

The impact of the provision of water for game on the woody vegetation around a dam in the Kruger National Park

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Quantitative inventory surveys were done on the woody vegetation in permanently marked plots at distance intervals from the Wik-en-Weeg Dam, Kruger National Park, in 1973. The surveys were repeated in 1990 so that changes in the community composition, the density and the canopy cover and the survival of the woody vegetation could be determined in relation to distance from the dam. Relationships with distance from the dam were shown for the relative density of *Combretum apiculatum* in all height classes, the relative canopy cover of the second height class of woody plants, the relative canopy cover of *C. apiculatum* plants, the survival of all height classes of woody plants and the survival of *C. apiculatum* and *Colophospermum mopane* plants. It was concluded that the provision of water for game at the Wik-en-Weeg Dam had an impact on the woody vegetation in the vicinity. The relationships of parameters of the two dominant species, *Combretum apiculatum* and *Colophospermum mopane*, with distance from the dam were compared. *Combretum apiculatum* parameters were more sensitive to impact associated with the dam than those of *Colophospermum mopane*.

Key words: woody vegetation, water provision, impact, elephant damage, Kruger National Park.

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Introduction

There is a paucity of information on the impact of water provision for game on the woody vegetation. Some work has been done on the woody vegetation along livestock foraging gradients away from watering points in the northern Transvaal (Friedel & Blackmore 1988; Friedel 1988) and in Australia (Andrew & Lange 1986). A qualitative assessment of trend in veld condition was done in the Kalahari Gemsbok National Park in relation to distance from watering points by Child *et al.* (1971). Several workers have also considered the influence of watering points in studies of the impacts of browsers (Du Toit 1988) and specifically elephants (Napier & Sheldrick 1963; Van Wyk & Fairall 1969; Laws 1970; Anderson & Walker 1974; Eltringham 1980; Stalmans 1982; Van Wyngaarden 1985) on the vegetation. None of the above-mentioned studies quantitatively determined the impact of the provision of water for game on the woody vegetation however.

The aim of this study was therefore to quantitatively determine whether the provision of a permanent supply of drinking water for game in the Wik-en-Weeg Dam, where there had previously been only an ephemeral supply in the Phugwane stream, would have any impact on the woody vegetation in the area through overutilization by game, particularly elephants. This work is part of a wider investigation on the impact of the provision of water for game. Work on herbaceous vegetation changes at the study site will be dealt with in another paper (Thrash *et al.* 1991).

The Wik-en-Weeg Dam, constructed in 1973, is in the Phugwane watercourse 30 km west-northwest of Shingwedzi, in the Far Northern District of the Kruger National Park. It is situated in the Tsende Sandveld landscape (Gertenbach 1983). The altitude of the area is between 300 m and 450 m above sea level. The mean annual rainfall is between 450 mm and 550 mm. The terrain is undulating with distinct hillsides and valleys. The parent rock is predominantly granite,

with some amphibolite and dolerite intrusions and gives rise to sandy soils (less than 15 % clay in the A-horizon) on the hillsides and clayey soils in the valleys. *Colophospermum mopane* (Kirk ex Benth.) Kirk ex J. Leon. and *Combretum apiculatum* Sond. are the dominant woody plants (Gertenbach 1983), with the latter more abundant on the hillsides and the former more abundant in the valleys.

Methods

In December 1973 seventeen permanently marked sampling plots (25 m by 50 m) were set out at intervals of about 1 km, north and south of the Wik-en-Weeg Dam along a firebreak. The woody vegetation in these sampling plots was then surveyed using an inventory technique similar to that described by Gertenbach & Potgieter (1979). Four cables were strung between the corner markers of the plots. Cables were strung at 5 m intervals across the breadth of each plot. The position of each woody plant was determined to the nearest 1 m² division with a measuring pole. The following variables were also recorded for each woody plant in the plots: the identity, the height, the maximum crown diameter, the number of stems and the diameters of the stems. Fourteen of these plots were relocated and their woody vegetation resurveyed in January and February 1990.

The number of species present in each plot, the number of species not present in 1973 but present in 1990 and the number of species present in 1973 that had disappeared by 1990 were calculated. The number of individuals per plot was converted to density (number per ha). The density of stems was also calculated to counter the problem of recognition of some individuals (Gertenbach & Potgieter 1979). The canopy cover was calculated using the formula $CC = \Sigma\pi(\frac{1}{2}C)^2$; where CC = canopy cover (%), and C = mean maximum crown diameter (m) (Gertenbach & Potgieter 1979). The percentage survival was the percentage of individuals recorded in the plots in 1973 that were recorded again in 1990. These parameters were then calculated for three height classes ($\leq 0,5$ m; $> 0,5$ m - ≤ 2 m; > 2 m).

Correspondence analysis was used to analyze the data matrix of the densities of species in the plots. The programme used was Simca 2 (Greenacre 1990). The data from the two sampling periods were merged into a single matrix, so that there were 28 columns (14 plots from the two sampling periods). Any outlying species which had first or second axis coordinates greater than 2,5 or less than -2,5 were made supplementary so that a more or less evenly spread map of the species was produced. The distances between the pairs of plots (one from each sampling period) in four dimensions were calculated from the axes coordinates in a similar way to Marten *et al.* (1990). Regression

analyses were then used to test for relationships between the distance between the pairs of plots and distance from the dam.

The density of woody plants, the density of woody stems and the canopy cover of woody plants were corrected for the initial condition by dividing by the values obtained prior to the dam's influence (in 1973) and multiplying by 100 to obtain relative values, as done by Andrew & Lange (1986). This was done to take into account any trends that may have existed with distance from the Phugwane stream before construction of the dam. Relative values greater than 100 indicated that the parameter was higher in 1990 than in 1973; relative values of 100 indicated no difference and relative values of less than 100 indicated that the parameter was higher in 1973 than in 1990. These relative values of the parameters were then tested for functional relationships with distance from the dam by means of regression analyses. Three types of regression curves were calculated to find the best fit. These were straight lines ($y = b + mx$), logarithmic curves ($y = b + m \ln x$) and exponential curves ($y = bm^x$) (Sokal & Rohlf 1969). The null hypotheses, that there were no functional relationships with distance from the dam, were rejected if $P \leq 0,05$. Significant relationships were taken to be sufficient evidence to conclude that the provision of water for game in the Wik-en-Weeg Dam had caused an impact on the woody vegetation initially present in the vicinity (Sokal & Rohlf 1969; Green 1979).

Results

The values for the various parameters in the plots are given in Table 1.

Community composition

An evenly spread map of species was obtained only after five species were made supplementary. The coordinates on the first four axes were calculated. Together these axes represented 67,26 % of the inertia in the data. No significant relationships between the distance between the pairs of points from the two surveys, in four dimensions, and distance from the dam were evident ($P=0,0529$).

