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THE INFLUENCE OF THE AFRICAN ELEPHANT ON THE VEGETATION OF THE ADDO ELEPHANT NATIONAL PARK

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Abstract – An increasing elephant *Loxodonta africana* population has been confined to a 2 770 ha enclosure since 1954. When compared to the vegetation adjacent to the enclosure, the plant biomass within has been reduced by more than one half. Changes in the botanical composition are described.

Introduction

The Addo Bush is a practically impenetrable scrub consisting mainly of *Portulacaria afra, Schotia afra* and *Euclea undulata* while the thorny shrubs *Azima tetracantha* and *Capparis sepiaria* var. *citrifolia* and the lianes *Sarcostemma viminale* and *Rhoicissus digitata* are also common. This dense bush and the Knysna Forest are the habitats of the last elephant in the Cape Province – the southernmost elephant populations on the continent.

In the Addo Elephant National Park the elephant have been confined to a 2 270 ha tract of this bush since 1954. The purpose of this investigation was to determine the influence of the elephants on the vegetation during that period. Although the elephant are confined, other large mammals such as the Cape buffalo *Syncerus caffer*, kudu *Tragelaphus strepsiceros*, bushbuck *T. scriptus* and bushpig *Potamochoerus porcus* are not; therefore, any differences in vegetation within and outside the camp are probably due to the influence of the elephant.

Historical background

The vegetation of the area was in a similar condition when the first permanent settlers arrived. The impenetrable scrub offered a safe retreat for large mammals which were rapidly exterminated in the surrounding areas.

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John Barrow trekked through the area in 1797 and described the following incident: " . . . . . we . . . . crossed a ford of the Sunday River, and encamped upon its bank. . . . . On the banks of this river we were disturbed, for the first time, by a troop of elephants that had intended to quench their thirst near the place where we were encamped, but, finding the ground already occupied, they turned quietly away without molesting us. The following morning we pursued them by the track of their feet into an extensive thick forest of brushwood, among which several made their appearance at a distance, but we were not lucky enough to kill any of them" (Barrow 1801).

Lichtenstein (1811) mentions a road hacked through the dense scrub east of the Sundays River and the spoor of elephant, rhinoceros and buffalo being encountered frequently.

Thomas Pringle visited the area in 1821 and described it as follows: "These rugged ravines and that far-stretching forest were still the haunt of elephants and buffaloes, protected from extirpation by the enormous extent of jungle, which, consisting chiefly of evergreens and succulent plants, such as milkwood, spekboom, and euphorbias from fifteen to forty-five feet high, cannot possibly be burned down . . . . " (Pringle 1966).

Thomas Baines, who trekked through the vicinity of the present park in 1848, made the following entry in his journal: "After six in the same evening we crossed the Sundays River, and, passing the comfortable-looking inn upon its western (*sic*) bank, entered the Addo Bush, which Abram, determined if possible to make me imagine myself in a savage land, represented as the haunt of elephants, lions, and numberless other wild animals. A few of these creatures I believe, do still inhabit its deepest recesses but they are rarely met with, and their spoor is only occasionally seen upon the road" (Baines 1961).

The increase in farming activities in this area, especially in the neigbouring Sundays River Valley, lead to the inevitable confrontation between agricultural interests and the large mammals. As a result, the Administrator of the Cape Province in 1919 commissioned Major P.J. Pretorius to eradicate the entire population of 130–140 elephant. He set about the task, but found the Addo Bush: " . . . a hunter's hell. . . . . a hundred square miles or so of all that you would think bad in Central Africa, lifted up as by some Titan and planked down in the Cape Province. It was scrub, generally some eighteen feet high, and exceedingly thick. Once in this jungle it was seldom possible to see more than five paces ahead, and the jumble of undergrowth consisted of thorns and spikes of every description. A terrible country" (Pretorius 1947). In a few months he succeeded in shooting 120 elephant. By that time there was considerable opposition to the slaughter and the campaign was abandoned when only 10–20 elephant remained.

The Addo Elephant National Park was proclaimed ten years later in 1931.

