Habitat utilization of white rhinoceros (*Ceratotherium simum simum*) on Willem Pretorius Game Reserve, Free-State Province, South Africa

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Abstract

The grassland biome of the Free-State Province of South Africa meets all the suggested habitat requirements for the white rhino, but in contrast to warmer savannah areas experiences extremely cold winters. The aim of this study was to investigate the habitat utilization of white rhinos in the Free-State area. Five major plant community types were identified and data on movement and habitat utilization of white rhinos were collected over one year. Adult cows (n = 5) had a mean range size of 3.78 km² (SE ± 0.37) during the wet and 4.08 km² (SE ± 0.570) during the dry season, but no significant differences between the two seasons were found. The adult bull had a range size of 8.13 km² during the wet and 6.37 km² during the dry season. Based on availability, the expected utilization of each habitat type differed significantly from the observed usage during both the wet (i.e.χ^2 = 2,236.6; 6 df; p = 0.05) and dry season (χ^2 = 4,721.3; 6 df; p = 0.05). Wetland, Damkom, Savannah, and Grassveld habitats were used significantly less than expected, but the Thornveld and the Trees and Shrub habitats were used significantly more than expected, during both seasons. The River habitat was preferred during the wet but not the dry season. White rhinos were recorded to feed on 33 plant species in varying proportions. The results of this study suggest that in areas that experience hot or cold environments, some form of cover for white rhinos is important.

Additional keywords: Diet, range size, plant communities

Résumé

Le biome des herbages de la province de l'Etat-Libre d'Orange de l'Afrique du Sud répond à toutes les exigences de l'habitat proposé pour le rhinocéros blanc, mais contrairement aux zones plus chaudes de la savane, il subit des hivers extrêmement froids. Le but de cette étude était d'étudier l'utilisation de l'habitat des rhinocéros blancs dans la zone de l'Etat-Libre d'Orange. Cinq grands types de communautés végétales ont été identifiés et les données sur les déplacements et l'utilisation de l'habitat par les rhinocéros blancs ont été recueillies sur un an. Les adultes femelles (n = 5) avaient un habitat d'une taille moyenne de 3,78 km² (SE ± 0,37) au cours de la saison humide et 4,08 km² (SE ± 0,570) pendant la saison sèche, mais aucune différence significative entre les deux saisons n'a été trouvée. Le rhinocéros mâle avait un habitat de la taille de 8,13 km² pendant la saison humide et 6,37 km² pendant la saison sèche. En se basant sur la disponibilité, l'utilisation prévue de chaque type d'habitat différait sensiblement de l'utilisation observée à la fois pendant la saison pluvieuse (χ^2= 2,236.6; 6 df; p= 0.05) et la saison sèche (χ^2= 4,721.3; 6 df; p = 0.05). La zone humide, Damkom, la savane, et le veld herbeux ont été utilisés beaucoup moins que prévu, mais le veld épineux et les habitats boisés et arbustifs ont été utilisés beaucoup plus que prévu au cours des deux saisons. L'habitat riverain a été préféré au cours de la saison pluvieuse, mais pas pendant la saison sèche. On a observé que les rhinocéros blancs se nourrissaient de 33 espèces de plantes dans des proportions variables. Les résultats de cette étude suggèrent

que dans les zones qui connaissent des environnements chauds ou froids, une certaine forme de couverture pour rhinocéros blancs est importante.

Mots-clés supplémentaires: Alimentation, taille de l'habitat, communautés végétales.

Introduction

Historically, the southern white rhinoceros (*Ceratotherium simum simum*) was distributed across southern Africa in suitable habitats of semi-arid savannah and grasslands (Owen-Smith 1988). By the late 19th century, except for a small population of less than 100 individuals in the Hluhluwe region of KwaZulu Natal, they were considered extinct (Rookmaaker 2002). After an intensive breeding programme set up in Hluhluwe with the remaining few, by the 1960s the white rhino population had increased sufficiently to relocate individuals to various other reserves around the country. Although the first white rhinoceros was relocated into the Willem Pretorius Game Reserve (WPGR) within the grassland biome during 1962 a 2009 survey indicated that 214 white rhinos (153 on private and 61 on state land) occurred within the Free-State Province of South Africa (Jordaan 2010). Despite this, only a study by Bermudez (1998) who analysed monitoring data collected from 1962 to 1997 to determine population performance of the WPGR population and a broad ecological management plan conducted by Krietzmann (1988) on WPGR have been conducted in the Free-State specifically focusing on the white rhino. Many studies conducted on the ecology of white rhinos, have been restricted to the savannah areas of the country (e.g. Owen-Smith, 1988; Conway and Goodman 1989; Pienaar et al. 1992; Perrin and Brereton-Stiles 1999; Shrader and Perrin 2006).