Species richness

No significant relationships between the relative species richness ($P=0,8058$), the number of species not present in 1973 that appeared by 1990 ($P=0,5468$), and the number of species present in 1973 that had disappeared by 1990 ($P=0,1042$) and distance from the dam were evident.

Table 1
Changes in parameters of the woody vegetation in permanently marked plots near the Wil-en-Weeg Dam, in the Kruger National Park, between 1973 and 1990

Parameter	Height class (m)	Plot number (distance from the dam in km)													
		1(0,2) 1973	1(0,2) 1990	2(0,5) 1973	2(0,5) 1990	3(1) 1973	3(1) 1990	4(1,1) 1973	4(1,1) 1990	5(1,68) 1973	5(1,68) 1990	6(2,68) 1973	6(2,68) 1990	7(3) 1973	7(3) 1990
Density of all individuals (no./ha)	≤0,5	707	947	2267	1280	160	48	832	472	56	32	1500	660	613	160
	>0,5-≤2	613	720	2080	2240	56	128	848	1168	240	168	800	1460	653	933
	> 2	213	227	213	1440	112	88	280	392	80	128	60	120	213	493
Total	1533	1893	4560	4960	328	264	1960	2032	376	328	2360	2240	1480	1586	
<i>Combretum apiculatum</i>	≤ 1	120	200	80	80	96	80	224	144	24	24	187	13		
	> 1	267	80	267	53	96	56	264	400	40	32	80	213		
	Total	387	280	347	133	192	136	488	544	64	56	267	227		
<i>Colophospermum mopane</i>	Total	867	1120	3653	4293	24	32	1024	1104	208	192	1780	1840	907	947
Density of stems (no./ha)	≤ 0,5	2400	1973	5173	2026	1096	64	3296	1256	264	160	7240	1880	2667	373
	> 0,5-≤2	3587	3720	6907	5067	296	456	5976	4200	2496	1048	8360	9800	4240	4106
	> 2	427	1013	640	5093	496	272	1432	1616	786	560	80	600	733	1960
Total	6413	6707	12720	12187	1888	792	10704	7072	3528	1768	15680	12280	7640	6440	
<i>Combretum apiculatum</i>	Total	2400	1507	1147	267	952	384	4160	1504	344	248	1267	920		
<i>Colophospermum mopane</i>	Total	1827	3640	9840	10293	88	72	4008	4472	2512	1272	11260	10360	4920	4253

Table 1 (continued)

Parameter	Height class (m)	Plot number (distance from the dam in km)																			
		1(0,2)	2(0,5)	3(1)	4(1,1)	5(1,68)	6(2,68)	7(3)	1973	1990	1973	1990									
Density of stems >20 mm in diameter (no./ha)	≤0,5	13	347	240	56	8	32	40													
	>0,5-≤2	667	3307	1947	40	264	848	952	64	240	480	640	213	747							
	>2	333	680	373	3813	240	264	808	1192	136	280	80	220	413	1187						
Total		1000	4027	6000	336	536	1688	2184	200	520	560	880	693	1947							
<i>Combretum apiculatum</i>	Total	600	133	400	160	280	200	656	776	80	72										
<i>Colophospermum mopane</i>	Total	347	933	3493	5600	8	56	856	1288	88	440	520	860	440	1453						
Canopy cover (%)	≤0,5	0,35	0,73	4,47	2,28	0,71	0,07	1,10	1,00	0,19	0,12	1,68	1,44	1,61	0,15						
	>0,5-≤2	7,5	10,5	57,2	18,7	0,3	2,1	8,0	12,9	1,9	4,0	6,6	20,4	6,7	16,6						
	>2	13,7	18,1	10,2	52,5	4,8	9,6	13,8	21,1	5,4	10,1	13,7	24,1	14,0	31,1						
Total		21,6	29,4	71,8	73,5	5,8	11,8	22,9	35,0	7,5	14,2	22,0	45,9	22,3	47,9						
<i>Combretum apiculatum</i>	≤1	2,20	0,98	0,11	0,08	0,33	0,49	0,61	0,40	0,13	0,09										
	>1	6,95	3,51	4,45	1,07	4,54	8,25	8,47	14,0	1,44	3,05										
	Total	9,2	4,5	4,6	1,1	4,9	8,7	9,1	14,4	1,6	3,1										
<i>Colophospermum mopane</i>	Total	11,4	22,8	63,0	67,2	0,1	0,8	8,8	17,3	5,2	9,2	20,3	43,5	16,9	35,6						

Table 1 (continued)

Parameter	Height class (m)	Plot number (distance from the dam in km)													
		1(0,2)		2(0,5)		3(1)		4(1,1)		5(1,68)		6(2,68)		7(3)	
		1973	1990	1973	1990	1973	1990	1973	1990	1973	1990	1973	1990	1973	1990
Percentage survival	≤0,5	43,40		55,29		55,00		50,00		71,43		62,67		78,26	
	>0,5-≤2	58,70		79,49		71,43		58,49		83,33		92,50		93,88	
	>2	25,00		87,50		57,14		60,00		70,00		100,00		93,75	
Total		51,81		74,33		61,11		56,07		80,00		78,72		88,42	
<i>Combretum apiculatum</i>	≤1	33,33		0		50,00		46,43		100,00		71,438		100,0	
	>1	35,00		30,00		66,67		75,76		60,00		100,0		80,96	
	Total	52,50		33,33		62,96		74,73		77,78		80,96		80,96	
<i>Colophospermum mopane</i>	Total	47,69		75,18		59,38		88,46		82,02		89,71			
Distance between points ^a	All	0,21		0,22		0,18		0,09		0,15		0,27		0,13	
Species richness	All	11	10	10	11	6	6	6	17	19	9	10	9	9	11
No. species only in 1973	All	3		2		1		5		1		2		2	0
No. species only in 1990	All	2		3		1		7		2		2		2	0

^a Distance, in four dimensions, between the positions of the pairs of points on the correspondence analysis map (Simca 2) for 1973 and 1990.