Prior to 1954 the elephant could not be confined to the Park and they often strayed beyond the boundaries, especially at night, and wreaked havoc upon crops on the neighbouring farms. In 1952 a woman was killed by an elephant on a neighbouring farm. Various attempts at fencing failed, including an electrified fence, until the Armstrong Fence was completed in 1954. This fence was named after the then Warden of the Park who was responsible for its design and construction. It consists of lengths of railway track, stout wooden poles and three strands of elevator cable, enclosing the elephant camp of 2 270 ha.

Vegetation

Acocks (1953) regards the Addo Bush as a Karroid veld type and describes the vegetation as follows: ". . . . a short, dense, dry forest,

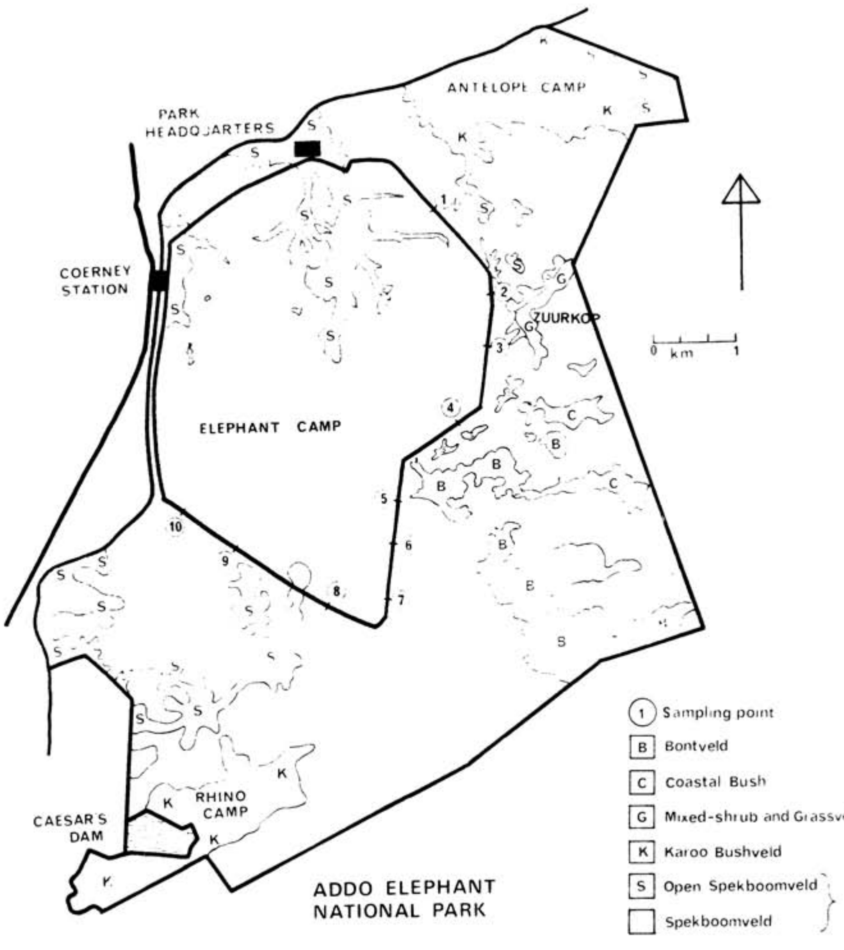

Fig. 1. Vegetation map of the Addo Elephant National Park (after Archibald 1955) showing the sampling points along the elephant camp.

dominated by such species as *Schotia speciosa, S. latifolia, Sideroxylon inerme, Olea africana, Cussonia spicata* and *C. kraussiana,* with an abundance of shrubs and climbers, e.g. *Azima tetracantha, Portulacaria afra, Rhoiacarpos capensis, Plumbago capensis, Rhus longispina, Scutia myrtina, Rhoicissus digitatus, Sarcostemma viminale* and *Capparis citrifolia.*" He states that the Addo Bush appears to be derived directly from the Alexandria Forest, a Coastal Tropical Forest type, rather than from the Valley Bushveld.