The habitat of the white rhino Africa-wide includes areas with medium-tall and short grass savannahs and woodlands with associated flat terrain, bush for cover, and water for drinking and wallowing (Player and Feely 1960; Traill 2004; Skinner and Chimimba 2005; Pienaar and du Toit 2010). White rhinos prefer to feed on high quality short grasses due to their wide square lips but will broaden their variety of grass species eaten and include longer less nutritious species during the dry season when green nutritious grasses become scarce (Owen-Smith 1988; Pienaar and du Toit 2010). The grassland biome in which this study was conducted is an environment with abundance of low quality food (Senft et al. 1987) and like other herbivores in the grassland biome, these white rhinos are exposed to this abundance of low quality food dispersed over the landscapes in which they occur (Senft et al. 1987). By having a sound understanding of how white rhinos utilize these landscapes, effective management tools can be implemented.

The WPGR complies with all of the above mentioned habitat requirements of white rhinos but being situated in the grassland biome it is much colder than the savannah biome during the dry season. The aim of this study was to investigate how white rhinos utilize available habitats on WPGR in the grassland biome of the Free-State Province and was conducted over a period of one year.

Material and methods

Study area and white rhinoceros population

WPGR is situated at 28° 21'S and 27° 23'E approximately 140 km north-east of Bloemfontein. The reserve is 12,091 ha and surrounds the Allemanskraal Dam (2,648 ha at full capacity). The general physiognomic features are represented by grassy plains, kopjes and hillocks covered with shady bushes. The gently sloping southern section of the reserve contains sandstones and mudstones of the Beaufort series, whilst the northern section consists of a series of resistant dolerite intrusions and sandstone ridges that extend from east to west along the Sand River and Allemanskraal Dam (Muller 1986). The average temperatures of WPGR range from 15° C to 30° C in summer and from below 0° C to 15° C in winter, (lowest temperature recorded was -11° C), with an average annual rainfall of 578 mm, most of which falls between October and March (Earle and Grobler 1987). WPGR falls within the severe frost region of the Free-State (Earle and Grobler 1987) with frost occurring between 30-180 (mean 107) days per annum (Kietzman, 1998).

The vegetation of WPGR is classified as Winburg Grassy Shrubland and Central Free State Grassland (Mucina and Rutherford, 2006). Prominent grasses

on WPGR include *Eragrostis curvula, Digitaria eriantha, Themeda triandra, Panicum coloratum, Cynodon dactylon, Aristida congesta* subsp. *congesta* and *Cymbopogon pospischili*. Prominent trees include, *Acacia karroo, Ziziphus mucronata, Grewia occidentalis, Olea europea africana, Celtis africana, Euclea crispa, Searsia pyroides, Searsia lancea and Lycium echinatum.* Other than white rhinos, wildlife species that occur on the reserve include: buffalo *(Syncerus caffer)*, Burchell's zebra *(Equus burchelli)*, warthog *(Phacochoerus aethiopicus)* and eighteen antelope species (Jordaan, 2010).

For the purpose of this study a section of about 1,103 ha of WPGR was used to investigate how the white rhinos utilize different habitats. The justification for this is that the chosen section of the reserve is the area that the rhinos utilize. At the time of this study (2007-2008) the total population was 19 individuals (one adult bull, eight adult cows, four sub-adult cows, two sub-adult bulls and four calves). All individuals had previously been micro-chipped and ear-notched for identification purposes. Records for the past 20 years indicate that the numbers of rhinos on WPGR have been maintained between 16 and 20 individuals, provided a sex ratio of 1:9 productive adults is maintained, with excess rhinos being translocated to other reserves (Jordaan 2010). The density of white rhinos is maintained between 0.5 and 0.7 ind/ km² which is similar to lower density figures of white rhino recorded in other study areas (e.g. Nduma Game Reserve (0.6-1.8 ind/km²) (Conway and Goodman 1989); Hluhluwe-iMfolozi Game Reserve (0.4-5.6 ind/ km²) (Owen-Smith 1973; Shrader et al. 2006); Kruger National Park (0.5-1.4 ind/km²) (Pienaar 1994). The annual growth rate of white rhinos on WPGR between 1976 and 1997 was 9.98% (Kietzman 1998). This value is slightly higher than the 9% suggested by Owen-Smith (1988) for the maximum sustained rate of population growth for white rhinos in savannahs.

