1993). Woody plant parts were classified as leaves, twigs, flowers and fruit. Feeding height was measured as the height above ground at which the animal fed on woody plant species. Utilisation of feeding heights was recorded in terms of frequency of utilisation, feeding time and number of bites. If several feeding heights were utilised during one feeding event, all were recorded. If branches were broken for feeding, the feeding height was taken as the height of the forage prior to being broken.

Available browse

Available browse refers only to woody plant species and was defined as the total material (leaves, twigs, flowers and fruit) of all woody plant species accessible to the focal animal while feeding. The amount of available browse was determined using number of plants available (hereafter frequency of occurrence) and standard browse volumes (SBV's, Emslie and Adcock 1990). The latter method is a non-destructive, time-efficient procedure in which the amount of available browse is estimated, using photographic standards, by visually judging how many times a one litre container can be filled with the browse on offer.

Based on the method of Owen-Smith and Cooper (1987a), the foraging path of the focal animal was noted for each feeding observation, then a string laid along the path and all woody plants within neck and height reach of the animal, rooted on either side of the string, were enumerated and the amount of browse visually estimated in SBV's. If only a single plant was fed on, then availability was assessed within a circle around the stem of the plant fed on, with the radius dependent on the appropriate neck reach of the animal. Neck reach for juvenile goats was assumed to be 0.35m, and 0.5m for sub-adults and adults on either side of its hoof placement. Maximum height reach was assumed to be 1.5m for juveniles, 2m for sub-adults and 2.5m for adults. If a plant was within neck reach but all plant material was above maximum height reach, then the plant was not recorded as available. Plant height and height of canopy bottom of each available woody plant were measured precisely and plant species was recorded.

Data analysis

Data considerations

Field studies of animal diet are beset by a host of problems that affect the validity of statistical tests. In this study, only one property could be selected for each of goats and wildlife. Evaluation of diet and dietary overlap is therefore location-specific. Observations of wildlife were not drawn at random because they were made only from roads (Breebaart 2000). Observations of goats were biased because only goats at the edge of the flock could be observed. Consecutive feeding events of the same animal may involve serial dependence. It was not time-efficient to compensate by recording only a single feeding event per animal. Defining available food in relation to neck length assumes knowledge of an animal's perceptual environment, which is unknowable. It is improbable large herbivores are not aware of plants outside of their neck reach. The pronounced spatial variation of savanna vegetation underscores this effect. We are not aware of any field study that has adequately addressed all these problems. Instead of discounting statistical procedures altogether, we conduct appropriate tests but emphasize they must be interpreted in the light of data deficiencies (see Stewartoaten 1995).

Diet composition was analysed separately for forage types and woody plant species. A forage type was defined as a class of food items for which it may be assumed there is less variability in quality within a class than among classes (Du Toit 1988). Forage types were classified as grasses (including sedges and reeds), forbs (including creepers), and the flowers, fruit, and forage (leaves, shoots, stems) of woody plant species (including succulents and alien species). Woody plant species were those fed on at the time of sampling, irrespective of plant part. Feeding height and available browse were analysed for woody plant species only.

To compare the feeding behaviour of Boer goats with indigenous browsers, data analysis follows that of Breebaart (2000), where feeding time was employed for assessing the use of forage types, frequency of utilisation was selected for evaluating the use of woody plant species and feeding heights, and frequency of occurrence was used for analysing availability. It was, however, recognised that discrepancies among the various methods used to quantify diet, feeding height and available browse may exist. Therefore, the relations between the different methods were examined with appropriate correlations. There were no inconsistencies among methods. The proportion of time spent feeding on forage types was closely correlated with both the frequency of utilisation and with the number of bites taken (each $r > 0.99$, df = 3, $P < 0.001$), frequency of utilisation of woody plant species was closely correlated with the number of bites taken ($r = 0.98$, df = 45, $P < 0.001$) and time spent feeding ($r = 0.91$, df = 45, $P < 0.001$), frequency of utilisation of feeding heights was closely correlated with time spent feeding ($r = 0.99$, df = 2, $P < 0.02$) and bites taken ($r = 0.86$, df = 2, $P < 0.02$), and frequency of occurrence of woody plant species was correlated with standard browse volumes ($r = 0.85$, df = 55, $P < 0.001$).

