J. Zool., Lond. (1993) **229**, 641–649

White rhinoceros range size in the south-western Kruger National Park

D. J. PIENAAR,* J. DU P. BOTHMA AND G. K. THERON

Centre for Wildlife Research, University of Pretoria, Pretoria, 0002

(*Accepted 11 March 1992*)

(With 3 figures in the text)

White rhinoceros range size was ascertained telemetrically in the south-western Kruger National Park. The mean annual range size of territorial males was 9·86 km^2 compared to 22·83 km^2 for adult females. White rhinoceros females' summer wet season range was larger (21·44 km^2) than the winter dry season range (11·64 km^2). It is argued that abundant field-water during the wet season enables animals to range further from permanent water supplies and to utilize larger foraging areas. White rhinoceros have core areas in their individual ranges that usually are situated along riverbanks in the preferred grazing regions. These core areas also include some favourite resting spots on high-lying areas. White rhinoceros range sizes in the south-western Kruger National Park were similar to those of other reserves with comparable white rhinoceros densities. In the Umfolozi Game Reserve, which has a higher white rhinoceros density than the Kruger National Park, the individual ranges are much smaller.

Contents

Introduction

The white rhinoceros *Ceratotherium simum simum* (Burchell) became extinct in the Transvaal in 1896 (Kirby, 1896). In 1961 the first white rhinoceroses were re-introduced from the Umfolozi Game Reserve to the Kruger National Park (Pienaar, 1970). Over a 12-year period a total of 345 white rhinoceroses were relocated to the Kruger National Park. By 1988 their numbers had increased to 1229.

No in-depth study has been done on the ecology of the white rhinoceros in the Kruger National Park. A study was begun in 1988 to ascertain the habitat preferences and dispersal of the white rhinoceros in the Kruger National Park. Part of the study dealt with establishing white rhinoceros range boundaries so as to identify areas of preference and to ascertain which environmental

* Present address: Kruger National Park, Private Bag X402, Skukuza 1350, RSA

parameters influence white rhinoceros distribution. The influence of seasonality on this component of white rhinoceros behaviour was also investigated.

The geomorphology of the study area consists of underlying granite and gneis that is deeply weathered, resulting in an undulating landscape with distinct uplands and bottomlands. The vegetation has been described as mixed *Combretum* savanna. The altitude ranges from 450 to 550 m above sea level. The mean annual rainfall varies between 600 and 700 mm and occurs mainly during the hot summer months (Gertenbach, 1987).

Methods

Fifteen white rhinoceroses were tracked using radio telemetry to ascertain their activities and habitat use. The immobilization and collaring procedures are explained by Pienaar & Hall-Martin (1991). All rhinoceroses fitted with transmitters occurred in areas of high white rhinoceros density ($> 0{\cdot}5$ per km^2). These high density areas were mapped using the aerial census data which are collected annually in the Kruger National Park (Joubert, 1983; Viljoen, 1990). The collared rhinoceroses were regularly tracked and observed on foot and all the locations were mapped on 1:50000 topographic maps.

Where the number of observations was adequate, range boundaries were drawn in by hand and the areas involved measured with a planimeter. Only in this way could the interpretation of spatial relationships between animals be as precise as how it occurs in reality (Macdonald, Ball & Hough, 1980).

The method used in this study was the minimum convex polygon, and involved drawing a polygon around the extremities of the observed locations (Dalke, 1942; Mohr, 1947). This allowed direct comparison of results with other studies carried out on white rhinoceros ranges employing similar methods (Condy, 1973; Owen-Smith, 1973; Conway & Goodman, 1989). A major concentration of rhinoceros sightings within a given range was taken to be a core area and was mapped accordingly.

Conway & Goodman (1989) considered 10 localities per group, the minimum necessary for a reasonable estimate of range size. Samuel, Pierce & Garton (1985) considered 30 independent observations the minimum necessary to detect core areas. In the present study, the animals were tracked on foot to gather habitat information and only one observation per animal was made per day to ensure independence of successive observations. The 15 animals involved were tracked until the transmitter batteries ran down after a mean time lapse of 13·9 months (Pienaar & Hall-Martin, 1991). Harris *et al.* (1990) mentions factors that influence the accuracy of radio fixes and the problems associated with estimating home ranges from radio fixes. These problems were overcome by locating and visually observing the radio-marked rhinoceroses regularly.