Due to sub-adults, juveniles and calves moving around with their mothers or other females, for the purpose of this study the ranging patterns and habitat utilization of these age classes are considered to be equivalent to those of the adult cows.

Plant communities of the study area

Two 1:10,000 ortho-photos were used to stratify the study area into physiognomic-physiographic vegetation units. Certain geological formations, such as steep slopes, dongas, wetlands and hills together with areas of similar vegetation textures were identified and delineated on the ortho-photo. To ensure that all variations in the vegetation of the study area were sampled, 40 sample plots of 400m^2 were placed on a randomly stratified basis within the various identified units. The number of sample plots per unit depended on the size of the unit delineated on the ortho-photo, with more plots being placed in large communities than in small communities (Brown et al. 2013). In each of the sample plots, all plant species were recorded and the cover abundance was estimated using the modified Braun-Blanquet cover abundance scale (Mueller-Dombois and Ellenberg 1974).

Floristic data was captured into the database programme TURBOVEG (Hennekens 1996) and exported to JUICE (Tichý 2002) from where a first approximation of the plant communities was derived using the modified TWINSPAN (two-way Indicator Species Analysis) classification algorithm (Roleček et al. 2009). Pseudospecies (separate variables for the different levels of abundance of a species) cut levels were set at 0-2-5-10-20 (Brown et al. 2013). By means of the phytosociological table and the habitat information collected during sampling, different plant communities were identified, described and ecologically interpreted. Plant communities were recognized by means of diagnostic species that are relatively restricted to a community (Westhoff and Van der Maarel 1978). A species was considered diagnostic for a particular community if it was present within the following constancy parameters (Grobler et al. 2006): ≥ 70% and with a constancy of ≤ 35% in all other communities; ≥ 50% and with a constancy of ≤ 25% in all other communities; ≥ 20% and with a constancy of ≤ 13% in all other communities. (e.g. if as species occurred in 70% of the sample plots of a specific community and less than 35% in sample plots outside the community, it would be considered a diagnostic species.

Range use

White rhino sightings (corresponding positions) through direct observation were collected between June 2007 and July 2008 using a handheld GPS, plotted on a map of the reserve, and analysed to determine ranging areas within the study area. Data were used to calculate range sizes as minimum convex polygons (Mohr 1947).

Habitat utilization and diet

Habitat utilization was determined by following the rhinos for 24 hours at a time (four days per month between July 2007 and June 2008). A group (more than one individual) was initially located at first light at their sleeping site and then followed for 24 hours. Each time they moved into a different plant community, this was recorded and utilized to determine preference (occurred more frequently in given habitat than expected based on availability of habitat) or avoidance (occurred less frequently in given habitat than expected based on availability of habitat), of the different plant communities based on their availability within the study area (Neu et al. 1974).

The plant species that the rhinos fed on were identified each new day during their wakeful hours, (each day determined by feeding after waking and recorded as feeding observation and only after the next sleeping period was the next feeding observation recorded). A one square metre area was visually marked close to the specific area where a group was feeding. Once the group moved far enough away from the area to allow access to the feeding patch, these visually marked patches were examined. Only one quadrat per individual present was sampled per feeding activity. The grass species utilized was identified and recorded. If more than one grass species was utilized within the one square metre then the most abundant grass species were recorded as being grazed. These data were used to calculate the percentage that each grass species contributed to the total number of grass species recorded to have been eaten by the rhinos during this study.

Results

Plant communities of the study area

Due to the heterogeneous topography of the study area, variation exists in the habitats, which resulted in the recognition of 10 plant communities, which were then grouped into five plant community types and their respective sub-communities:

1. *Cynodon hirsutus* dam edge grassland (195 ha)
2. *Themeda triandra-Setaria incrassata* moist grassland
   - 2.1 *Panicum coloratum-Eragrostis obtusa* moist grassland (23.5 ha)
   - 2.2 *Sporobolus-fimbriatus-Verbena bonariensis vlei* grassland (266.5 ha)
3. *Cymbopogon excavatus* valley grassland (11.5 ha)
4. *Eragrostis curvula-Acacia karroo* rocky woodland
   - 4.1 *Acacia karroo-Setaria verticillata* dense woodland (118 ha)
   - 4.2 *Acacia karroo-Cynodon dactylon* savannah woodland (342 ha)
   - 4.3 *Acacia karroo-Enneapogon scoparius* rocky hill woodland (22 ha)
   - 4.4 *Acacia karroo-Grewia occidentalis* midslope woodland (52 ha)
5. *Triraphus andropogonoides-Aristida diffusa* plateau grassland
   - 5.1 *Aristida diffusa-Cymbopogon pospischili* plateau grassland (52 ha)
   - 5.2 *Aristida diffusa-Hyparrhenia hirta* plateau grassland (20 ha)

A detailed description of the plant communities identified in this study can be found in Jordaan (2010) but for the purpose of this study, a brief description is given below for the major communities only.