Diet composition and feeding heights

Goodness-of-fit tests (G statistic) were conducted to determine if, firstly, woody plant species and, secondly, feeding heights on woody plants were utilised with equal frequency, but only if data met both the Roscoe and Byars (1971) [average expected frequency (i.e., n/k) must be ≥ 2.0 at $\alpha = 0.05$] and Koehler and Larntz (1980) [$k \geq 3$; $n \geq 10$; $n^2/k \geq 10$] guidelines (where n is the sample size and k is the number of categories). Feeding heights were grouped into the height categories of 0 to ≥0.5m, >0.5 to ≥1.0m, >1.0 to ≥1.5m, and >1.5 to ≥2m. Average feeding height was calculated based on the median of the height classes (Du Toit 1988, 1990).

Woody plant species eaten by goats were grouped into microphyllous (*Acacia* species) and broadleaved plants (all other species), which ensured that average expected frequencies were at least 6.0 (Roscoe and Byars 1971). Firstly, a G-test was conducted to determine if microphyllous and broadleaved species were utilised with equal frequency. Secondly, the diet of Boer goats was compared with that of eland, kudu, giraffe and black rhinoceros using a Chi-squared (χ^2) test to determine if the proportions of microphyllous and broadleaved plants were dependent on animal species.

Food preferences

Food preferences of goats were determined for woody species only, using Ivlev's forage ratio (FR) (Ivlev 1961) and Bonferroni confidence intervals (Neu *et al.* 1974, Byers *et al.* 1984). The FR of a species was calculated as the proportion of a species eaten divided by the proportion of that species available, with values greater or less than 1.0, respectively indicating species that are preferred or avoided (Petrides 1975). Only forage ratios calculated for species which were encountered frequently, i.e., ≥5, were considered accurate.

For Bonferroni confidence intervals, an adjustment of $\alpha/2k$ is required because several parameters are estimated simultaneously (Neu *et al.* 1974). The Bonferroni method assumes that sample size is sufficiently large so a *normal* distribution approximation to the binomial distribution is valid. Therefore, confidence intervals were regarded as accurate only when np_i and $n(1-p_i)$ were both ≥5 (Alldredge and Ratti 1986). Use of the method assumes that availabilities are measured without error and are not estimated quantities (Thomas and Taylor 1990, Alldredge and Ratti 1986). However, available browse is always estimated.

Dietary overlap between goats and indigenous browsers

Overlap in diet, based on forage types, was estimated for the browser pairs eland-goat, kudu-goat and giraffe-goat. Overlap in the use of forage types between black rhinoceros and goats could not be determined because the method for assessing the diet of black rhinoceros precluded recording the use of forage types (Breebaart 2000). Similarities in the use of woody plant species and feeding heights were assessed between goats and each of the four indigenous browsers. Based on recommendations by Linton *et al.*

(1981) both Percentage Similarity (PS) and Pianka's overlap index were used for assessing dietary overlap. PS ranges from 0 (no overlap) to 100 (total overlap), while Pianka's values range from 0 (no resources used in common) to 1.0 (complete overlap of resources). Similarity measures are descriptive coefficients that do not estimate a statistical parameter (Krebs 1999) and, therefore, statistical testing of overlap indices is meaningless. Total dietary overlap in the use of woody plant species was estimated by multiplying the measures of overlap in diets and feeding heights (as proportions) to give 'product a' (May 1975). This assumes that the resource dimensions are independent of each other. This is questionable, but marked interdependence is unlikely.

Results

Diet composition and feeding heights

Feeding by Boer goats was observed for 219 hours. Woody forage comprised the majority of the diet (Figure 1), with goats spending 14% of their time feeding on the succulent species (*Aloe ferox* and *Aloe maculata*). Fallen leaves of *Ziziphus mucronata* contributed a relatively large portion (6%) of their diet. Goats spent little time feeding on grass, flowers, fruit and forbs (Figure 1). Grass species eaten included *Bothriochloa insculpta*, *Cymbopogon excavatus*, *Eragrostis plana* and *Themeda triandra*, while the flowers of the forbs *Asparagus setaceus* and *Peristrophe natalensis* and the fruit of *Acacia ataxacantha*, *Datura stramonium* and *Z. mucronata* were consumed. Other forbs in the diet included *Asparagus virgatus*, *Issoglosa grantii* and *Jasminum multipartitum*.

Woody plant species were not utilised by Boer goats with equal frequency (G = 1325.16, df = 46, P<0.001). *Rhus pentheri* formed the bulk of the diet (Figure 2). The straight-thorned *Acacia nilotica* and *Acacia karroo* were eaten more frequently than the hooked-thorned *Z. mucronata* and *Acacia tortilis*. *Euclea crispa*, *D. stramonium*, *A. ferox*, *A. maculata* and *Maytenus senegalensis* each contributed more than 3% to the diet.