Table 1 (continued)

Parameter	Height class (m)	Plot number (distance from the dam in km)													
		8(3,68)		9(4)		10(4,68)		11(5)		12(5,68)		13(6,68)		14(7)	
		1973	1990	1973	1990	1973	1990	1973	1990	1973	1990	1973	1990	1973	1990
Density of all individuals (no./ha)	≤0,5	1787	1787	1840	1867	368	232	480	100	880	1320	704	400	290	380
	>0,5-≤2	773	907	853	1093	312	416	400	660	740	1380	720	1232	370	530
	>2	160	320	507	827	112	168	220	420	260	380	256	384	300	300
Total		2720	3013	3200	3786	792	816	1100	1180	1880	3080	1680	2016	960	1210
<i>Combretum apiculatum</i>	≤1	240	160	427	267	48	24	40		320	240			160	120
	>1	133	213	480	720	88	96	240	220	240	500			350	350
	All	373	373	907	987	136	120	280	220	560	740			510	470
<i>Colophospermum mopane</i>	-	880	773	827	1547	208	224	660	800			1424	1696	90	110
Density of stems (no./ha)	≤0,5	9920	4800	6080	3707	1192	520	1340	260	5820	3640	4960	944	1670	910
	>0,5-≤2	6240	6080	6213	4160	3080	2760	4200	2820	7860	14560	4704	7552	3950	2440
	>2	480	1733	3120	3307	1112	1304	1100	1580	1460	1160	800	1712	1420	1210
Total		16640	12613	15413	11173	5384	4584	6640	4660	15140	19360	10464	10208	7040	4560
<i>Combretum apiculatum</i>	-	3280	2027	6053	3707	1488	536	2560	940	5260	2120			3500	1750
<i>Colophospermum mopane</i>	-	6800	6027	3173	3787	1536	2016	2900	3080			8176	8208	860	420

Table 1 (continued)

Parameter	Height class (m)	Plot number (distance from the dam in km)													
		8(3,68)		9(4)		10(4,68)		11(5)		12(5,68)		13(6,68)		14(7)	
		1973	1990	1973	1990	1973	1990	1973	1990	1973	1990	1973	1990	1973	1990
Density of stems >20 mm in diameter	≤0,5		27			8				40				32	10
	>0,5-≤2	613	853	267	400	96	176	240	380	220	460	240	1088	430	320
	>2	480	640	1013	1840	320	392	700	1120	820	880	272	736	930	950
	Total	1093	1520	1280	2240	416	576	940	1500	1080	1340	512	1856	1370	1270
<i>Combretum apiculatum</i>	-	400	480	827	1307	280	168	520	600	660	940			1050	990
<i>Colophospermum mopane</i>	-	667	907	400	667	112	128	420	900			464	1360	60	150
Canopy cover (%)	≤0,05	2,9	3,9	1,0	2,2	0,3	0,2	0,4	0,1	0,9	1,5	1,2	0,7	0,5	0,5
	>0,5-≤2	7,2	15,9	6,2	13,6	3,0	5,9	2,9	8,3	3,9	11,5	5,0	28,2	3,2	6,9
	>2	16,1	21,5	52,7	89,5	15,8	21,7	9,4	29,4	20,4	29,3	19,1	25,8	25,8	29,6
	Total	26,2	41,3	60,0	105,3	19,1	27,8	12,7	37,8	25,2	42,2	25,3	54,6	29,4	37,1
<i>Combretum apiculatum</i>	≤1	0,6	0,7	1,9	2,3	0,1		0,2		1,4	0,9			0,5	0,5
	>1	2,5	13,1	10,4	48,7	6,3	10,3	6,8	13,7	19,8	30,0			26,7	29,2
	All	3,1	13,8	12,3	51,0	6,4	10,4	7,0	13,7	21,2	30,9			27,2	29,8
<i>Colophospermum mopane</i>	-	21,0	19,5	42,1	44,3	6,3	11,6	5,3	23,4			24,1	47,3	0,5	3,2

Table 1 (continued)

Parameter	Height class (m)	Plot number (distance from the dam in km)													
		8(3,68)		9(4)		10(4,68)		11(5)		12(5,68)		13(6,68)		14(7)	
		1973	1990	1973	1990	1973	1990	1973	1990	1973	1990	1973	1990	1973	1990
Percentage survival	≤0,5	62,7		66,7		47,8		79,2		56,8		84,1		79,3	
	>0,5-≤2	79,3		84,4		76,9		90,0		75,7		93,3		75,7	
	>2	83,3		89,5		92,9		81,8		100,0		87,5		70,0	
	All	69,1		78,5		72,8		84,3		72,5		90,0		75,3	
<i>Combretum apiculatum</i>	≤1	77,8		87,5		66,7		50,0		93,8		81,3		81,3	
	>1	80,0		88,9		90,9		75,0		100,0		65,7		65,7	
	All	82,4		90,2		83,3		73,3		97,4		74,6		74,6	
<i>Colophospermum mopane</i>	-	69,7		77,4		80,8		93,9		87,6		77,8		77,8	
Distance between points ^a	All	0,21		0,58		0,35		0,17		0,68		0,03		1,06	
Species richness	All	8	9	11	11	14	17	4	5	14	16	7	8	16	16
No. species only 1973	All	1		2		1		0		2		1		1	
No. species only 1990	All	2		2		4		1		4		2		1	

^a Distance, in four dimensions, between the positions of the pairs of points on the correspondence analysis map (Simca 2) for 1973 and 1990

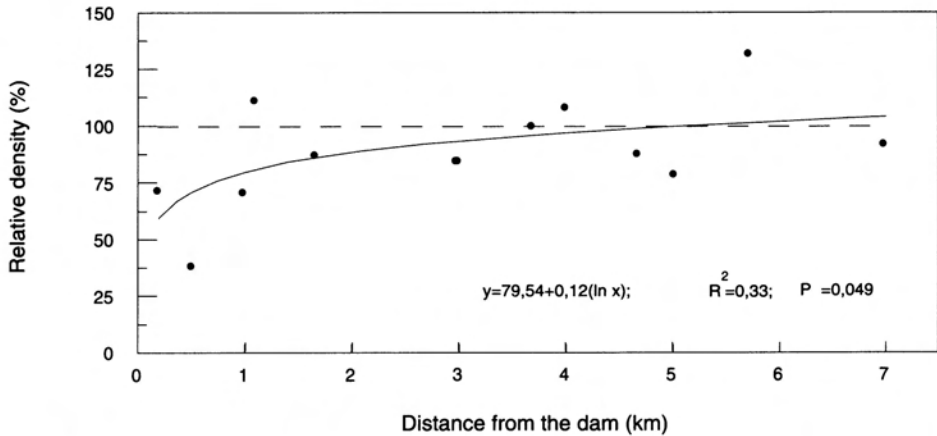


Fig. 1. The positive logarithmic relationship between the relative density (calculated as 100 times the density measured in 1973 divided by the density measured in 1990) of *Combretum apiculatum* plants in permanently marked plots and distance (km) from the Wik-en-Weeg Dam, Kruger National Park.