1. Cynodon hirsutus dam edge Grassland

This community occurs on the lowest lying areas along the edge of the Allemanskraal Dam and floods when the dam is at full capacity. The vegetation is dominated by the grass *Cynodon hirsutus* with the grasses *Aristida bipartita*, *Eragrostis curvula*, *Aristida adscensionis* and the forbs *Schkuhria pinnata* and *Conyza bonariensis* being locally prominent.

2. Themeda triandra-Setaria incrassata Grassland

This community is located throughout the study area on gentle slopes and lower-lying areas associated with drainage lines and seasonal moist conditions. The vegetation is dominated by the palatable grasses *Themeda triandra* and *Setaria incrassata*. The grasses *Eragrostis curvula* and *Digitaria eriantha* are prominent throughout this community.

Table 1. Range size of white rhinos within study area of the Willem Pretorius Game Reserve between July 2007 and June 2008

Individual ID	Dry season range (km²)	Number of observations	Wet season range (km²)	Number of observations
Cow 21	4.756	38	4.661	31
Cow 25	3.609	29	4.520	23
Cow 26	5.047	25	3.126	25
Cow 8	1.973	10	3.840	13
Cow 13	4.754	25	2.773	12
Bull	6.367	61	8.134	42

3. Cymbopogon excavatus valley Grassland

This is the smallest community and occurs as an isolated area within the *Acacia karroo-Cynodon dactylon* savannah woodland sub-community. The vegetation is dominated by the grasses *Cymbopogon excavatus* and *Themeda triandra* while the forbs *Pentzia viridus* and *Monsonia angustifolia* are also present.

4. Eragrostis curvula-Acacia karroo rocky Woodland

This community is located throughout the study area on slopes, lower-lying and high-lying areas associated with drainage lines and seasonal moist conditions. *Acacia karroo* dominates the woody layer while dominant grasses include *Sporobolus fimbriatus* and *Eragrostis curvula.* The forbs *Conyza bonariensis*, *Tagetes minuta* and *Bidens pilosa* are present throughout the community

5. Triraphus andropogonoides-Aristida diffusa plateau Grassland

This community lies on top of the Doringberg Mountain to the north of the study area. The vegetation is dominated by a mixture of species including the grasses *Triraphus andropogonoides*, *Aristida diffusa*, *Digitaria eriantha*, *Cymbopogon pospischili*, and the forbs *Cheilanthes eckloniana* and *Blepharis squarrosa*.

Range use

The criteria of at least 10 data points to generate Minimum Convex polygons (Conway and Goodman 1989) within the study area were only applicable to the bull and five of the eight adult cows. Criteria of more than 30 points to generate density kernel estimates (Seaman et al. 1999) were not met and therefore density kernels could not be calculated between seasons. The overall range size of five adult cows within the 1,300 ha study area ranged from 5.83 to 5.98 km² (mean: 5.88 km², SE ± 0.04) and that for the bull was 8.34 km² (Table 1). The range size of cows within the study area during the wet season ranged from 3.13 km² to 4.66 km² (mean 3.78 km², SE ± 0.37) and from 1.97 to 5.05 km² (mean: 4.08 km², SE ± 0.57) during the dry season. Wilcoxon signed rank tests indicated no significant differences in range sizes between the wet and dry season ($z = -0.32$; $p = 0.83$). The bull had a range size of 8.13 km² during the wet and 6.37 km² during the dry season.

Table 2. Occurrence of white rhinos in different habitat types in the wet and dry season on Willem Pretorius Game Reserve, Free State Province of South Africa. (* indicates statistical significance at p = 0.05)