Boer goats utilised broadleaved plants more frequently than microphyllous plants (72% versus 28%; G_c = 135.10, df = 1, P<0.001; Figure 3). The proportion of microphyllous and broadleaved plants in the diet of Boer goats and indigenous browsers depended on animal species (χ^2 = 382.81, df = 4, P<0.001). During winter, eland utilised only microphyllous species (*A. karroo* and *Acacia sieberiana*), while giraffe and black rhinoceros utilised microphyllous species more frequently than broadleaved species (Breebaart 2000). The converse was true for kudu (Breebaart 2000) and goats (Figure 3).

Feeding height classes were not utilised with equal frequency by goats (G = 379.73, df = 3, P<0.001). Goats fed mostly between 0m and 1.0m, and uncommonly at heights greater than 1.5m (Figure 4). Their average feeding height was 0.67m.

Dietary preferences

Bonferroni confidence intervals demonstrated a negative selection for *Acacia ataxacantha*, *Coddia rudis* and *Euclea natalensis*, which was supported by these species FR values being less than 1.0 (Table 1). FR values also indicated that *Clerodendrum glabrum*, *Hippobromus pauciflorus*, *Maytenus heterophylla*, *Maytenus senegalensis*, *Rhus rehmanniana*, *Zanthoxylum capense* and, especially, *Calpurnia aurea* and *Rhoicissus tridentata* were avoided. For principal species in the diet (Figure 3), the FR values were greater than 1.0 (Table 1), indicating they were preferred. The exceptions were *A. maculata* and *M. senegalensis*. Based on FR values, other preferred species included *Cussonia spicata*, *Putterlickia verrucosa*, *Tarchonanthus camphoratus* and *Vepris lanceolata*. Relatively high FR values (>1.8) indicated *Capparis sepiaria*, *Phyllanthus verrucosus* and *Scolopia zeyheri* were strongly preferred species of goats. The remainder of the species eaten by goats, encountered more than five times, were considered to be neutrally selected. Eleven available species were not eaten, including *Celtis africana*, *Opuntia ficus-indica*, *Ptaeroxylon obliquum* and *Vitex rehmannii*.

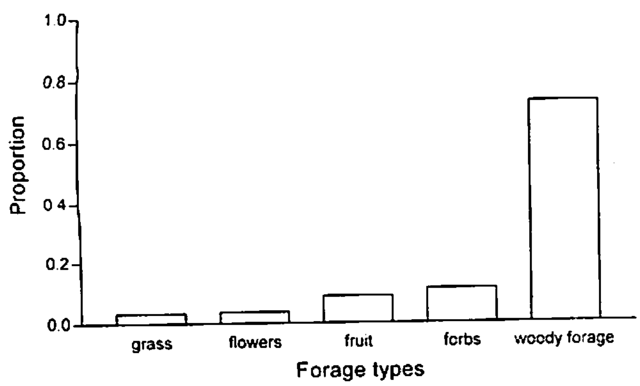

Figure 1: Proportion of time spent feeding by Boer goats on different forage types

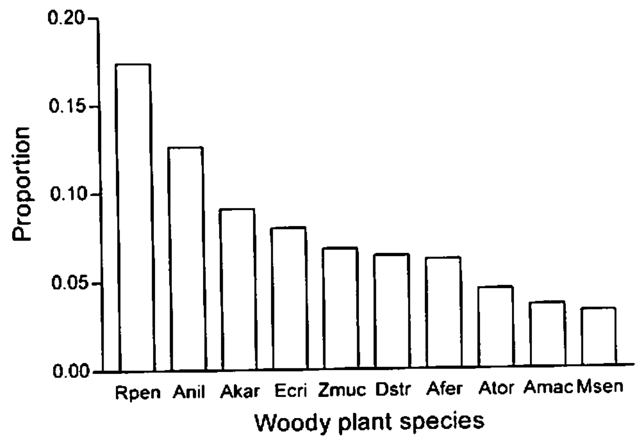

Figure 2: Proportion of woody plant species utilised by Boer goats. Only plant species which contributed ≥3% to the diet are included. Key to plant species: Akar – *Acacia karroo*, Anil – *Acacia nilotica*, Ator – *Acacia tortilis*, Afer – *Aloe ferox*, Amac – *Aloe maculata*, Dstr – *Datura stramonium*, Ecri – *Euclea crispa*, Msen – *Maytenus senegalensis*, Rpen – *Rhus pentheri*, Zmuc – *Ziziphus mucronata*