Density

Regression analyses on the relative densities of woody plants in total ($P = 0,0606$) and in the three height classes ($\leq 0,5$ m: $P = 0,3756$; $> 0,5 - \leq 2$ m: $P = 0,3921$; > 2 m: $P = 0,2738$) failed to yield significant relationships with distance from the dam.

Two species, *Combretum apiculatum* and *Colophospermum mopane* dominated the woody vegetation of the study area (20,6 % and 48,5 % of all individuals recorded respectively). Only these species exceeded 5 % of all woody plants recorded in the surveys. It was therefore decided to analyze the relative densities of these two species further.

There was a significant ($R^2=0,333$; $P=0,049$; $y=79,540+0,124(\ln x)$) positive logarithmic relationship between the relative density of *Combretum apiculatum* plants and distance from the dam (Fig. 1). The regression line crossed the 100 % level 5 km from the dam and levelled off after 3,5 km. A regression coefficient of 0,33 means that distance from the dam only accounted for one third of the variation in the relative density of *C. apiculatum*. Therefore the relative densities of *C. apiculatum* plants in two height classes were tested.

There was a significant ($R^2=0,345$; $P=0,045$; $y=90,019+38,655(\ln x)$) positive logarithmic relationship between the relative density of *C. apiculatum* plants in the second height class (>1 m) and distance from the dam (Fig. 2). The regression line intersected the 100 % level 1,3 km from the dam and levelled off after 4 km.

There was a significant ($R^2=0,641$; $P=0,005$; $y=98,440-22,635(\ln x)$) negative logarithmic relationship between the relative density of *C. apiculatum* plants in the first height class (≤ 1 m) and distance from the dam (Fig. 2). The regression line intersected the 100 % level 1 km from the dam and levelled off after 4 kilometres.

No significant relationships between the relative density of *Colophospermum mopane* plants and distance from the dam were evident ($P=0,7864$).

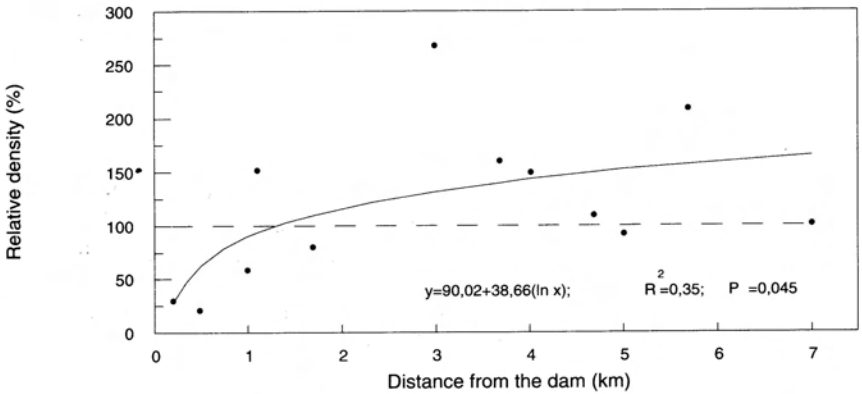
No significant relationships with distance from the dam were evident for the relative densities of all stems ($P=0,9726$) or for the relative densities of stems with diameters ≥ 20 mm ($P=0,3936$). Nor were any significant relationships with distance from the dam evident for the relative densities of all stems ($\leq 0,5$ m: $P=0,3253$; $> 0,5$ m - ≤ 2 m: $P=0,6563$; > 2 m: $P=0,3042$) or for the rela-

tive densities of stems with diameters ≥ 20 mm ($\leq 0,5$ m: $P=0,1526$; $> 0,5$ m - ≤ 2 m: $P=0,7207$; > 2 m: $P=0,1305$) for the woody plants in the three height classes.

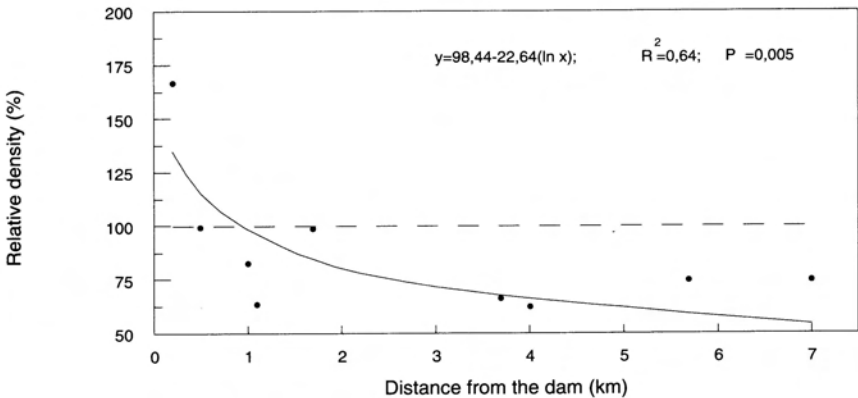
No significant relationships between the relative density of *Combretum apiculatum* stems and distance from the dam were evident ($P=0,8820$). There was, however, a significant positive logarithmic relationship ($R^2=0,474$; $P = 0,013$; $y = 78,330 + 27,430 (\ln x)$) between the relative density of *C. apiculatum* stems with diameters 20 mm and distance from the dam (Fig. 3). The regres-

sion line intersected the 100 % level 2,2 km from the dam and levelled off after 4 km. There was also a significant negative logarithmic relationship ($R^2=0,397$; $P=0,038$; $y=64,728-17,586(\ln x)$) between the relative density of *C. apiculatum* stems with diameters <20 mm and distance from the dam (Fig. 3). The regression line intersected the 100 % level 0,1 km from the dam and levelled off after 3 kilometres.

No significant relationships with distance from the dam were evident for the relative density of all *Colophospermum mopane*



Second height class



First height class

Fig. 2. The positive logarithmic relationships between the relative density (calculated as 100 times the density measured in 1973 divided by the density measured in 1990) of *Combretum apiculatum* plants in the second and first height classes in permanently marked plots and distance (km) from the Wik-en-Weeg Dam, Kruger National Park.