Wet season (summer) and dry season (winter) ranges were mapped for each of the study animals. Winter was taken to begin with the drying of the grass layer and lasted till the grass started sprouting again after the first rains in spring. The wet season commences in November and lasts until April and the dry season ranges from May to October.

The annual range and core area sizes of white rhinoceros females and territorial males were compared with a Wilcoxon 2-Sample Test to detect any sex-related differences (Schlotzhauer & Littel, 1987). The summer and winter range sizes of white rhinoceros females and territorial males were also compared with a *t*-test for seasonally-induced shifts in range size.

Results

The annual range size of territorial white rhinoceros males in the south-western Kruger National Park ranged from 6·2 to 13·8 km^2 with a mean of $9{\cdot}86 \pm 3{\cdot}36$ km^2. Associated core area

TABLE I

Territorial male white rhinoceros annual range and core area sizes (km²) in the south-western Kruger National Park

Animal number	Sex	Number of observations	Territory	Core area
8537	♂	60	10·71	3·68
8317	♂	44	6·2	1·66
8262	♂	48	13·23	1·82
8970	♂	53	13·46	3·27
8351	♂	45	6·04	2·62
8854	♂	42	6·95	2·09
8334	♂	31	8·5	2·63
8900	♂	55	13·81	3·53
Mean ± 1 S.D.	—	—	9·86 ± 3·36	2·66 ± 0·78

sizes ranged from 1·66 to 3·68 km² with a mean of 2·66 ± 0·78 km² (Table I). The boundaries of annual ranges for males did not overlap although short forays into neighbouring ranges were occasionally observed (Fig. 1).

The annual range size of white rhinoceros females ranged from 7·23 to 45·23 km² with a mean of

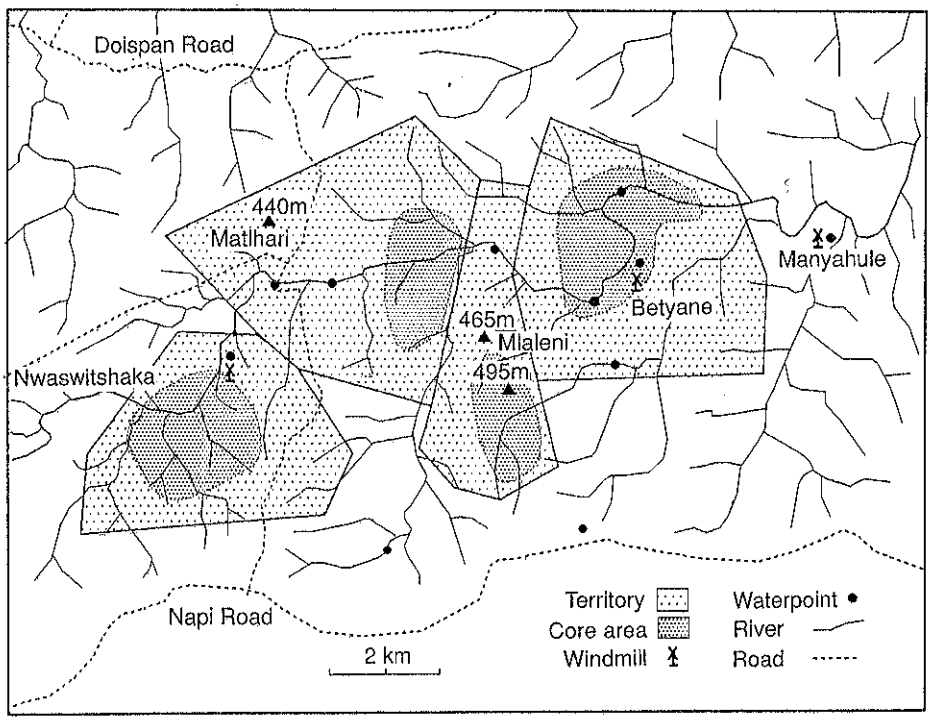

FIG. 1. Annual range (territory) boundaries of four male white rhinoceros in the south-western Kruger National Park, Republic of South Africa, to show that no overlap occurs. Mean territory size was 9·86 km².

