Supplement to *Koedoe* 1984: 107-118

THE EFFECT OF WINDMILL CLOSURE ON THE MOVEMENT PATTERNS OF UNGULATES ALONG THE AUOB RIVERBED

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Abstract – Three groups of six consecutive windmills along the Auob riverbed were closed down for periods of one year and the responses of the three major ungulate species in the area to this practice were studied. The movements of springbok *Antidorcas marsupialis* and gemsbok *Oryx gazella* were not found to be affected by the windmill closure, but blue wildebeest *Connochaetes taurinus* showed significant tendencies to move out of areas in which windmills were closed.

Introduction

The provision of artificial water is an extensively used management tool in the Kalahari Gemsbok National Park (KGNP) and in other large wildlife areas in Africa (Young 1970; Weir 1971; Ayeni 1975). The effects of this practice on the ecosystems are the cause of much speculation and debate, yet little attempt has been made to study them (Child 1972). Eloff (1966) has documented how the provision of potable artificial water along the Auob riverbed led to the stabilisation of a small segment of a mobile blue wildebeest *Connochaetes taurinus* population. Child, Parris & Le Riche (1979) have shown that animals make regular use of mineralised water along the Nossob riverbed and suggest that this may raise the numbers of springbok *Antidorcas marsupialis*, red hartebeest *Alcelaphus buselaphus* and gemsbok *Oryx gazella* in this area.

In this paper we analyse the effect that the closure of windmills along the Auob riverbed had on the movement patterns of springbok, gemsbok and wildebeest, so as to gain more information on the importance of this potable artificial water to these three species and the usefulness of such a practice for the management of ungulate populations in the southern Kalahari.

The study area

For the most part the Auob riverbed is a narrow channel 100 – 500 m wide and 30 – 50 m deep with steep limestone banks. In the north the banks tend to be more gentle-sloping and in some areas dunes form the bank of the river. The Auob riverbed in the KGNP is 117 km in length and there are 17 windmills which deliver potable water along its length (Fig. 1).

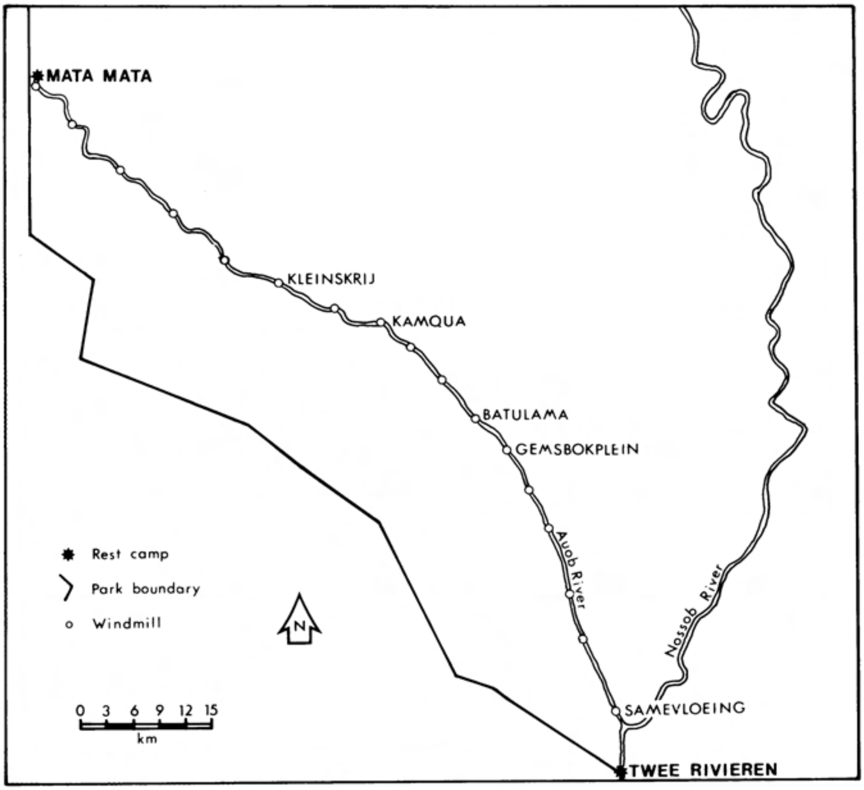

Fig. 1. The Auob riverbed showing the positions of the windmills and the names of those mentioned in the text.