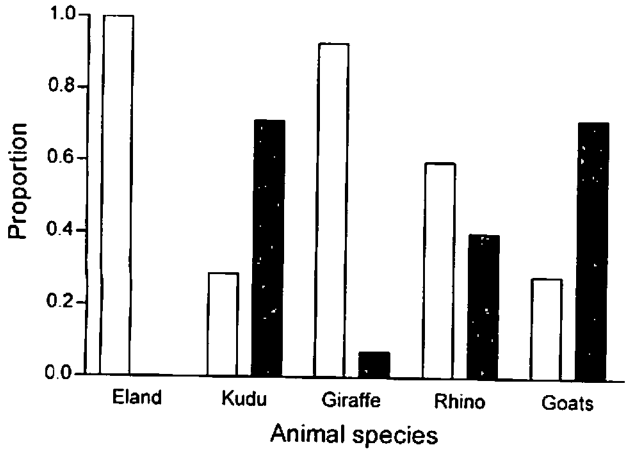

Figure 3: Proportion of microphyllous (clear) and broadleaved (black) woody plant species utilised by Boer goats and indigenous browsing animal species

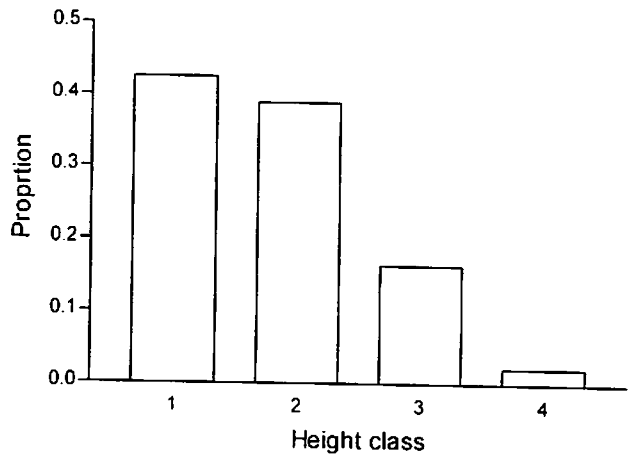

Figure 4: Proportion of height classes utilised by Boer goats, considering woody plant species. Key to height classes: 1 = 0 – ≤0.5; 2 = >0.5 – ≤1.0; 3 = >1.0 – ≤1.5; 4 = >1.5 – ≤2.0

Dietary overlap between Boer goats and indigenous browsers

Of the 188 species encountered at both Roodedraay and WNR, 10 species were not available at WNR and 14 were not available at Roodedraay. Following the guidelines of Linton *et al.* (1981), the PS index was used as an estimate of overlap because all PS values, except one, were less than 80.0% and only two Pianka values exceeded 0.92.

In terms of forage types, the PS was great between goats and eland (60.9), goats and kudu (74.3) and giraffe and goats (75.9), mainly owing to the extensive use of woody plant forage by each animal species. Overlap in diet and feeding height of woody plant species was marked for the kudu-goat pair and, especially, the black rhinoceros-goat pair (Table 2; Figure 5). The diets of giraffe and goats were similar, but, not unexpectedly, their feeding levels overlapped to a small degree. Eland and goats fed at similar heights but their diets were dissimilar. Total dietary overlap was relatively small for the eland-goat and giraffe-goat pairs, but extensive between kudu and goats and, especially, between black rhinoceros and goats (Table 2).

Discussion

Dietary patterns

Although goats utilised all forage types during winter, they devoted the majority of their feeding time to woody plant forage, which is in accordance with other findings (Du Toit 1972, Nge'the and Box 1976, Owen-Smith and Cooper 1985, Cooper and Owen-Smith 1986). Boer goats can thus be considered predominantly browsers during winter (Grunow 1980, Owen-Smith and Cooper 1985) as grass contributed less than 4% of their diet during this period. Goats spent little time feeding on flowers, but the flowers and needle like leaves of *Asparagus setaceus* were readily sought after (see also Kok *et al.* 1994). Although fruit and forbs formed a relatively small proportion of the diet they may act as reserve foods during the dry winter period. Similarly, the leaves shed by deciduous trees, especially *Ziziphus mucronata*, became an important food source during winter. Likewise, goats at Nylsvley Nature Reserve made substantial use of leaf litter during winter (Owen-Smith and Cooper 1985).

In terms of woody plant species, goats exhibit a generalist food choice, as found by Owen-Smith and Cooper (1987b), with no one species contributing more than 18% to the diet. Important woody plants in the winter diet of goats included *Acacia* and *Aloe* species. Condensed tannin in *Acacia* species do not appear to affect greatly acceptability of plants by goats (Owen-Smith and Cooper 1985) which can be attributed to an active tannin enzyme in their rumen mucosa (Kumar and Singh 1984). The leaves of the succulent species *Aloe ferox* and *Aloe maculata*, and fruit of *D. stramonium* were utilised extensively. The bitter sap of *Aloe* leaves contains anthraquinone derivatives (Hutchings 1996), while the pods of *D. stramonium* are highly toxic owing to the presence of the alkaloids hyoscyamine, hyocine and atropine (Watt and Breyer-Brandwijk 1962). Boer goats thus appear to have a high tolerance for certain plant chemical products.