TABLE II

Female white rhinoceros annual range and core area sizes (km²) in the south-western Kruger National Park

Animal number	Sex	Number of observations	Territory	Core area
8375	♀	63	21·45	3·12
8390	♀	71	23·98	3·32
8411	♀	67	45·23	4·89
8990	♀	71	22·08	4·14
8596	♀	51	26·22	8·88
8940	♀	51	13·62	5·42
8254	♀	49	7·23	2·96
Mean ± 1 S.D.	—	—	22·83 ± 11·87	4·68 ± 2·07

22·83 ± 11·87 km². The sizes of the associated core areas ranged from 2·96 to 8·88 km² with a mean of 4·68 ± 2·07 km² (Table II). Annual ranges of females showed extensive overlap (Fig. 2).

The mean annual range size of male white rhinoceroses differed significantly from that of female white rhinoceroses ($P = 0{\cdot}005$, $n = 15$). There was also a significant difference in core area size for

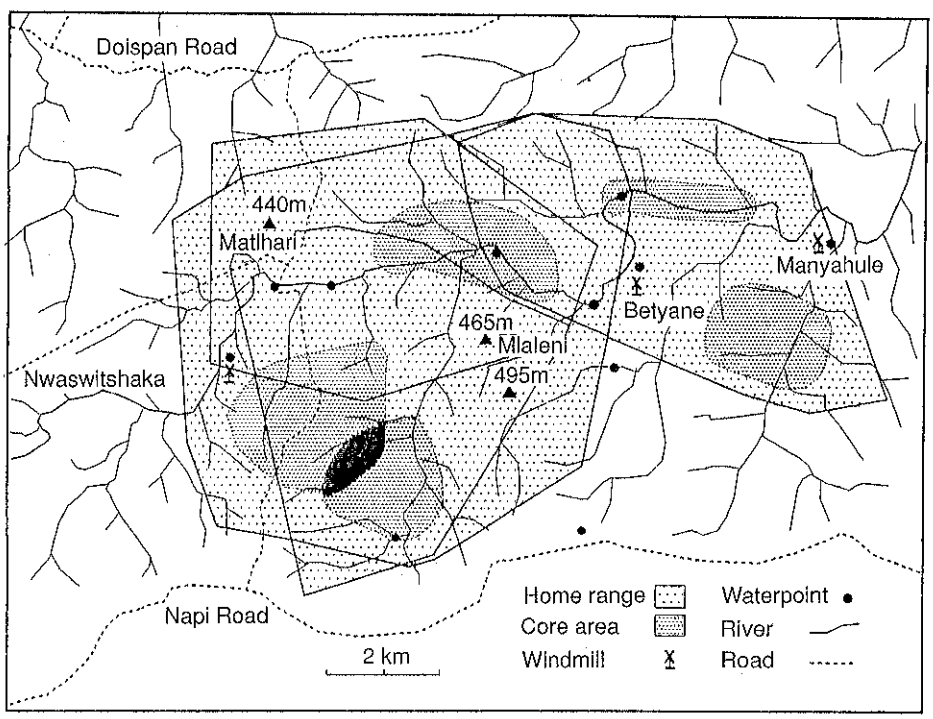

FIG. 2. Annual (wet season) range boundaries of four adult female white rhinoceros in the Kruger National Park, Republic of South Africa, to show the extensive overlap compared to that of white rhinoceros males (Fig. 1). Mean range size was 22·83 km².

TABLE III

Summer wet and winter dry season range sizes (km²) in the south-western Kruger National Park

Animal number	Wet season range	Number of observations	Dry season range	Number of observations
8375	21·45	38	10·75	25
8390	23·98	41	12·94	30
8411	45·23	39	14·63	28
8990	22·08	40	6·9	31
8596	16·49	29	23·56	22
8254	7·23	26	7·23	23
8940	13·62	28	5·5	23
Mean ± 1 S.D.	21·44 ± 11·98	—	11·64 ± 6·2	

male and female white rhinoceroses ($P = 0{\cdot}011$, $n = 15$). White rhinoceros densities in the study area in the south-western Kruger National Park ranged from 0·5 to 1·4 per km².