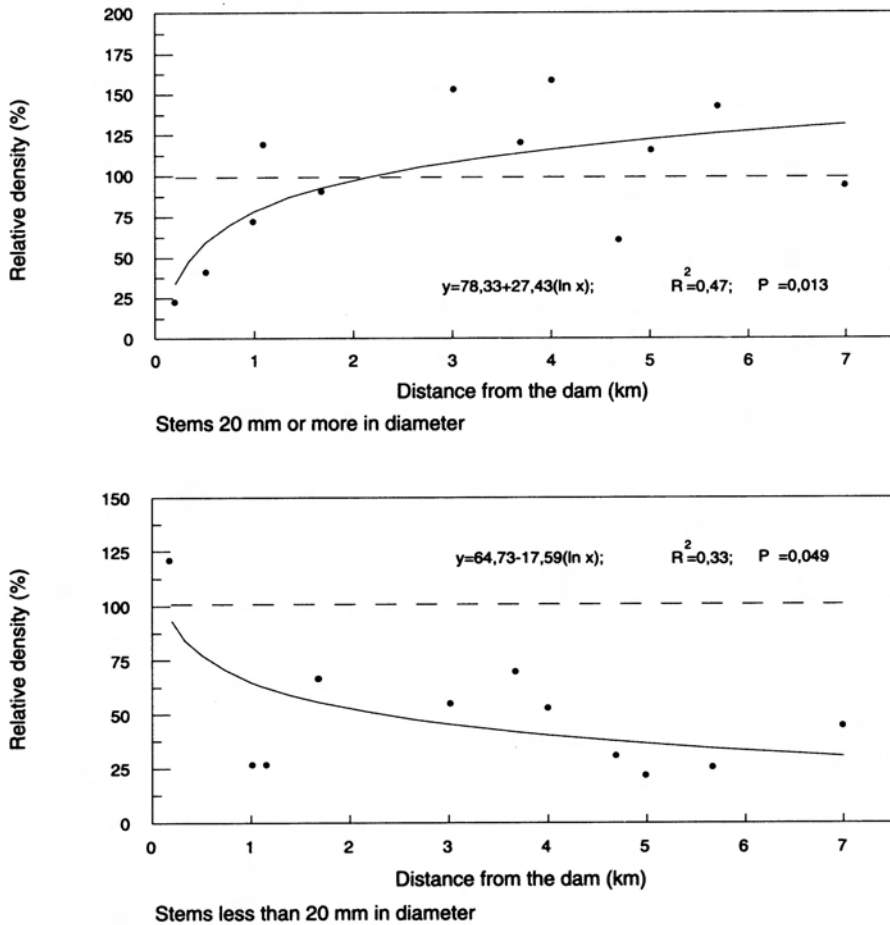


Fig. 3. The positive logarithmic relationships between the relative density of *Combretum apiculatum* stems ≥ 20 mm and < 20 mm in diameter (calculated as 100 times the density of stems measured in 1973 divided by the density of stems measured in 1990) in permanently marked plots and distance (km) from the Wik-en-Weeg Dam, Kruger National Park.

stems ($P=0,0643$) or for the relative density of *C. mopane* stems with diameters ≥ 20 mm ($P=0,4930$).

Canopy cover

No significant relationships between the relative total canopy cover of woody plants and distance from the dam were evident ($P=0,1900$). When the relative canopy cover of woody plants in the three height classes was analyzed, however, a significant positive logarithmic relationship ($R^2=0,376$; $P=0,020$; $y=191,807+49,046(\ln x)$) between

the relative canopy cover of plants in the second height class ($> 0,5$ m - ≤ 2 m) and distance from the dam was found (Fig. 4). The regression line intersected the 100 % level at 0,2 km from the dam and levelled off after 3,5 kilometres. No significant relationships between the relative canopy cover of plants in the first ($\leq 0,5$ m; $P=0,2400$) and third (> 2 m; $P=0,2412$) height classes and distance from the dam were evident.

When plants 5 m and taller were omitted from the analysis, a significant positive logarithmic relationship ($R^2=0,450$; $P=0,017$;

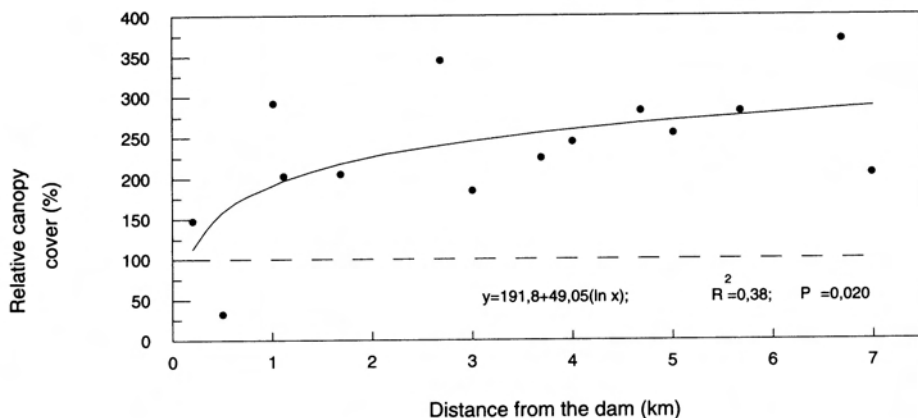


Fig. 4. The positive logarithmic relationship between the relative canopy cover (calculated as 100 times the canopy cover measured in 1973 divided by the canopy cover measured in 1990) of woody plants in the second height class (>0,5 m - ≤ 2 m) in permanently marked plots and distance (km) from the Wik-en-Weeg Dam, Kruger National Park.

$y=150,497+62,936(\ln x)$ was found for the relative canopy cover of *Combretum apiculatum* plants with distance from the dam (Fig. 5). The regression line intersected the 100 % level at 0,5 km from the dam and levelled off after 3 km. No significant relationships between the relative canopy cover of *C. apiculatum* in two height classes (≤ 1 m: $P=0,6200$; > 1 m: $P=0,1400$) and distance from the dam were evident, however.

No significant relationships between the relative canopy cover of *Colophospermum*

mopane and distance from the dam were evident ($P=0,2100$).

Survival

No significant relationships between the percentage survival in 1990 of all woody plants originally recorded in 1973 and distance from the dam were evident ($P=0,5900$). The survival of woody seedlings is expected to be low and linked to competition for limiting resources and the suitability of the microhabitat. Therefore woody plants 0,2 m

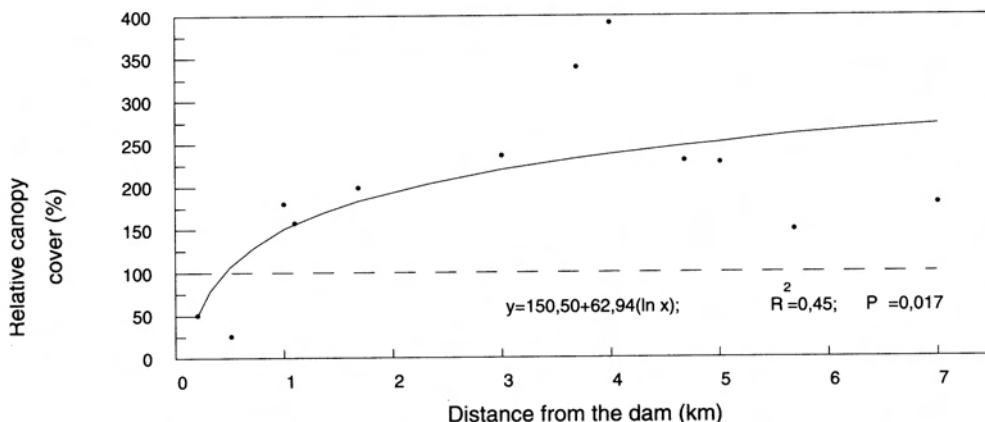


Fig. 5. The positive logarithmic relationship between the relative canopy cover (calculated as 100 times the canopy cover measured in 1973 divided by the canopy cover measured in 1990) of *Combretum apiculatum* plants less than 5 m in height in permanently marked plots and distance (km) from the Wik-en-Weeg Dam, Kruger National Park.