The vegetation along the riverbed provides a distinct habitat which is clearly different from the surrounding dunes. It comprises large *Acacia haematoxylon* and *Acacia erioloba* trees, the bush *Acacia mellifera* subsp. *detinens*, the dwarf shrubs *Rhigozum trichotomum* and *Monechma australe*, the perennial grasses *Panicum coloratum*, *Stipagrostis obtusa* and *Stipagrostis uniplumis* and the annual grasses *Schmidtia kalahariensis* and *Eragrostis* sp. (Leistner 1967; Leistner & Werger 1973).

The area receives an irregular rainfall and experiences large temperature fluctuations on both a daily and seasonal basis. Summer maximum temperatures are normally 30 °C to 40 °C and winter minimums normally –5 °C to 5 °C. The mean annual rainfall for Twee Rivieren between 1961 and 1983 was 222,2 mm and for Mata Mata between 1962 and 1983 232,1 mm. Rainfall during this study was generally low (Table 1).

Materials and methods

The experiment commenced in May 1978 and continued until April 1982. The 17 windmills along the Auob riverbed were turned off in the following sequence (Fig. 1):

1. 1st May 1978 – 30th April 1979. The six windmills in the northern region: Klein Skrij to Mata Mata (Zones N – W).
2. 1st May 1979 – 30th April 1980. The six windmils in the southern region: Samevloeiing to Gemsbokplein (Zones A – G).
3. 1st May 1980 – 31st May 1981. The six windmills in the central region: Batulama to Klein Skrij (Zones H – O).
4. 1st June 1981 – 1st April 1982: the six northern region windmills as in No. 1 above.

It should be noted that Klein Skrij falls in both the northern and central regions and therefore zones N and O do so as well.

For practically every month (42 out of 47) of the study a road count of the ungulates along the Auob riverbed was done. As the riverbed is a narrow channel, nowhere more than 500 m wide, and visibility along its entire length is excellent, the counts are considered to accurately represent the number of ungulates present along the riverbed. During each count the position of all animals seen along the Auob was noted by referring to the vehicle's odometer reading, as was the position of each windmill and the presence or absence of water at each windmill. The riverbed was divided up into 23 × 5 km zones and labelled A – W from south to north.

The percentage of animals in a closed region for each month was calculated. For each period of closure, the percentage of animals in the closed region were compared with the expected percentage. The expected percentage was calculated from the proportion of riverbed within the closed region relative to the total river length. The percentages were transformed using an arcsin transformation (Sokal & Rohlf 1969). The expected variance of an arcsin transformed variate is $\frac{1}{4\ n}$ where n is the number of observations – in this case the number of animals counted in the whole river for that month (Sokal & Rohlf 1969). For each closure period, a standardised normal variate, Z, was calculated as the sum of the deviations of the transformed percentages from the tranformed expected percentage, divided by the square root of the sum of the variances (F. Lombard *pers. comm.*). This Z-score was compared with tables of the standard normal distribution to determine significance.

During the study it sometimes happened that a windmill which was supposed to be closed inadvertently delivered water and *vice-versa*. This was particularly so during the second phase of the project, in the southern region, when the animals at times were able to get at the water from some windmills which were meant to be closed. In the analyses this has been accounted for whenever possible *i.e.* when the data were analysed at a zone level, but could not be accounted for when the data were analysed at the region level.

Three seasons were distinguished: The hot wet season: January to April, when the mean monthly temperature is approximately 20 °C or higher and when 70% of the rain usually falls. The cold dry season: May to August, when the mean monthly temperature is below 20 °C and rainfall is very rare. The hot dry season: September to December, when the mean monthly temperature is approximately 20 °C and usually not more than 20% of the rain falls. Rainfall was monitored at three stations along the riverbed, at Twee Rivieren, Kamqua and Mata Mata (Table 1).

Results

Ungulate numbers along the Auob riverbed over the study period

Figure 2 shows how ungulate numbers along the Auob riverbed varied with time between May 1978 and April 1982. Table 1 shows the annual rainfall at the three stations during the same years.

Table 1

Annual rainfall in mm at three stations along the Auob riverbed – 1978–1982

YEAR	STATION		
	Twee Rivieren	*Mata Mata*	*Kamqua*
1978	125,7	83,5	137,0
1979	167,2	267,9	324,5
1980	118,2	158,7	82,4
1981	174,7	143,9	116,9
1982	107,5	126,4	215,0
Mean	138,7	156,1	175,2
S.D.	± 30,3	± 68,6	± 96,6

Springbok numbers varied from a low of 113 (January 1982) to a high of 3 412 (May 1978). Springbok were generally present in considerable numbers along the riverbed, with the highest numbers occurring between March and June (late rainy season – early dry season) and the lowest numbers between November and January (late dry season).