One of the females (number 8254) marked in the present study was a sub-adult animal with a smaller range than that of the adult females. She was accompanied by a slightly older sub-adult

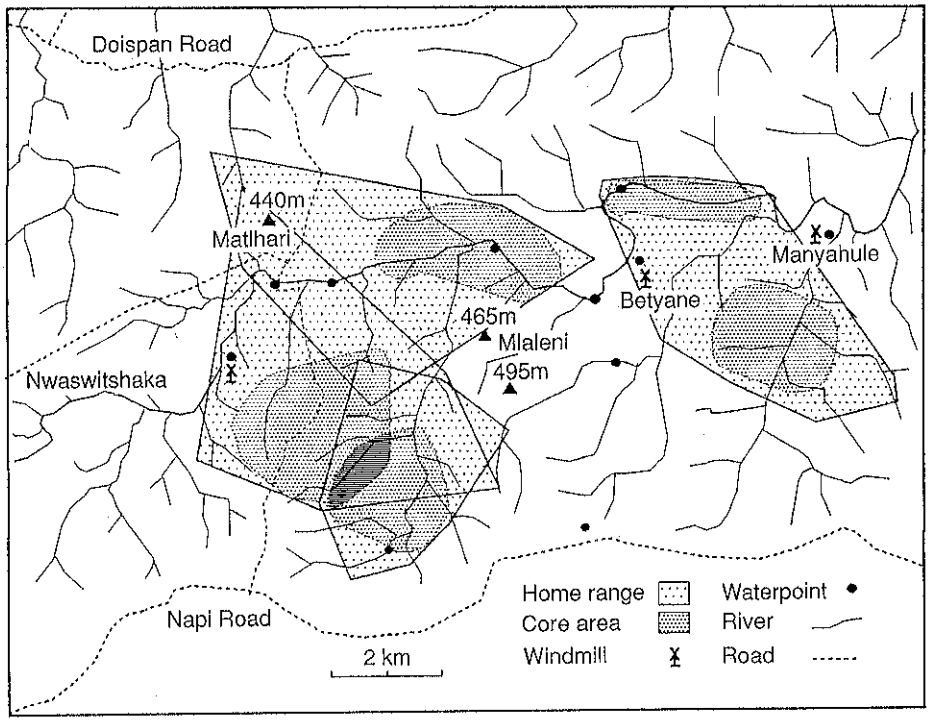

FIG. 3. Reduced winter, dry season range boundaries of four adult female white rhinoceros in the south-western Kruger National Park, Republic of South Africa, to show the degree of overlap and that some areas are not utilized in the dry season compared with the wet season (Fig. 2). The mean range size during the dry season was 11·64 km².

male for 7 months until she had her first calf after which she and the calf continued to stay in the same area as before. Owen-Smith (1973) also observed a sub-adult white rhinoceros male and female with a small range of 2·1 km^2, although he found that sub-adult females more commonly move over larger ranges than sub-adult males. It seems that where sub-adult males and females move around together, the range is determined by the older individual.

Two male territory take-overs were observed during the study period. In one case the defeated male moved to a neighbouring territory where he assumed a subordinate position. In the second case, the defeated male stayed on in the same territory but restricted his movements to a small area and assumed a subordinate position. In both cases the defeated territorial males ceased to spray-urinate or scatter their dung.

No seasonal movements, such as those mentioned by Heppes (1958) for the northern white rhinoceros *Ceratotherium simum cotoni*, were found in the present study, although white rhinoceros females did show a seasonal variation in range size.

In the summer wet season, the mean range size of white rhinoceros females in the Kruger National Park was $21{\cdot}44 \pm 11{\cdot}98$ km^2 compared with $11{\cdot}64 \pm 6{\cdot}2$ km^2 in the winter dry season ($P = 0{\cdot}03$, $n = 8$) (Table III). The wet season range size was comparable to the annual range size (Fig. 2), whereas a reduction in range size was observed during the dry season (Fig. 3). The winter dry season range size of female white rhinoceros was similar to the annual range size of territorial white rhinoceros males. The ranges of territorial males did not show seasonally induced shifts in size. One white rhinoceros female (number 8596), however, had a dry season range that was larger than the wet season range.