Season	Habitat type	Plant sub communities (this study)	Total habitat type	Proportion of total hectares (Pi_0)[a]	Number of observations of rhinos	Proportion observed in each habitat type (Pi)	Expected[b] number of rhino sightings	Confidence interval (95%) on observed proportion of occurrence (Pi)[c]	More / less than expected
Wet season	Wetland	2.1, 2.2	290	0.263	86	0.067	336	$0.048 \leq p \leq 0.086$	Less*
	Thornveld	4.3	22	0.020	227	0.177	26	$0.149 \leq p \leq 0.206$	More*
	River	4.1	118	0.107	253	0.198	137	$0.168 \leq p \leq 0.228$	More*
	Damkom	1	195	0.177	186	0.145	226	$0.119 \leq p \leq 0.172$	Less*
	Savannah	4.2	342	0.310	273	0.213	397	$0.183 \leq p \leq 0.244$	Less*
	Grassveld	3, 5.1,5.2	83.5	0.076	59	0.046	97	$0.030 \leq p \leq 0.062$	Less*
	Trees and Shrubveld	4.4	52	0.047	195	0.152	60	$0.125 \leq p \leq 0.180$	More*
Dry Season	Wetland	2.1, 2.2	290	0.263	100	0.074	355	$0.055 \leq p \leq 0.093$	Less*
	Thornveld	4.3	22	0.020	192	0.142	27	$0.117 \leq p \leq 0.168$	More*
	River	4.1	118	0.107	113	0.084	144	$0.064 \leq p \leq 0.104$	Less*
	Damkom	1	195	0.177	60	0.045	238	$0.029 \leq p \leq 0.060$	Less*
	Savannah	4.2	342	0.310	281	0.208	418	$0.179 \leq p \leq 0.238$	Less*
	Grassveld	3, 5.1,5.2	83.5	0.076	78	0.058	102	$0.041 \leq p \leq 0.075$	Less*
	Trees and Shrubveld	4.4	52	0.047	524	0.389	64	$0.353 \leq p \leq 0.424$	More*

[a]Proportions of total hectares represent expected rhino observation values as if rhinos occurred in each habitat in exact proportion to availability.
[b]Calculated by multiplying proportion p_{i0} x n
[c]pi represents theoretical proportion of occurrence and is compared to corresponding pi_0 to determine if hypothesis of proportional use is accepted or rejected, i.e., $p_i = p_{i0}$.

Table 3. The percentage that different grass species contributed to the diet of white rhinos on Willem Pretorius Game Reserve during the wet (n = 637) and dry (n = 490) season during this study

Plant species eaten	Wet season	Dry season
Cynodon species	47.4	31.4
Enneapogon scoparius	7.7	12.9
Themeda triandra	7.4	7.8
Eragrostis curvula	6.3	6.7
Aristida congesta	6.1	13.5
Hemarthria altissima	5.5	4.5
Panicum coloratum	3.6	2.4
Chloris virgata	3.0	5.1
Eragrostis lehmanniana	2.0	0.0
Digitaria eriantha	1.6	0.4
Cymbopogon plurinodes	1.3	1.6
Anthephora pubescens	1.1	0.0
Eragrostis rotifer	1.1	0.0
Heteropogon contortus	1.1	0.0
Sporobolus fimbriatus	1.1	2.0
Fingerhuthia Africana	0.9	0.0
Melica decumbens	0.9	0.0
Setaria sphacelata	0.9	0.0
Urochloa panicoides	0.9	0.0
Aristida adsensionis	0.0	2.2
Aristida diffusa burkei	0.0	0.6
Atriplex semibaccata	0.0	3.28
Brachiaria eruciformis	0.0	1.6
Eragrostis obtuse	0.0	0.2
Panicum maximum	0.0	4.9
Tragus racemosus	0.0	1.0
Urochloa oligotricha	0.0	1.0

Habitat utilization and diet

To facilitate comparisons with previous vegetation descriptions of WPGR the plant communities identified during this study were grouped into broad habitat types as described by Muller (1986): Savannah (sub community 4.2), River (sub community 4.1), Grassveld (communities 5 and 3), Wetland (sub communities 2.1 and 2.2), Thornveld (sub community 4.3), and Trees and Shrubveld (sub community 4.4). An additional habitat type Damkom (community 1), which was the depressed grassland area between the full water mark and the water surface of the Allemanskraal Dam was also included (Jordaan, 1990). A total of 2,667 rhino observations in the various habitat types recorded during this study were used to determine preference and or avoidance of the different habitat types within the study area. Of these 2,667 observations, 77% (n = 2,058) were of rhinos in a habitat with tree cover (Tree and Shrubveld, Savannah, Thornveld and River) and 21% (n = 569) in open areas such as the Wetland, Damkom and Grassveld habitat types. Chi square Goodness-of-fit comparisons showed that the expected utilization of each habitat type (based on their availability) differed significantly from the observed usage of habitat types by the white rhinos during both the wet ($\chi^2 = 2,236.6$; 6 df; $p < 0.0001$) and dry season ($\chi^2 = 4,721.3$; 6 df; $p < 0.0001$). The rhinos used the Wetland (sub communities 2.1 and 2.2), Damkom (community 1), Savannah (sub community 4.2), and Grassveld (communities 5 and 3) areas less than expected but used the Thornveld (sub community 4.3) and the Trees and Shrub (sub community 4.4) habitat types more than expected during both the wet and dry season (Table 2, below). The River habitat was used more than expected during the wet season, but less during the dry season.