Archibald (1955) describes five plant communities in the Park (Fig. 1), the most extensive being the *Spekboomveld* which covers more than 90 per cent of the Park and is synonymous with the Addo Bush. Spekboom *Portulacaria afra* is the dominant species. The elephant camp is confined to this plant community.

The four minor plant communities are *Karoo-bushveld, Mixed Shrub and Grassveld, Bontveld* and *Coastal Bush.*

Physiography

The Park has an area of 6 852 ha and is situated at 33°31'S, 25°45'E.

The elephant camp covers a series of low undulating hills in the central and northwestern part of the Park and the altitude ranges from 125 to 275 metres. The soil is a light-red clay loam (Archibald 1955) derived from sandstone and mudstone of the Sundays River Stage, Uitenhage Series, Cretaceous System (Toerien 1972).

Several small vleis and pans occur within the elephant camp but they are dry during the greater part of the year. The only permanent water is provided by two boreholes. During the period 1963–71 the average annual precipitation at the Park headquarters on the northern boundary was 442,1 mm and 410,3 mm at the Citrus Research Station 3 km southwest of Caesar's Dam (Table 1).

Table 1:

Annual rainfall (1963–1971) in the Addo Elephant National Park and at the Citrus Research Station, Sundays River Valley (in mm)

Year	Park headquarters	Citrus Research Station
1963	550,8	454,4
1964	449,6	430,9
1965	457,6	481,4
1966	261,0	266,3
1967	518,5	388,9
1968	408,5	410,1
1969	325,0	316,3
1970	436,5	418,2
1971	521,0	526,1
ANNUAL AVERAGE	442,1	410,3

Elephant population

In 1931 the population consisted of 11 elephant. The number gradually increased to 25 in 1938, after which it declined to 18 and remained static for a few years. A second peak of 23 in 1949 was followed by another decline in the early 1950's. When the Armstrong Fence was completed in 1954, 20 elephant were enclosed in the camp. Since then the population has constantly increased. By 1960 there were 29 elephant, 45 by 1965 and in 1971 the 60-mark was reached (Fig. 2). The population has trebled in 18 years.

The construction of the Armstrong Fence was the turning-point in the history of the population. Prior to this, individuals had to be destroyed regularly which resulted in the number remaining virtually constant. Since 1954 only two elephants, those which succeeded in escaping from the camp in 1968 and 1971, have had to be destroyed.

The position of the Knysna elephants is apparently similar to that at Addo prior to 1954. The population is static due to illegal hunting which cancels the natural increase (Carter 1971).

Methods

Plant biomass per unit areas was used as an indication of the condition of the vegetation. Ten points at which sampling plots were laid out were spaced at 1 km intervals along the Armstrong Fence using aerial photographs (Fig. 1). Where conspicuous differences occurred in the vegetation within and outside the elephant camp the point was advanced a further 0,16 km. In one instance the point had to be advanced a further 0,16 km before the vegetation on both sides of the fence appeared similar. The points were then located in the veld by using the odometer of a vehicle. When the predetermined distance had been covered, the vertical railway track in the fence nearest to the vehicle was designated as the point and was permanently marked. All points were located before the survey commenced.

At each point a sampling plot of 2 m x 10 m was examined within and outside the elephant camp. The long axis of the plot was perpendicular to the fence and the proximal end of the plot was 12 m from the fence. The distance to the proximal end of the plots outside the fence was increased to 18 m due to the tourist road along the fence. To facilitate the survey, each plot was divided into five subplots of 2 m x 2 m (Fig. 3). The corners of the plots were marked with short iron posts driven into the ground.