Gemsbok numbers varied from 2 (December 1982) to 343 (April 1979). Peaks occurred in May 1978, April 1979, April 1980, March to May 1981 and March 1982, thus showing marked seasonal peaks towards the end of the rainy season each year.

Wildebeest numbers varied from a low of 74 (January 1982) to a high of 420 (March 1979). A seasonal cycle was less obvious for wildebeest than for springbok and particularly for gemsbok, but peaks occurred in March and June of 1979, January and March 1980 and February, March, June, July and September of 1981. Troughs occurred in December 1980 and January 1981 and January and February 1982; *i.e.* at or near the end of the hot dry season.

Observations of marked animals and aerial surveys suggest that during the troughs in the total counts wildebeest were not very far from the riverbed, but the springbok and gemsbok were more widely dispersed.

In general, therefore, ungulate numbers along the riverbed during the study period followed the normal cyclic pattern for each species in this area as discussed by Mills & Retief (1984), despite the dry conditions prevailing during the study (Table 1).

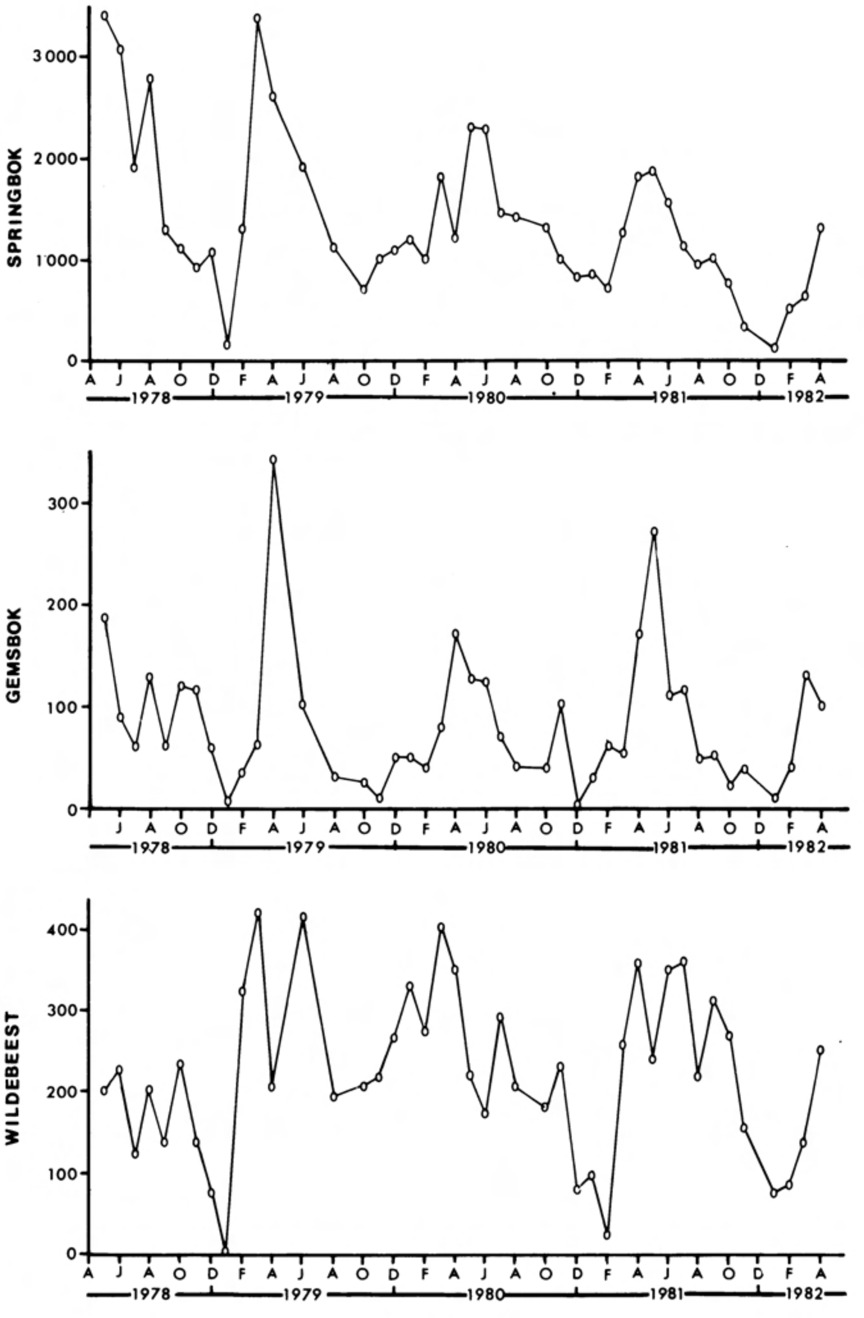

Fig. 2. Numbers of springbok, gemsbok and blue wildebeest counted along the Auob riverbed each month during the study.