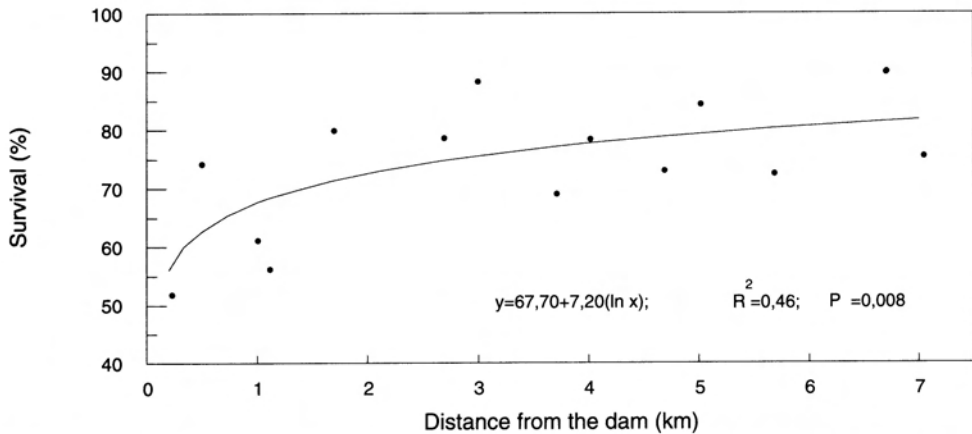


Fig. 6. The positive logarithmic relationship between the percentage survival of woody plants > 0,2 m high in permanently marked plots and distance (km) from the Wik-en-Weeg Dam, Kruger National Park.

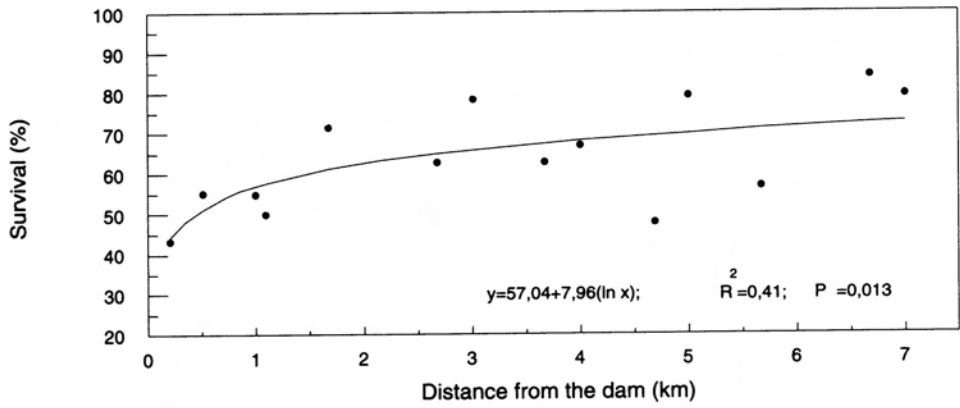
and less high were omitted from the analysis. There was a significant positive logarithmic relationship ($R^2=0,456$; $P=0,008$; $y=67,699+7,204(\ln x)$) (Fig. 6). The regression line levelled off after 2,5 kilometres.

There were also significant positive logarithmic relationships between the percentage survival and distance from the dam for the first ($\leq 0,5$ m; $R^2=0,414$; $P=0,013$; $y=57,037+7,961(\ln x)$), second ($>0,5 - \leq 2$ m; $R^2=0,356$; $P=0,024$; $y=74,075+6,434(\ln x)$), and third (> 2 m; $R^2=0,497$; $P=0,005$; $y=66,904+13,682(\ln x)$) height classes (Fig. 7). The low intercept and low slope of the regression line of the survival of the first height class indicate that factors other than distance from the dam affected the survival of these woody plants. The intercept of the regression line for the survival of woody plants in the second height class was considerably higher than that of woody plants in the first height class. The slope of the regression line for the survival of woody plants in the second height class was also greater than that of the first height class. The relationship between survival and distance from the dam was thus stronger for woody plants in the second height class than for those in the first height class. The intercept of the regression line for the survival of woody plants in the third height class (> 2 m) was similar to that of woody plants in the first height class. The slope of the regression line was far greater

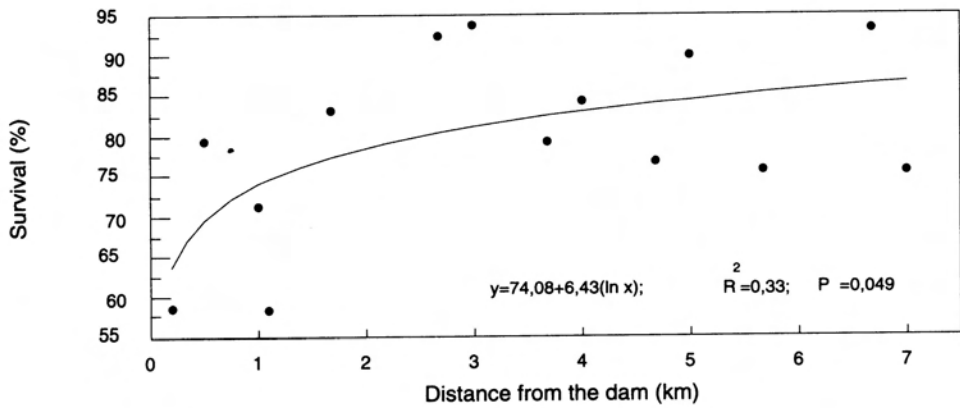
than those of either of the other height classes. The upper asymptote of the line was also higher than those of the other two height classes. The relationship between survival and distance from the dam was thus stronger for woody plants in the third height class than for those in the other two height classes.