A total of 215 plant species were identified in the study area representing 134 genera and 51 families (Jordaan 2010). A total of 1176 feeding occurrences were observed and 33 plant species were recorded to be eaten by the white rhinos. These included 26 grass species, 1 shrub species (*Asparagus* sp) and 6 forb species. With the exception of *Atriplex semibaccata*, which was utilised during the dry season (n = 17), five observations suggest that forbs were accidentally ingested along with grass.

Grass species contribution to the diet of the rhinos varied between the wet and dry season (Table 3). *Cynodon* spp. (n = 456) were utilized the most frequently throughout the year with a higher utilization for it during the wet season (47.4%, n = 302) compared to that of the dry season (31.4%; n = 154). During the wet season the second most frequently eaten grass was *Enneapogon scoparius* (7.7%) and in the dry season *Aristida congesta* and *Enneapogon scoparius* contributed 13.6% and 12.9% to the diet respectively. *Themeda triandra* (7.4%), *Eragrostis curvula* (6.3%), *Aristida congesta* (6.1%) and *Hemarthria altissima* (5.5%) were the only other grass species that contributed more than 5% to the diet of the rhinos during the wet season. *Themeda triandra* (7.8%), *Eragrostis curvula* (6.7%), *Chloris virgata* (5.1%), and *Panicum maximum* (4.9%) were the only other grass species that contributed 5.0% or more to the diet of the rhinos during the dry season. Species that were not observed to be eaten during the wet season but during the dry season were *Panicum maximum, Aristida adscensionis, Brachiaria eruciformis, Urochloa oligotricha, Tragus racemosus, Aristida diffusa* and *Eragrostis obtusa*.

Discussion

This study was the first detailed study investigating habitat utilization by white rhinos in the Free State Province grassland biome of South Africa. Five major plant communities and their respective sub communities were identified, indicating that the landscape of the study area is heterogeneous and consists of a variety of habitats and resources. Although range size between wet and dry season did not differ significantly in this study, this may be due to the abundance of water in WPGR throughout the year in the Allemanskraal dam and therefore rhinos do not have to travel longer distances to find water as they do in other landscapes which could explain why differences in seasonal home ranges are found in other studies (Pienaar et al. 1993).

The preference of some habitat types over others indicates that certain habitat types provide preferred resources. The Thornveld and Trees and Shrub habitat types were preferred habitats during both the wet and dry season, whereas the River habitat was preferred only during the wet season. All three of these preferred habitat types are associated with some extent of tree cover which would be important in protecting the rhinos from the heat during the hot summer days and from cold winds during the cold winter months. The Thornveld had 65%-80% grass layer cover and is

dominated by *Enneapogon scoparius* which is also within the top three grass species that contribute to the rhino's diet in both seasons. The tree layer and shrub layer had 50%–70% and 10%–30% cover respectively. The Tree and Shrubveld had a tree density of 2,450 trees per hectare, with the woody species covering between 45% and 70% of the area compared to the low grass cover of only 5%–15% of the area. Despite having such a low grass cover, during the dry season 39% of rhino observations were in the thickets of steep cliffs and gullies within this habitat. Important dietary species such as *Enneapogon scoparius, Panicum coloratum, Eragrostis curvula* and *Panicum maximum* occur within this habitat, and during the dry season were protected from frost due to them growing under trees and shrubs. The woody canopy cover of the River habitat ranged between 70% and 100%, with the grass layer covering approximately 50% of the area. The River habitat is characterized by *Cynodon* grass species, which contributed the most to the rhino's diet throughout the year.

Despite having suitable grass species present, the Wetland, Damkom and Grassveld areas were less preferred or avoided habitat types. This may be due to lack of tree or shrub cover, which protects the rhinos from the heat during the wet season and the cold during the dry season. The wetland and Damkom areas had a grass cover of more than 97% and a woody layer covering less than 1% and 2% respectively. The Grassveld areas had a grass layer of between 75% and 85% and a woody layer of less than 3%-35% of the area.