The effect of the closure of windmills on the distribution of ungulates along the Auob

Table 2 shows the mean percentage of animals counted in each region during the time that the windmills in that region were closed, as well as the expected percentage, if the animals were evenly distributed along the length of the riverbed, and the relevant Z value. The analysis takes no account of those windmills which were inadvertently either providing, or not providing water.

Springbok numbers were significantly higher than expected in the northern region during both periods of closure and significantly lower than expected in the southern and central regions during their periods of closure.

The mean numbers of gemsbok were significantly higher than expected in the northern region during the second period of closure and in the southern region during its period of closure. The numbers were lower than expected in the northern region during the first period of closure and in the southern regions when the windmills there were closed. The extent of the reactions by gemsbok, as indicated by the Z-values in Table 2, are considerably less than for the other two species.

The mean numbers of wildebeest, were significantly lower than expected in the northern region during both periods of closure and in the central region during its period of closure. In the southern region, wildebeest numbers were higher than expected, although this reaction was relatively less intense than for the other regions. As pointed out it was in this region that the biggest problems in keeping the windmills closed were encountered.

The previous analysis of the effect of windmill closure considered entire regions (north, central, south) as closed or open for each period of closure. We now consider the effect of windmill closure by categorizing each 5 km zone as having windmill water, or not, and by looking at the data on a seasonal basis. This analysis has the advantage over the previous one in that allowance is made for those windmills which were inadvertently, either delivering water, or not. The mean number of animals in zones with water was calculated and compared with the mean number in zones without water at different seasons, using a Mann-Whitney U-test. The results of the analysis are given in Table 3.

Except for the hot dry season, when significantly more springbok were found in zones without water than in zones with water, no significant differences were found between the numbers of springbok in zones with or without water. Gemsbok numbers were not significantly different in zones with or without water at any season. Wildebeest numbers were significantly higher in zones with water in the hot dry, cold dry and in all seasons combined, but not in the hot wet season.

The effect of windmill water on the distribution of ungulates along the Auob

Figure 3 shows the distribution of ungulates from windmill water in the wet season and the two dry seasons combined. The graphs show the density of each species, as a function of increasing distance from open windmills, in the two seasons. Spear-

Table 2

Mean and S.D. percentages of the total counts of ungulates in each reagion when the windmills in that region were closed, the expected percentages for each region if the ungulates were evenly distributed along the riverbed, and the Z values for the differences between the observed and expected figures

	EXPECTED PERCENTAGE	OBSERVED PERCENTAGE		
		SPRINGBOK	GEMSBOK	WILDEBEEST
NORTH CLOSED (1) n = 12	43	55,2 ± 15,6 Z = 26,4517 ***	37,3 ± 26,9 Z = –3,0796 **	8,9 ± 12,8 Z = –11,4444 ***
NORTH CLOSED (2) n = 9	43	50,2 ± 20,4 Z = 9,7145 ***	59,4 ± 28,3 Z = 6,7190 ***	21,2 ± 28,5 Z = –23,5277 ***
SOUTH CLOSED n = 9	30	20,0 ± 12,3 Z = –26,300 ***	41,1 ± 26,2 Z = +3,8856 **	35,2 ± 11,8 Z = 5,1773 ***
CENTRAL CLOSED n = 12	35	23,6 ± 24,4 Z = –43,2068 ***	31,8 ± 240 Z = –2,0678 *	21,9 ± 19,0 Z = –17,9430 ***

* $P < 0{,}05$ (two-tailed)
** $P < 0{,}01$ (two-tailed)
*** $P < 0{,}001$ (two-tailed)

Table 3

Mann-Whitney U-test of the mean numbers of ungulates seen in zones with or without windmill water