At each plot the undergrowth was removed initially and the species placed in separate paper bags for mass determination in the laboratory. This proved to be an unnecessary refinement as the undergrowth represented but a small percentage of the total biomass and the mass of only a few species exceeded 1 kg/plot. Where the mass of a species was less than 1 kg/plot, it was therefore ignored and the species only recorded as

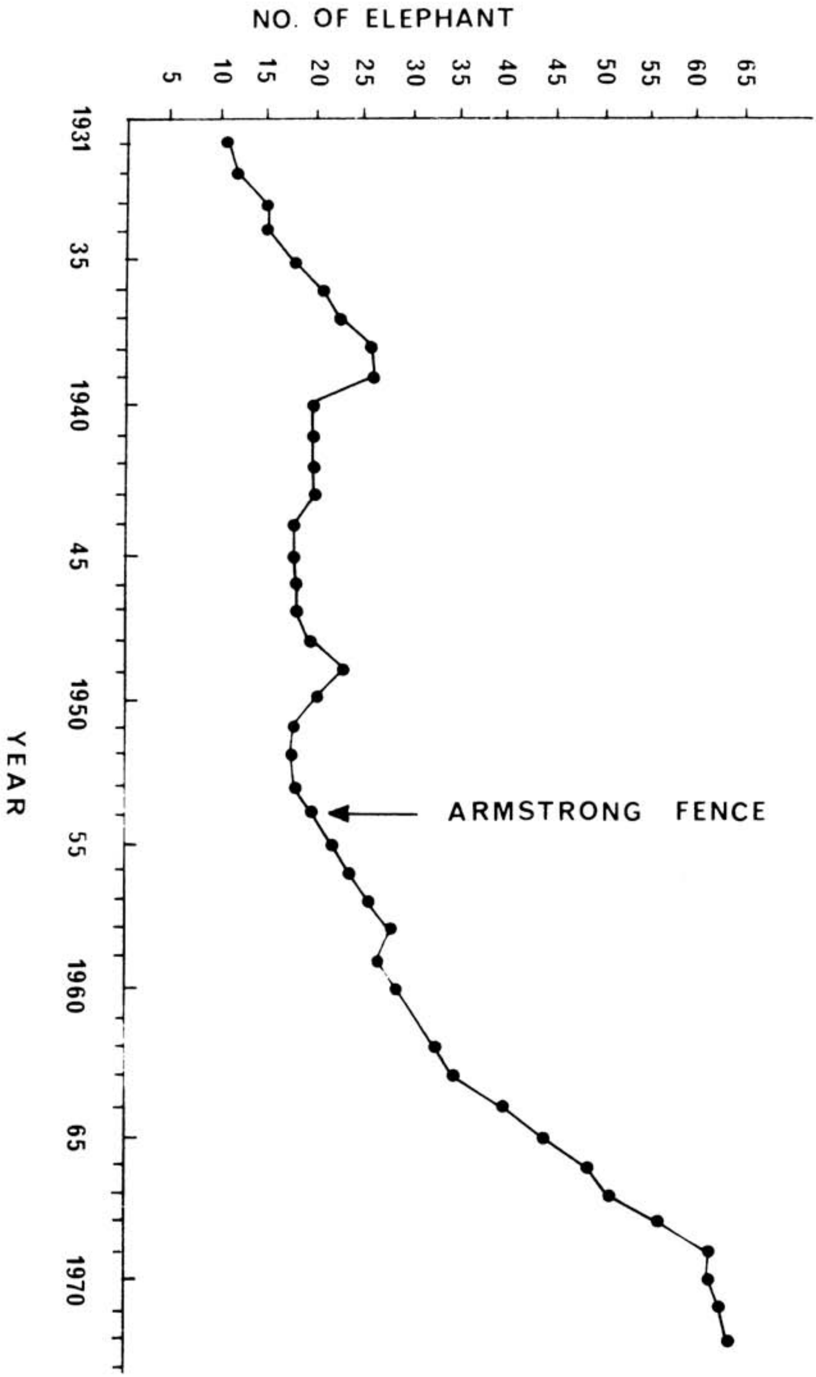

Fig. 2. Increase of the elephant population since the construction of the Armstrong Fence.

Fig. 3. A denuded subplot (2mx2m).

being present. The larger woody species were hacked off at ground level and weighed on a spring balance suspended from a tripod (Fig. 4).