There was a significant positive logarithmic relationship ($R^2=0,622$; $P=0,002$; $y=64,424+12,356(\ln x)$) between the survival of *Combretum apiculatum* plants and distance from the dam (Fig. 9). The regression line levelled off after 3 km from the dam. There were significant positive logarithmic relationships between the survival of *C. apiculatum* plants in the first (≤ 1 m; $R^2=0,495$; $P=0,011$; $y=49,540+18,317(\ln x)$) and second (>1 m; $R^2=0,615$; $P=0,003$; $y=60,297+16,158(\ln x)$) height classes and distance from the dam (Fig 8). The regression line for the survival of *C. apiculatum* plants in the first height class levelled off after 3 km from the dam. The regression line for survival of *C. apiculatum* plants in the second height class levelled off after 4 km from the dam.

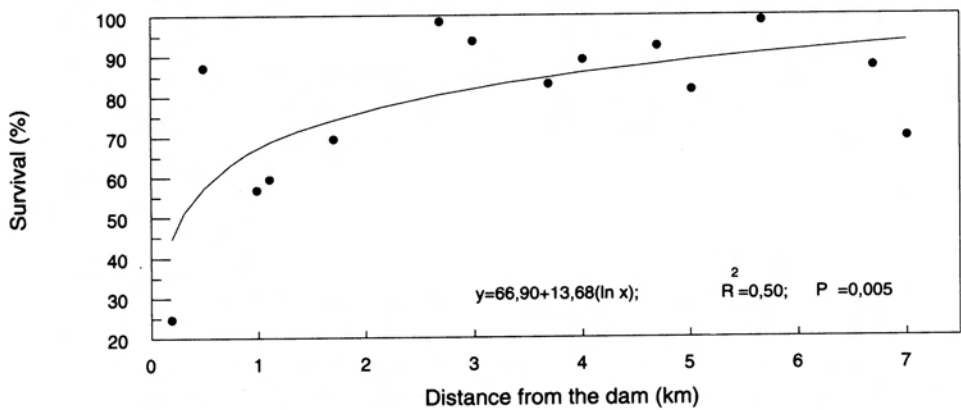
There was a significant positive logarithmic ($R^2=0,498$; $P=0,010$; $y=70,212+8,642(\ln x)$) relationship between the survival of *Colophospermum mopane* plants and distance from the dam (Fig 9). The regression line levelled off after 2 km from the dam. The regression line of the survival of *Combretum*



First height class



Second height class



Third height class

Fig. 7. The positive logarithmic relationships between the percentage survival of woody plants in the first, second and third height classes in permanently marked plots and distance (km) from the Wik-en-Weeg Dam, Kruger National Park.

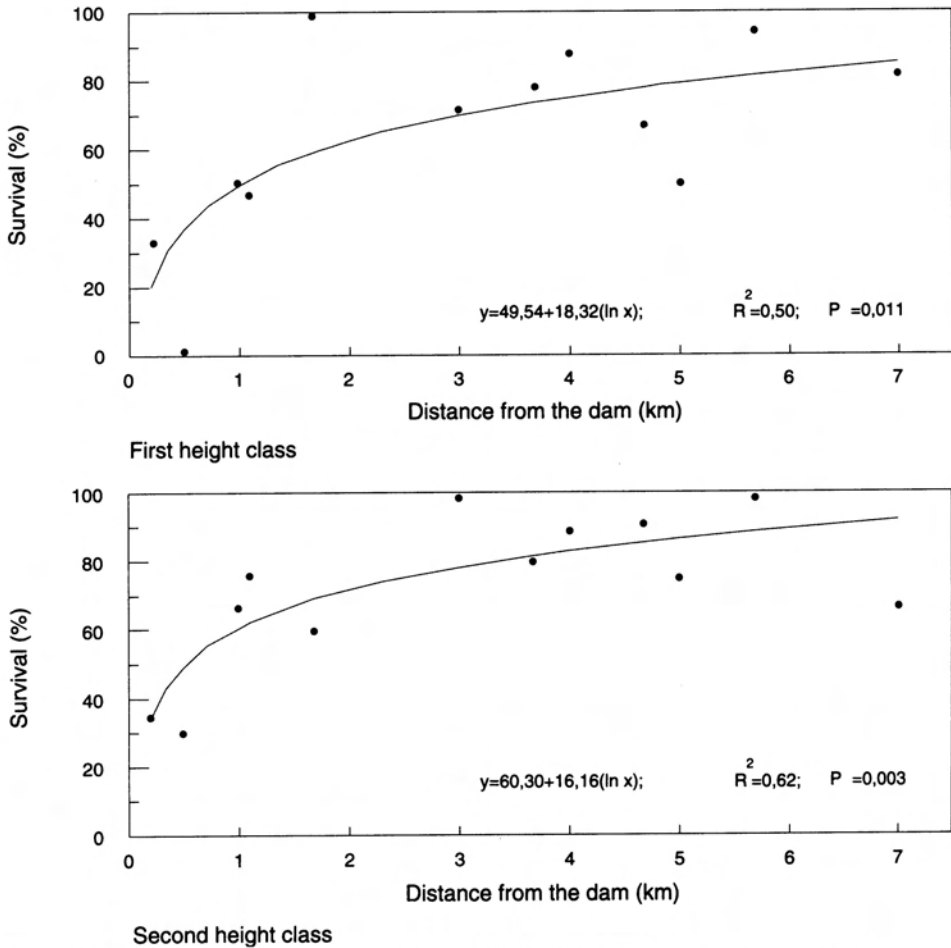


Fig. 8. The positive logarithmic relationships between the percentage survival of *Combretum apiculatum* plants in the first and second height classes in permanently marked plots and distance (km) from the Wik-en-Weeg Dam, Kruger National Park.

apiculatum plants was steeper than that of *Colophospermum mopane* plants. The relationship between survival and distance from the dam for *C. apiculatum* plants was stronger than that for *Colophospermum mopane* plants.

Discussion

This study includes temporal and spatial controls and complies with the optimal impact study design of Green (1979). Therefore those relationships between woody plant parameters and distance from the dam that were significant were considered sufficient evi-

dence to conclude that the influence of the dam indeed had an impact on the woody vegetation (Green 1979; Sokal & Rohlf 1969). However, as relationships were evident for only a few of the parameters tested we concluded that an impact on only a few of the more sensitive parameters was detectable at the level of sampling used.