SPECIES	ALL SEASONS			HOT WET SEASON			HOT DRY SEASON			COLD DRY SEASON		
	Mean no/zone		Z-value	Mean no/zone		Z-value	Mean no/zone		Z-value	Mean no/zone		Z-value
	With water	No water		With water	No water		With water	No water		With water	No water	
Springbok	61	63	–0,8396	59	57	–0,7869	43	48	–2,2161*	82	87	–0,0632
Gemsbok	4	4	–0,9856	2	2	–0,1537	3	5	–1,5117	5	4	–0,3645
Wildebeest	12	7	–6,0785**	11	11	–1,0284	12	5	–3,9838**	14	7	–4,4550**

* $P < 0{,}05$ (two-tailed).
** $P < 0{,}01$ (two-tailed).

man rank correlation co-efficients (r_S) were calculated for each species for the two seasons. For this purpose all distances above 20 km from water were lumped because of the small number of available 2 km intervals at this or greater distances from water.

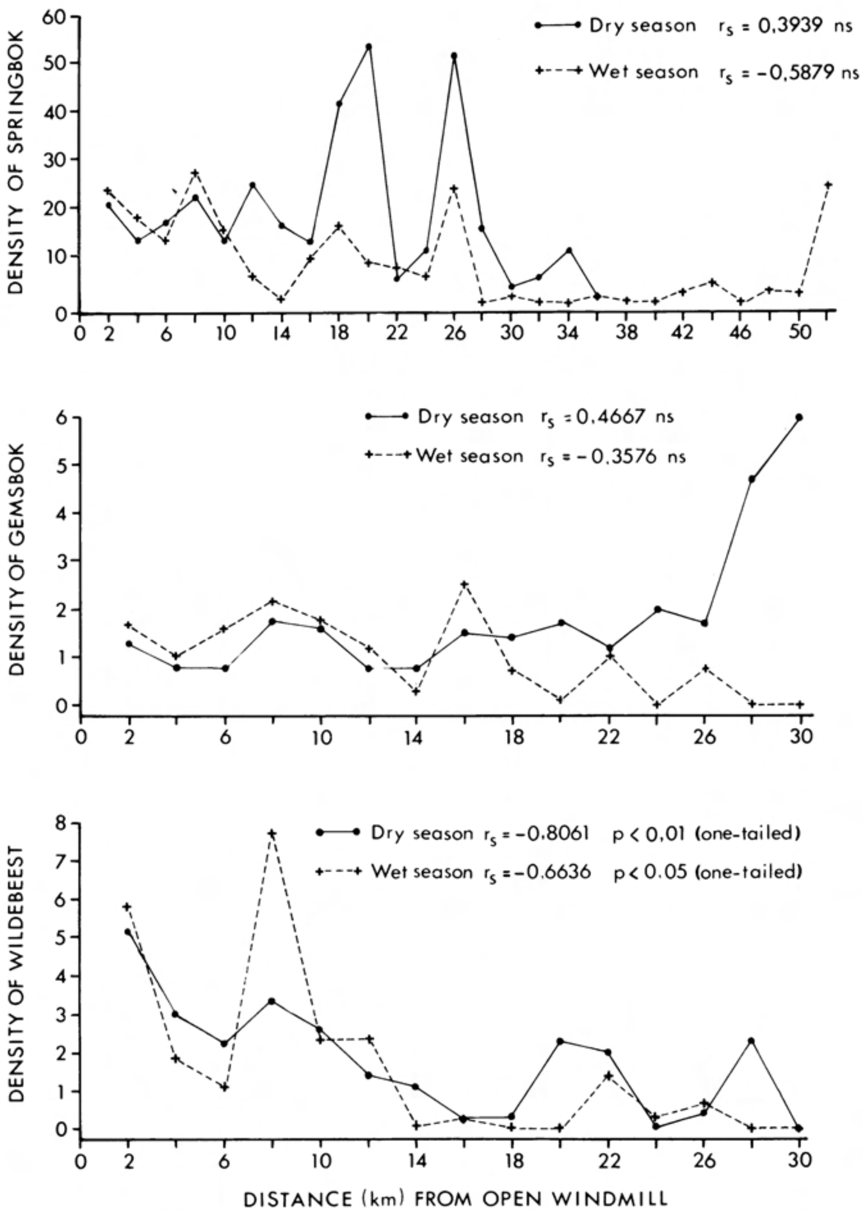

Fig. 3. The density, expressed in numbers of animals counted per 2 km, of springbok, gemsbok and blue wildebeest along the riverbed with increasing distance from windmill water.

Figure 3 shows the erratic distribution of springbok and gemsbok from water in both seasons, the r_s values supporting the data. Wildebeest, however, show a decline in density with increasing distance from water in both seasons, a conclusion which is supported by the significant values of r_s, particularly during the dry season.