Discussion

'No wild animal roams at random over the country; each has a home-region, even if it has not an actual home' (Seton, 1909). Burt (1943) defined home range as the area an animal transversed during its normal activities of food-gathering, mating and caring for its young.

For this study it was decided to use the terms range, seasonal range and annual range instead of home range. One cannot accurately base the home range of such a long-lived animal on the basis of only 14 months of observation.

The ranges of dominant white rhinoceros males meet the criteria for a territorium (Brown & Orians, 1970) and are characterized by the following features based on Owen-Smith (1971) and personal observations:

1. Territorial males inhabit a fixed area, which may change slightly over time.
2. Each territorial male's range is exclusive of, and does not overlap with, that of other neighbouring territorial males.
3. The territorial areas are scent-marked.
4. A territorial male will attempt to prevent an oestrous cow from leaving its territory.
5. Neighbouring territorial bulls engage in ritualized encounters when they meet at a common boundary.

A territorial white rhinoceros male undertakes regular boundary patrols and scent-marks frequently as Owen-Smith (1973) also found. When followed on foot on one of such occasions an accurate perception of the location of the territory boundaries is gained.

The white rhinoceros population densities, male territory sizes and female range sizes in the Umfolozi Game Reserve (Owen-Smith, 1973), Ndumu Game Reserve (Conway & Goodman,

TABLE IV

Comparison of white rhinoceros densities (animals km^{-2}), male territory and female range sizes (km^2) in four game reserves; The Kruger National Park, Umfolozi Game Reserve and Ndumu Game Reserve in South Africa and Kyle National Park in Zimbabwe

Area	Density	Male territory	Female range
Kruger	0·5–1·4	6·2–13·8*	7·23–45·23
Kyle	0·7	5–11*	3–20
Ndumu	0·6–1·8	2·5–13·9	4·7–22·9
Umfolozi	3–5·7	0·75–2·6*	8·9–20·5

* Male territory sizes are significantly smaller than female ranges

1989), Kyle National Park (Condy, 1973) and the south-western Kruger National Park (this study) are compared in Table IV.

The ranges and territory sizes of white rhinoceroses in the high density area in the south-western Kruger National Park were similar to those found by Condy (1973) in Kyle National Park and by Conway & Goodman (1989) in Ndumu Game Reserve, but considerably larger than those found by Owen-Smith (1973) in Umfolozi Game Reserve. The range of white rhinoceros densities in Kruger National Park, Kyle National Park and Ndumu Game Reserve are also similar, but considerably smaller than the mean for Umfolozi Game Reserve.

This difference in white rhinoceros density in these areas is probably the reason for the difference in range size. The higher the number of adult animals, the greater the competition for resources and breeding encounters. Initial results of work done in areas of low white rhinoceros density in the Kruger National Park indicates that these range sizes are, indeed, larger than those found in the high density areas.

Player & Feely (1960) mention regular straying from normal ranges by white rhinoceroses in the Umfolozi Game Reserve during summer when all life requirements are in optimum supply. They speculated that this behaviour may be an attempt at colonizing new ranges. In drought years straying occurred at all times, probably in search of food and water.

Owen-Smith (1973) found that white rhinoceroses extended their ranges during the dry winter season when field water supplies were not readily available. The animals were forced to make excursions to long-lasting water supplies every two to three days.

The territory and range of each marked animal in the Kruger National Park incorporated a permanent water supply. The animals did not have to make excursions to other permanent water supplies during winter. This could explain why the ranges of females are larger in the wet season than in the dry season. In the summer or wet season, field-water is widely dispersed, enabling the animals to range further from permanent water supplies and to utilize a larger foraging area. In the dry winter season they concentrate around the remaining water-points and the related areas of grazing preference.

Core areas were found to be most commonly situated along or around riverbanks in preferred grazing areas and encompassed a few favourite resting spots on high-lying areas. One white rhinoceros cow had two core areas (Fig. 3).