Correspondence analysis has been successfully used to demonstrate trends in community composition (Martens *et al.* 1990). The lack of such evidence for a change in the woody community composition at the Wik-en-Weeg Dam means that the impact on the

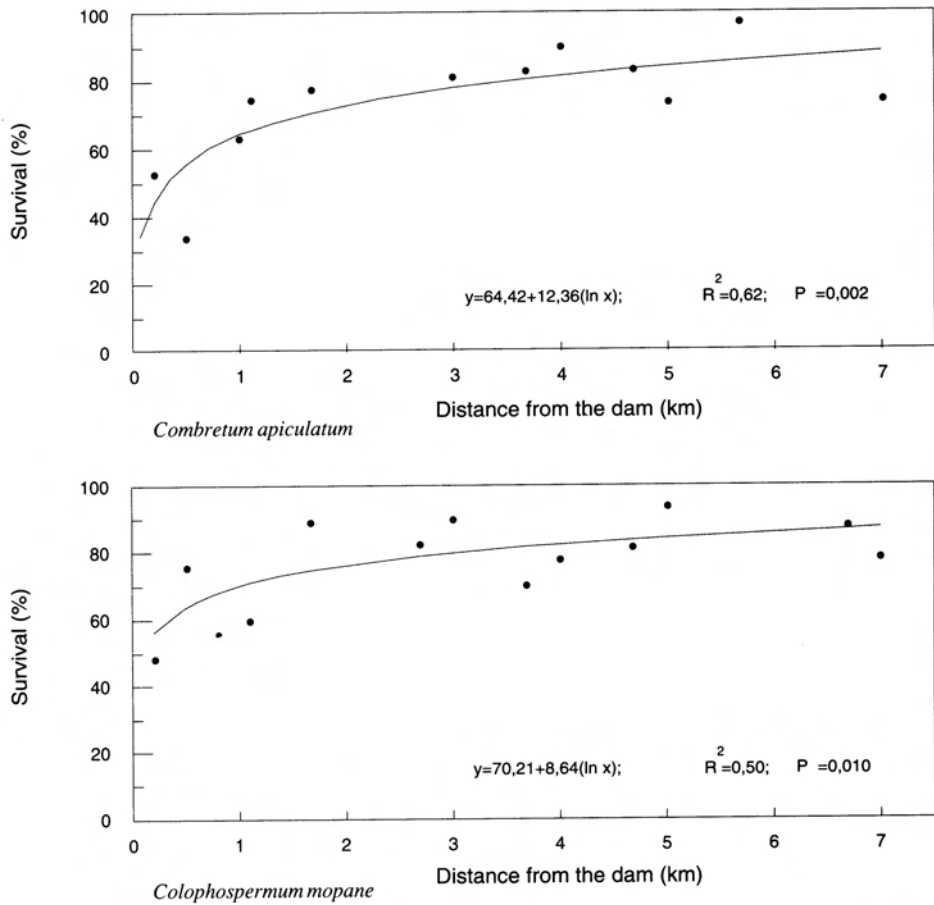


Fig. 9. The positive logarithmic relationships between the percentage survival of *Combretum apiculatum* and *Colophospermum mopane* plants in permanently marked plots and distance (km) from the Wik-en-Week Dam, Kruger National Park.

community composition, if any, was not large enough to be detectable at the sampling intensity applied.

Although no impact of the dam on the woody community composition as a whole was detected, there is evidence for an impact on the density and canopy cover of *C. apiculatum*. According to Joubert (1986) a sustained high elephant density in the Wik-en-Weeg dam area has led to high utilization of the woody vegetation and excessive destruction of *C. apiculatum* trees.

The existence of relationships between the relative density of all *Combretum apiculatum* plants and of those in the two height classes

and distance from the dam, when there was no evidence for such relationships for all woody plants or for *Colophospermum mopane* plants, was probably because of selective damage of *Combretum apiculatum* by game, particularly elephants. This was probably because, according to Van Wyk & Fairall (1969), Field (1971) and Guy (1976), trees are selectively eliminated by elephants according to the ease with which they can be pushed over. Van Wyk & Fairall (1969) found that *C. apiculatum* plants were disproportionately selected for by elephants when pushing over trees and that the occurrence of this activity was inversely proportional to distance from water in the Kruger National Park.

The existence of the relationship between the relative canopy cover and distance from the dam for *Combretum apiculatum* and not for *Colophospermum mopane* is, again, probably the result of selective browsing pressure on the former species by elephants. Stalmans (1982) found strong positive relationships for the canopy volume of plants selected for by browsing elephants with distance from a watering point. According to Guy (1976) elephants in the Sengwa area, Zimbabwe, did not select for *C. mopane* when feeding. There was, however, positive selection for the two *Combretum* species for which Guy calculated selection indices.

The reason for the relationship of survival with distance from the dam being stronger for the third height class of woody plants than for the other two height classes is probably that, according to Field (1971), damage by elephants has a disproportionately large effect on the survival of tall trees.

The negative relationships between the density of *C. apiculatum* plants in the first height class (≤ 1 m) and distance from the dam was probably because, according to Spence & Angus (1971), the destruction of trees by elephants is often followed by regrowth from the persistent root stocks. The density of *C. apiculatum* regrowth, in the first height class, will probably be directly proportional to the amount of damage to *C. apiculatum* plants in the taller height class.

According to Guy (1976) elephants mostly browse woody vegetation between 0,57 m and 2 m in height (more than 55 % of their feeding activity). Concentration of browsing pressure on woody plants in the second height class by elephants could thus be why a positive relationship exists between the relative canopy cover of plants in this height class and distance from the dam.

The regression lines for the various significant relationships with distance from the dam were all logarithmic curves. The regression lines of the positive relationships had upper asymptotes at the level reached where the influence of the dam is negligible. The re-

gression lines of the negative relationships had lower asymptotes at the level reached where the influence of the dam is negligible. The logarithmic transformation was the most useful. The distance at which the influence of the dam, modelled by regression analysis, became negligible varied from 2 - 5 km from the dam, depending on the parameter measured.

Conclusion

The following conclusions concerning the woody vegetation at the Wik-en-Weeg Dam seem valid from this study:

- The provision of a permanent water supply for game in the Wik-en-Weeg Dam has had a significant impact on certain parameters of the woody vegetation in the vicinity.
- The density and canopy cover of *Combretum apiculatum* plants, the canopy cover of all woody plants in the second height class ($> 0,5$ m - ≤ 2 m) and survival of all groups of woody plants have been affected by the construction of the dam.
- No effects of the dam on the composition of the woody community, the species richness, the relative density of all woody plants, the relative density of all woody plants in three height classes, the relative density of *Colophospermum mopane* plants, the relative density of all woody stems, the relative density of woody stems of all plants in three height classes, the relative total canopy cover, the relative canopy cover of the first and third height classes and the relative canopy cover of *C. mopane* plants were detected.
- Parameters of *Combretum apiculatum* plants were more sensitive to impact associated with the dam than those of *Colophospermum mopane*.
- The impact of the Wik-en-Weeg Dam on the woody vegetation nearby can best be described by logarithmic curves.

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