Discussion

Springbok numbers were highest along the Auob riverbed in late summer – early winter during each year of the study (Fig. 2) *i.e.* at the end of the rainy season. Springbok, therefore, obviously react to rainfall by moving into the riverbed. However, in the analyses of the effect of windmill closure on springbok movements, we were unable to detect any consistent reaction. Although significantly fewer springbok than expected were found in the southern and central regions when the windmills there were closed, significantly more were found in the northern regions during both periods of windmill closure (Table 2). This was probably due to a preference by springbok for the northern region irrespective of water availability, rather than as a result of an avoidance of the region of closed windmills. The greater width and more gently sloping banks of the riverbed covered with dwarf shrubs in the northern region, when compared with the southern and central regions, probably make the northern region better springbok habitat. Furthermore, significantly more springbok were found in zones without water than in zones with water during the hot dry season (Table 3) and the density of springbok along the riverbed was not correlated with distance from water at any time of the year (Fig. 3).

Gemsbok numbers along the Auob riverbed followed a similar, but more seasonally fluctuating pattern. The analyses for avoidance or attraction to closed regions by gemsbok show mixed reactions and also ones of lower intensity than for the other two species (Table 2). This suggests no real avoidence or attraction by gemsbok for closed regions, nor any preference for a region. The analysis by zones also revealed no reaction by gemsbok to a lack of water (Table 3) and there was no correlation between density of gemsbok along the riverbed and distance from water (Fig. 3).

Wildebeest numbers did not show the same regular seasonal pattern as springbok and gemsbok numbers did, although lowest numbers were evident at the hottest and driest time of the year (Fig. 2). The analyses by region of windmill closure (Table 2) demonstrated an avoidance of closed regions by wildebeest except in the southern region. It is likely that this different and reduced reaction in the south was due to the unsuccessful closure of certain windmills in the southern region, rather than to a preference for the region. In the analysis by zones, wildebeest exhibited a significant attraction to zones with water in all seasons, except the hot wet season, as well as in all seasons combined (Table 3).

The low numbers of wildebeest observed along the riverbed in the hot dry season are mainly due to a local movement out of the riverbed into the adjacent dune areas. From the graphs of density versus distance from water and the correlation coefficients obtained for these data (Fig. 3), it is apparent that wildebeest along the Auob riverbed show a significant tendency to stay close to water in all seasons.

This is in agreement with observations by Berry & Louw (1982) who never recorded wildebeest more than 15 km from water in the Etosha National Park. All the available data suggest, therefore, that the wildebeest along the Auob riverbed exhibit a relatively high dependence on windmill water, particularly in the dry season.

The results obtained in this study can largely be explained in terms of the minimum water requirements of each species (Taylor 1968), assuming that those of the gemsbok and springbok are similar to those of the East African oryx *Oryx beisa* and Grant's gazelle *Gazella granti* respectively. Although the blue wildebeest is obviously the most water dependent species of the three, in parts of the southern Kalahari they may occur in large numbers in areas where free standing water of any description is absent even in the dry season (personal observations). How they achieve this and why these resident wildebeest have apparently become so much more water dependent, are intriguing and important questions which need to be answered.

Conclusions

Of the major ungulates of the area, the provision of artificial water along the Auob riverbed favours only the blue wildebeest. In spite of the very dry conditions prevailing during much of this study (Table 1) the closing of windmills could not be found to have had any noticeable effect on the movement patterns of springbok and gemsbok. The provision of potable artificial water and of using windmill closures as a management tool for manipulating ungulate movements along the riverbed, therefore, appear to have potential only for wildebeest.

Acknowledgements

We would like to express our thanks to the management staff in the Kalahari Gemsbok National Park: the late warden Mr. C. F. S. A. le Riche, the present warden Mr. E. A. N. le Riche and the ex-ranger at Mata Mata, Mr. I. Meyer, for their cooperation and patience during the project. We are also grateful to the tourist officers for their patience in handling tourist complaints. We also thank Prof. F. Lombard of the University of South Africa and Gill Beardall and Merwyn Kopinsky of the University of the Witwatersrand, for their valuable help in the analysis of the data and Total (S.A.), whose financial support enabled the work at the University of the Witwatersrand. Finally we express our appreciation to Dr. P. T. van der Walt for initiating and guiding this project and to Margie Mills, Maureen Rochat and Merle Whyte for help in preparing the manuscript.

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