Although goats have the ability to adopt a bipedal stance when feeding, thus allowing them to feed at a higher level, they favoured feeding between ground level and 1m. Grunow (1980) reported goats feed between 0.1–1.57m. A consequence for *A. ferox* was that small plants were utilised more frequently than tall plants, which, together with high mortality, suggests that recruitment will be limited. Future existence of this species in this savanna system is thus threatened (Breebaart *et al.* 2002). It was not possible to observe in the field, but goats probably impact the recruitment of most palatable woody plants.

Rhus pentheri, the most frequently available species was also the most frequently eaten species. The more preferred species, *Capparis sepiaria, Phyllanthus verrucosus* and *Scolopia zeyheri*, were amongst the most uncommon species. Although *R. pentheri* may be available in sufficient quantities to act as a food reserve during winter, the rarer species may not. Severe utilisation of these latter species could result in their decline.

Table 1: Simultaneous Bonferroni confidence intervals[1] and forage ratio[2] (FR) values for the utilisation of woody plant species, p_i, by Boer goats, where p_o is the expected proportion of usage of a species based on availability

Species	p_i	p_o	Bonferroni interval for p_i			FR values
Acacia ataxacantha	0.020	0.054	0.002	≤ p ≤	0.038*	0.37
Acacia karroo	0.091	0.075	0.055	≤ p ≤	0.128	1.22
Acacia nilotica	0.126	0.112	0.084	≤ p ≤	0.168	1.13
Acacia tortilis	0.045	0.036	0.019	≤ p ≤	0.071	1.26
Aloe ferox	0.062	0.040	0.032	≤ p ≤	0.093	1.56
Aloe maculata	0.036	0.041	0.013	≤ p ≤	0.060	0.89
Calpurnia aurea	0.001	0.009	-0.003	≤ p ≤	0.006	0.16
Capparis sepiaria	0.020	0.010	0.002	≤ p ≤	0.038	1.97
Clausena anisata	0.004	0.004	-0.004	≤ p ≤	0.013	1.06
Clerodendrum glabrum	0.001	0.003	-0.003	≤ p ≤	0.006	0.42
Coddia rudis	0.023	0.044	0.004	≤ p ≤	0.042*	0.53
Cussonia spicata	0.004	0.003	-0.004	≤ p ≤	0.013	1.27
Datura stramonium	0.064	0.047	0.033	≤ p ≤	0.095	1.35
Euclea crispa	0.080	0.053	0.046	≤ p ≤	0.114	1.51
Euclea natalensis	0.016	0.039	0.000	≤ p ≤	0.032*	0.41
Hippobromus pauciflorus	0.003	0.006	-0.004	≤ p ≤	0.010	0.47
Maytenus heterophylla	0.017	0.022	0.001	≤ p ≤	0.034	0.79
Maytenus senegalensis	0.032	0.054	0.010	≤ p ≤	0.054	0.59
Phyllanthus verrucosus	0.013	0.007	-0.001	≤ p ≤	0.027	1.90
Putterlickia verrucosa	0.006	0.004	-0.004	≤ p ≤	0.015	1.41
Rhamnus prinoides	0.004	0.004	-0.004	≤ p ≤	0.013	1.06
Rhoicissus tridentata	0.001	0.021	-0.003	≤ p ≤	0.006	0.07
Rhus dentata	0.004	0.005	-0.004	≤ p ≤	0.013	0.90
Rhus pentheri	0.174	0.157	0.126	≤ p ≤	0.222	1.11
Rhus rehmanniana	0.004	0.006	-0.004	≤ p ≤	0.013	0.70
Scolopia zeyheri	0.009	0.005	-0.003	≤ p ≤	0.020	1.81
Tarchonanthus camphoratus	0.016	0.011	0.000	≤ p ≤	0.032	1.45
Vepris lanceolata	0.007	0.005	-0.003	≤ p ≤	0.018	1.51
Zanthoxylum capense	0.003	0.007	-0.004	≤ p ≤	0.010	0.42
Ziziphus mucronata	0.068	0.059	0.036	≤ p ≤	0.100	1.15
Berchemia zeyheri	0.003	0.001	-0.004	≤ p ≤	0.010	2.11
Boscia albitrunca	0.003	0.001	-0.004	≤ p ≤	0.010	2.11
Brachylaena elliptica	0.001	0.002	-0.003	≤ p ≤	0.006	0.70
Buddleja dysophylla	0.001	0.003	-0.003	≤ p ≤	0.006	0.53
Combretum erythrophyllum	0.001	0.001	-0.003	≤ p ≤	0.006	2.11
Croton gratissimus	0.001	0.001	-0.003	≤ p ≤	0.006	2.11
Diospyros whyteana	0.001	0.001	-0.003	≤ p ≤	0.006	2.11
Drypetes gerrardii	0.001	0.001	-0.003	≤ p ≤	0.006	2.11
Ehretia rigida	0.003	0.002	-0.004	≤ p ≤	0.010	1.41
Euclea racemosa	0.004	0.002	-0.004	≤ p ≤	0.013	2.11
Grewia occidentalis	0.001	0.001	-0.003	≤ p ≤	0.006	1.06
Ochna natalitia	0.001	0.001	-0.003	≤ p ≤	0.006	2.11
Olea europaea	0.004	0.002	-0.004	≤ p ≤	0.013	2.11
Populus x canescens	0.006	0.003	-0.004	≤ p ≤	0.015	2.11
Rhus pallens	0.001	0.001	-0.003	≤ p ≤	0.006	2.11
Schotia brachypetala	0.001	0.001	-0.003	≤ p ≤	0.006	2.11
Scutia myrtina	0.003	0.001	-0.004	≤ p ≤	0.010	2.11