White et al. (2007) found that female white rhinos in the warmer Hluhluwe savannah area preferred open grassland and Owen-Smith (1988) found that white rhinos in the Hluhluwe-iMfolozi Game Reserve utilised four broad grassland types. During the wet season they foraged in the short grasslands which were dominated by *Digitaria argyrograpta*, *Panicum. coloratum, Urochloa mosambicensis* and *Sporobolus nitens*. During the early dry season the white rhinos fed in the woodland grassland areas that were dominated by *Panicum maximum* but towards the end of the dry seasons they used the Themdea triandra grasslands. White rhinos in the high-density site of iMfolozi portion of Hluhluwe-iMfolozi Game Reserve favoured short and *Cynodon* type grasslands during both the wet and dry season but neglected the *Themeda* and *Bothriochloa* grassland types (Shrader and Perrin, 2006). In the low density site of Hluhluwe-iMfolozi Game Reserve, white rhinos preferred Sandy Grasslands but neglected *Themeda* grasslands during the wet season and neglected *Cynodon* grasslands during the dry seasons but utilized other grassland types in proportion to their availability. This study indicates that white rhinos in WPGR avoid grassland areas and prefer habitats that have some form of cover which is in contrast to what was found for white rhinos in savannah grassland areas.

Cynodon species contributed the most to the rhino's diet in both the wet and dry season during the study period. *Cynodon* spp. are low growing, highly nutritious species which form nutritious grazing lawns that are 'maintained' by the rhinos (Owen-Smith 1988; Shrader et al. 2006). Other than *Cynodon* spp. the most important grass species include *Aristida congesta, Enneapogon scoparius, Themeda triandra, Eragrostis curvula*, *Hemarthria altissima* and *Themeda triandra* during the wet season and *Aristida congesta, Enneapogon scoparius, Eragrostis curvula, Chloris virgate, Panicum maximum* and *Themeda triandra*, during the dry season. *Panicum maximum* was found to be important in Hluhluwe-iMfolozi (Owen-Smith 1988) during the early dry season as was it in this study. During the dry season *Themeda triandra* was used more frequently than in the wet season in the Hluhluwe-iMfolozi area (Owen-Smith 1988; Perrin and Brereton-Stiles 1999), but in this study was observed to contribute more or less equally to the rhino's diet (7.4% in the wet and 7.8% in the dry season). Strongly avoided species in the Hluhluwe-iMfolozi area included *Cymbopogon* spp., *Aristida* spp. and *Tragus berteronanus*. In this study, however; *Aristida congesta* contributed 13% to the diet of white rhinos during the dry season indicating that in WPGR it is an important food source during these times. This could be due to insufficient high quality grass species being available and therefore the rhinos may be forced to eat poor quality food to meet their energy requirements. *Cymbopogon pospichili* and *Tragus berteronanus* were however utilised very little. This study confirms previous findings that white rhinos are predominantly short grass feeders (Player and Feely 1960; Owen-Smith 1988; Shrader et al. 2006) with the exceptional utilization of medium and tall grass (Mills and Hes 1997).

Previous ecological studies of white rhinos have generally occurred in savannah areas that are characterized by hot, wet summers and mild, dry winters whereas the grassland areas in which this

study was conducted are characterized by hot, wet summers and dry cold winters. The results of this study suggest that differences in habitat resources influence the habitat utilization of white rhinos in WPGR. Although less food is available during the dry season, adequate, although less nutritious grass species were available throughout the year. The white rhino in WPGR prefer habitat types that have cover in the form of trees and or shrubs, and unlike white rhinos in savannah areas, avoid open grassland areas. With its extremely cold winters and poor quality food, the Free-State is a potentially harsh environment for white rhinos however, provided the habitats are suitable with sufficient palatable short grass, water and suitable protection from extreme cold and heat in the form of woody species, white rhinos can be successfully kept in this region.

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References

Bermudez FNG. 1998. The white rhinoceros population of the Willem Pretorius Game Reserve. Project report for the Higher Diploma in Game Ranging, Allenby College, South Africa.

Brown LR, Du Preez PJ, Bezuidenhout H, Bredenkamp GJ, Mostert THC, Collins NB. 2013. Guidelines for phytosociological classifications and descriptions of vegetation in southern Africa. *Koedoe* 55:1-10.

Conway AJ, Goodman PS. 1989. Population characteristics and management of black rhinoceros *Diceros bicornis minor* and white rhinoceros *Ceratotherium simum simum* in Ndumu Game Reserve, South Africa. *Biological Conservation* 47:109-122.

Earle R, Grobler N. 1987. *First Atlas of Bird distribution in the Orange Free-State*. National Museum, Bloemfontein.

Grobler CH, Bredenkamp GJ, Brown LR. 2006. Primary grassland communities of urban open spaces in Gauteng, South Africa. *South African Journal of Botany* 72:367-377.