The range boundaries of female white rhinoceroses are not as distinct as those of the males as the females do not patrol or mark their range boundaries (Owen-Smith, 1973). This was also the situation with the white rhinoceroses in Kruger National Park. The number of observations on female white rhinoceros showed a gradual decrease closer to the range boundaries.

Conclusions

Female white rhinoceroses in the Kruger National Park have range sizes larger than male white rhinoceroses. The territorial boundaries of white rhinoceros males are non-overlapping while the ranges of females show extensive overlap. A female's range may, however, overlap with the territories of up to six males. In the south-western Kruger National Park, white rhinoceros females have a range which is larger in the wet summer season than in the dry winter season.

We are grateful to the National Parks Board of Trustees for allowing us to carry out this study and for assistance of several kinds. We thank the Rhino & Elephant Foundation for the use of a vehicle and for financial support. We are grateful to several members of the Shikar-Safari Club International—Charles E. Wilson, Charles F. Lathrop, Alex F. Maddox and the late Lee Basset in particular—who donated funds for the purchase of radio transmitters in their private capacities. We thank the University of Pretoria and the FRD for financial support and our colleagues in the Kruger National Park for assistance of several kinds. In particular we thank Dr A. Hall-Martin, Dr W. Gertenbach and T. Yssel. We also thank Elias Zima for his skilful assistance and companionship in the field. His knowledge of white rhinoceros habits and the bush made his assistance invaluable. The data in this paper form part of an MSc study conducted on white rhinoceros in the Kruger National Park by the senior author.

REFERENCES

Brown, J. L. & Orians, G. H. (1970). Spacing patterns in mobile animals. *A. Rev. Ecol. Syst.* **1:** 239–262.

Burt, W. H. (1943). Territoriality and home range concepts as applied to mammals. *J. Mammal.* **24:** 346–352.

Condy, P. R. (1973). *The population status, social behaviour, and daily activity pattern of the white rhino (**Ceratotherium simum simum**) in Kyle National Park, Rhodesia.* MSc thesis, University of Rhodesia.

Conway, A. J. & Goodman, P. S. (1989). Population characteristics and management of black rhinoceros *Diceros bicornis minor* and white rhinoceros *Ceratotherium simum simum* in Ndumu Game Reserve, South Africa. *Biol. Conserv.* **47:** 109–122.

Dalke, P. D. (1942). The cottontail rabbits of Connecticut. *Bull. Conn. St. geol. nat. Hist. Surv.* No. 65: 1–87.

Gertenbach, W. P. D. (1987). *'n Ekologiese studie van die suidelikste mopanieveld in die Nasionale Kruger Wildtuin.* PhD thesis, University of Pretoria, Pretoria.

Harris, S., Cresswell, W. J., Forde, P. G., Trewhella, W. J., Woollard, T. & Wray, S. (1990). Home-range analysis using radio-tracking data—a review of problems and techniques particularly as applied to the study of mammals. *Mamm. Rev.* **20:** 97–123.

Heppes, J. B. (1958). The white rhinoceros in Uganda. *Afr. wild Life* **12:** 272–280.

Joubert, S. C. J. (1983). A monitoring programme for an extensive national park. In *Management of large mammals in African conservation areas*: 201–212. Owen-Smith, R. N. (Ed.). Pretoria: Haum Publishers.

Kirby, F. V. (1896). *In haunts of wild game.* A hunter-naturalist's wanderings from Kahlamba to Libombo. London: William Blackwood & Sons.

Macdonald, D. W., Ball, F. G. & Hough, N. G. (1980). The evaluation of home range size and configuration using radio tracking data. In *A handbook on biotelemetry and radio tracking.* Amlander, C. J. & Macdonald, D. W. (Eds). Oxford: Pergamon Press.

Mohr, C. O. (1947). Table of equivalent populations of North American small mammals. *Am. Midl. Nat.* **37:** 223–249.

Owen-Smith, R. N. (1971). Territoriality in the white rhinoceros *Ceratotherium simum* Burchell. *Nature, Lond.* **231:** 294–296.

Owen-Smith, R. N. (1973). *The behavioural ecology of the white rhinoceros.* PhD thesis, University of Wisconsin.