[1] where $\alpha = 0.05$, $k = 47$, $Z_{\alpha/2k} = 3.32$, $n = 689$; [2] FR calculated prior to rounding off of p_i and p_o

Species in bold: $np_i \geq 5$ and $n(1 - p_i) \geq 5$; species above line: availability ≥ 5

* indicates a difference at the 0.05 level of significance

Overlap with indigenous browsers

The extensive overlap in diet, in terms of woody plant species, between goats and black rhinoceros, kudu and giraffe does not confirm the presence or absence of competition (Colwell and Futuyama 1971, Schoener 1974, Lawlor 1980) but does indicate the potential for goats to compete with these browsers when resources are limited (Abrams 1980, Lawlor 1980). Not only do goats, kudu and black rhinoceros consume a similar suite of foods, they also feed at similar heights. Kudu have been proposed as a suitable complement to livestock in savanna systems (Owen-Smith 1985), but this study suggests this may not be so if goats are involved.

Despite the fact that goats and giraffe utilised different feeding levels, their diets were similar. Giraffe are partially

Table 2: Percentage similarity values for the overlap in diet composition, feeding height and total overlap for woody plant species between Boer goats and indigenous browsers

Browser pair	Diet composition	Feeding height	Total overlap
Eland–goat	9.1	60.7	0.06
Kudu–goat	30.0	63.4	0.19
Giraffe–goat	38.1	12.1	0.05
Black rhinoceros–goat	41.6	92.9	0.39

separated from most other browsers in terms of feeding height (Owen-Smith 1985, Du Toit 1988, 1990, Breebaart 2000) indicating that giraffe and goats may be compatible in a mixed farming system. Owen-Smith (1985) suggests that a combination of browsing ungulates favouring different height levels, such as giraffe, kudu and goats, could potentially increase animal production over cattle alone in typical savanna vegetation. However, giraffe do not restrict their feeding to a height beyond the reach of smaller browsers (Pellew 1984, Du Toit 1988, 1990, Breebaart 2000) so that separation is not complete and the potential for interspecific competition still exists (Du Toit 1990, Breebaart 2000).

Eland and goats fed at similar heights, yet they utilised different woody plant species and therefore they can be a compatible browsing pair. However, this suggestion should be viewed with caution because the sample size for the winter diet of eland was very small (Breebaart 2000). Eland graze when grass is available (Nge'the and Box 1976, Owen-Smith and Cooper 1985, Cooper and Owen-Smith 1986, Breebaart 2000) and thus goats and eland may compete for this food resource. Furthermore, goats and eland may compete with grazers to some extent if they are incorporated in a mixed farming system (Owen-Smith 1985).

Conclusion

The potential for competition appears to be greatest between goats and black rhinoceros as well as between goats and kudu and it is therefore recommended that these two indigenous browsers not be incorporated with livestock production enterprises that include goats. Additional factors bearing on this recommendation, such as black rhinoceros aggression, diversification of economic opportunities and disease or drought tolerance, have not been considered here.