Hennekens SM, 1996. TURBO (VEG): Software package for input, processing and presentation of phytosociological data. User's guide. Version July 1996. IBN-DLO, Wageningen and Lancaster University, Lancaster.

Jordaan HL. 1990. Population dynamics and habitat use of white rhinoceros *Ceratotherium simum simum* on Willem Pretorius Game Reserve. Internal report.

Jordaan HL. 2010. Behavioural ecology of the white rhinoceros (*Ceratotherium simum simum*) in the Willem Pretorius Game Reserve. MSc thesis, Department of Environmental Sciences, University of South Africa, Pretoria.

Kietzman A, 1998. Development of the Willem Pretorius Game Reserve Management Plan. MSc thesis, University of the Free State, Bloemfontein.

Mills G, Hes L. 1997. *The complete book of southern African mammals.* Struik Publishers, Cape Town.

Mohr CO, 1947. A table of equivalent populations of North American small mammals. *American Midland Naturalist* 37:223-249.

Mucina L, Rutherford MC. 2006. *The Vegetation of South Africa, Lesotho and Swaziland*. Strelitzia 19. South African National Biodiversity Institute, Pretoria, South Africa.

Muller DB, 1986. Plantekologie van die Willem Pretorius Wildtuin. Ph.D thesis, University of the Orange Free State, Bloemfontein.

Mueller-Dombois D, Ellenberg H. 1974. *Aims and methods of vegetation ecology*. John Wiley and Sons, New York.

Neu CW, Byers CR, Peek JM. 1974. A Technique for Analysis of Utilization-Availability Data. *Journal of Wildlife Management* 38:541-545.

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

Perrin MR, Brereton-Stiles R. 1999. Habitat use and feeding behaviour of the buffalo and the white rhinoceros in the Hluhluwe-iMfolozi Game Reserve. *South African Journal of Wildlife Research* 29:72-80.

Pienaar DJ, du Toit JG. 2010. The white and the black rhinoceros In: Bothma J du P, du Toit JG, editors. *Game Ranch Management*. Van Schaik Publishers, Hatfield Pretoria.

Pienaar DJ, Bothma J du P, Theron GK. 1992. Landscape preference of the white rhinoceros in the southern Kruger National Park. *Koedoe* 35:1-7.

Pienaar DJ, Bothma J du P, Theron GK. 1993. White rhinoceros range size in the south-western Kruger National Park. *Journal of Zoology,* London. 229: 641-649.

Player IC, Feely JM. 1960. A preliminary report on the square-lipped rhinoceros *Ceratotherium simum simum*. *The Lammergeier* 9:3-21.

Roleček J, Tichý L, Zelený D, Chytrý M. 2009. Modified TWINSPAN classification in which the hierarchy respects cluster heterogeneity. *Journal of Vegetation Science* 20:596-602.

Rookmaaker LC. 2002. Miscounted population of the southern white rhinoceros (*Ceratotherium simum simum* in the early 19th century? *Pachyderm* 32:22-28.

Seaman DE, Millspaugh JJ, Kernohan BJ, Brundige G, Kenneth RJ, Gitzen RA. 1999. Effects of sample size on kernel home range estimates. *Journal of Wildlife Management* 63:739-747.

Senft RL, Coughenour MB, Bailey DW, Rittenhouse LR, Sala OA, Swift DM. 1987. Large herbivore's foraging and ecological hierarchies. *Bioscience* 37:789-799.

Skinner JD, Chimimba CT. 2005. The mammals of the Southern African subregion. University of Pretoria, Pretoria.

Shrader AM, Perrin MR. 2006. Influence of density on the seasonal utilization of broad grassland types by white rhinoceroses. *African Zoology* 41:312-315.

Shrader AM, Owen-Smith N, Ogutu JO. 2006. How a mega-grazer copes with the dry season: food and nutrient intake rates by white rhinoceros in the wild. *Functional Ecology* 20:376-384.

Tichý L. 2002. JUICE: Software for Vegetation Classification. *Journal of Vegetation Science* 13:451-453.

Traill LW. 2004. Seasonal utilization of habitat by large grazing herbivores in semi-arid Zimbabwe. *South African Journal of Wildlife Research* 34(1):13-24.

Westhoff V, Van Der Maarel E. 1978. The Braun Blanquet approach. In: Whittaker RH, editor. *Classification of Plant Communities*. Dr W. Junk Publishers, The Hague, Netherlands.

White AM, Swaisgood RR, Czekala N. 2007. Ranging patterns in white rhinoceros, *Ceratotherium simum simum*: implications for mating strategies. *Animal Behaviour* 74:349-356.