Eland and giraffe appear to be most compatible with goats for ensuring more efficient use of savanna vegetation by utilising different plant species and feeding at different heights. In addition, bush encroachment, particularly of *Acacia* species, is likely to be contained in a savanna system which incorporates these browsers. Eland and goats together with grazers may, however, decrease animal production and be detrimental to savanna vegetation.

Despite the apparent importance of goats in farming systems, there is a lack of information pertaining to their diet, performance and productivity. Future research should test whether the combination of wild browsing species and goats in savanna systems optimises the use of natural resources and increases animal productivity.

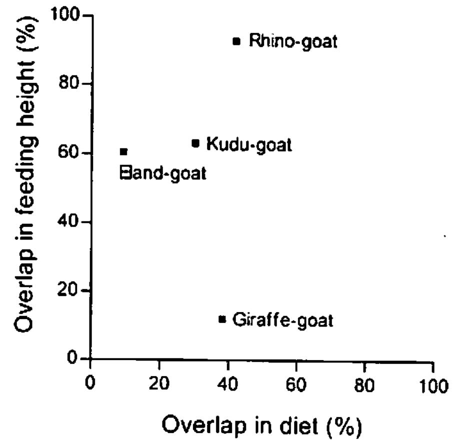

Figure 5: Overlap in feeding height and in diet composition of woody plant species for pairs of browsers

References

Abrams P 1980. Some comments on measuring niche overlap. Ecology 61(1): 44–49.

Acocks JPH 1953. Veld Types of South Africa. Memoirs of the Botanical Survey of South Africa 28.

Alldredge JR and Ratti JT 1986. Comparison of some statistical techniques for analysis of resource selection. Journal of Wildlife Management 50: 157–165.

Arnold TH and De Wet BC 1993. Plants of southern Africa: Names and Distribution. Memoirs of the Botanical Survey of South Africa 62.

Breebaart L 2000. Resource Overlap within a Guild of Browsing Ungulates in a South African Savanna. MSc thesis, University of Natal, Pietermaritzburg, South Africa.

Breebaart L, Bhikraj R and O'Connor TG 2002. Impact of goat browsing on *Aloe ferox* in a South African savanna. African Journal of Range & Forage Science 19: 77–78.

Byers CR, Steinhorst RK and Krausman PR 1984. Clarification of a technique for analysis of utilisation-availability data. Journal of Wildlife Management 48: 1050–1053.

Camp KGT 1999a. A Bioresource Classification for KwaZulu-Natal. MSc thesis, University of Natal, Pietermaritzburg, South Africa.

Camp KGT 1999b. The bioresource groups of KwaZulu-Natal. KwaZulu-Natal 4.1: 71–73.

Colwell RK and Futuyama DJ 1971. On the measurement of niche breadth and overlap. Ecology 52: 567–576.

Cooper SM and Owen-Smith N 1986. Effects of plant spinescence on large mammalian herbivores. Oecologia 68: 446–455.

Coppock DL, Ellis JE and Swift DM 1986. Livestock feeding ecology and resource utilization in a nomadic pastoral ecosystem. Journal of Applied Ecology 23: 573–580.

De Villiers JF, Letty B, and Braun A. 1998. Cashmere production in KwaZulu-Natal. In: Letty B (ed) Goat production — A compilation of papers presented at a Goat Day held by the KwaZulu-Natal Department of Agriculture, Cedara 26 November 1997. KwaZulu-Natal Department of Agriculture, Pietermaritzburg. pp 57–66.

Du Toit PF 1972. The goat in a bush-grass community. Proceedings of the Grassland Society of Southern Africa 7: 44–50.

Du Toit JT 1988. Patterns of Resource Use within the Browsing Ruminant Guild in Central Kruger National Park. PhD thesis, University of Witwatersrand, Johannesburg, South Africa.

Du Toit JT 1990. Feeding-height stratification among African browsing ruminants. African Journal of Ecology 28: 55–61.

Edwards D 1967. A plant ecological survey of the Tugela basin.

Memoirs of the Botanical Survey of South Africa No. 36.
Emslie RH and Adcock K 1990. Black rhino 2000 update: preliminary findings on black rhino habitat use in Hluhluwe/Umfolozi. Endangered Wildlife 4: 13–23.
Grunow JO 1980. Feed and habitat preferences among some large herbivores on African veld. Proceedings of the Grassland Society of Southern Africa 15: 141–146.
Hoffman MT and O'Connor TG 1999. Vegetation change over 40 years in the Weenen/Muden area, KwaZulu-Natal: evidence from photo-panoramas. African Journal of Range & Forage Science 16: 71–88.
Hutchings A 1996. Zulu-Medicinal Plants. University of Natal Press.
Ivlev VS 1961. Experimental ecology of the feeding of fishes. Yale Univeristy Press, New Haven, Connectticut, USA. p 302.
Jarman PJ and Sinclair ARE 1979. Feeding strategy and pattern of resource partioning in ungulates. In: Sinclair ARE and Norton-Griffiths M (eds) Serengeti: Dynamics of an Ecosystem, University of Chicago Press, London. pp 130–163.
Koehler KJ and Larntz K 1980. An empirical investigation of goodness-of-fit statistics for sparse multinomials. Journal of the American Statistical Association 75: 336–344.
Kok OB, Fourie LJ and Barkhuizen LM 1994. Diet of free ranging Angora goats in a False Upper Karoo veld type. South African Journal of Animal Science 24: 80–86.
Krebs CJ 1999. Ecological methodology (2nd ed.). Menlo Park, California. p 620.
Kumar R and Singh M 1984. Tannins: their adverse role in ruminant nutrition. Journal of Agricultural Food Chemistry 32: 447–453.
Lawlor LR 1980. Overlap, similarity and competition coefficients. Ecology 61: 245–251.
Linton LR, Davies RW and Wrona FJ 1981. Resource utilisation indices: an assessment. Journal of Animal Ecology 28: 55–61.
Low AB and Rebelo TGA (eds) 1998. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.
May RM 1975. Some notes on estimating the competition matrix. Ecology 56: 737–741.
Neu CW, Byers CR and Peek JM 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38: 541–545.
Nge'the JC and Box TW 1976. Botanical composition of eland and goat diets on an Acacia-grassland community in Kenya. Journal of Range Management 29: 290–293.
Owen-Smith N 1985. The ecology of browsing by African wild ungulates. In: Tothill JC and Mott JJ (eds) Ecology and Management of the Worlds Savannas — International Savanna Symposium. Australian Academy of Science, Canberra. pp 345–349.
Owen-Smith N and Cooper SM 1985. Comparative consumption of vegetation components by kudus, impalas and goats in relation to their commercial potential as browsers in savanna regions. South African Journal of Science 81: 72–76.
Owen-Smith N and Cooper SM 1987a. Assessing food preferences of ungulates by acceptability indices. Journal of Wildlife Management 51: 372–378.
Owen-Smith N and Cooper SM 1987b. Palatability of woody plants to browsing ruminants in a South African savanna. Ecology 68: 319–331.
Pellew RA 1984. The feeding ecology of a selective browser, the giraffe (*Giraffa camelopardalis tippelskirchi*). Journal of Zoology 202: 57–81.
Petrides GA 1975. The principal foods versus preferred foods and their relations to stocking rate and range condition. Biological Conservation 7: 161–169.
Roscoe JT and Byars JA 1971. Sample size restraints commonly imposed on the use of the chi-square statistic. Journal of the American Statistical Association 66: 755–759.
Schoener TW 1974. Some methods for calculating competition coefficients from resource utilization spectra. American Naturalist 108: 332–340.
Schoener TW 1982. The controversy over interspecific competition. American Scientist 70: 586–595.
Slippers SC, Lubout PC and De Villiers JF 1998. Current status and future prospects of goat production in KwaZulu-Natal. In: Letty B (ed) Goat production — A compilation of papers presented at a Goat Day held by the KwaZulu-Natal Department of Agriculture, Cedara 26 November 1997. KwaZulu-Natal Department of Agriculture, Pietermaritzburg. pp 1–12.
Smith JMB 1999. Use of browsers and licks in grazing management systems. In: Hardy MB and Hurt CR (eds) Veld in KwaZulu-Natal — Agricultural Production Guidelines for KwaZulu-Natal. KwaZulu-Natal Department of Agriculture, Pietermaritzburg. pp 173–175.
Stewartoaten A 1995. Rules and judgments in statistics: three examples. Ecology 76: 2001–2009.
Stuart-Hill GC 1987. Refinement of a model describing production, animal production and profitability as a function of bush density in the False Thornveld of the Eastern Cape. Journal of the Grassland Society of Southern Africa 41: 18–24.
Thomas DL and Taylor EJ 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54: 322–330.
Voeten MM 1999. Living with Wildlife. Tropical Resource Management Papers 29.
Voeten MM and Prins HHT 1999. Resource partitioning between sympatric wild and domestic herbivores in the Tarangire region of Tanzania. Oecologia 120: 287–294.
Watt JM and Breyer-Brandwijk MG 1962. Medicinal and Poisonous Plants of Southern and Eastern Africa. E & S Livingstone Ltd., London.