Fig. 4. The tripod and spring balance used for determining the sample mass. Note the dense vegetation (outside the elephant camp).

The two plots at each point were surveyed on the same day to eliminate the influence of short term fluctuations in climatic conditions, e.g. rain.

The project was completed between December 1971 and May 1972.

Results

A total of 66 species was recorded. The mass/plot of only 26 species exceeded 1 kg in one or more plots (Table 2). The 40 species of which the mass/plot never exceeded 1 kg are given in Table 3.

Table 2

List of plant species of which the mass/plot exceeded 1 kg on at least one plot (a = outside the elephant camp b = inside the elephant camp)

	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b	10a	10b
Aloe africana			16				9		29		4						*			
Asparagus africanus				*							2	*								
A. crassicladus																	*	2		*
A. racemosus	2				*	*	*	*	*	*			2	*	*	*	4		*	*
A. striatus	1		*	*													*	*	*	
Azima tetracantha	1	8	12	9	8	20	2	*			7	*	45	*	11	2			12	*
Cadaba aphylla	6	7									2		*	3		*	*	5		*
Capparis sepiaria var. *citrifolia*	24	22	48	6	*	12	14	79	12	16	4	31	9			*	6	15	4	*
Carissa haematocarpa	10		15				*	*							*			4	5	
Cotyledon sp.		*	*	*			2		*	*			*				10			
Crassula cultrata								*	2	*			4	*			*	*	*	
C. perforata			*	*			*		*	*			*	*	*		*	3	*	*
Crassula sp.		*							*			*	*				*	1	2	
Euclea undulata	*	45		10	43			*	80		*		5	*	*	*	*	19	25	5
Hypoestes verticillaris									*	1	*	*	*	*	*		*	*		*
Maytenus heterophylla	*	*			*	7	*	*	*	*	*	*	2	*	*			*	*	*
Pelargonium peltatum	1		*	*				*	*	*			*							
Plumbago auriculata		1			*		*			2	*	2	2	*	*		*			
Portulacaria afra	368	87	495	108	619	13	322	96	23	145	140	196	46	135	282	217	188	69	119	103
Rhoicissus digitata	*	*	*			*	*	*	3	*	*	*	*	*	*	*		*	*	*
Rhus longispina	*	*			*	*					*			*				*	9	
Sansevieria spp.	11	18	3	1	2	2	7	5	2	3	7	3	2	*	4	1	*	11	7	*
Sarcostemma viminale		1	*	*	*		*	*	6	*	3		*		*	*	4	2	*	*
Schotia afra	107	19	39	2	109	20	5	57	*	13	98		10	58	37		9	8	2	3
Sideroxylon inerme					*								78							
Teclea natalensis											*		11	1						
TOTAL	531	208	628	136	781	74	359	237	157	180	267	202	216	197	334	220	221	139	185	111

**Mass/plot < 1 kg*

Table 3

List of plant species of which the mass/plot did not exceed 1 kg.
a = outside the elephant camp
b = inside the elephant camp

	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b	10a	10b
Abutilon sonneratianum	*					*		*		*	*	*		*	*					
Aizoon sp.		*																		*
Asclepiadaceae cf.																				
Ceropegia sp.	*														*	*	*			
Asparagus asparagoides	*	*				*			*	*	*				*			*	*	
A. suaveolens			*	*																
A. subulatus		*																		*
Asparagus sp.		*					*			*			*	*			*	*		
Cassine aethiopica							*		*											
Cassine tetragona										*										
Chenopodium album				*		*		*				*			*	*	*			*
Compositae (sp.indet.)																				*
Commelina spp.				*			*		*	*	*	*	*	*	*	*		*	*	*
Crassula corymbulosa										*										
C. rossularis																		*		
C. spatulata								*	*	*										
C. tetragona																	*		*	*
Crassula sp.cf.*cordata*							*		*											*
Cynodon sp.								*									*			*
Delosperma echinatum																		*		

Drosanthemum sp.																				*
Euclea schimperi											*									
Euphorbia sp.		*																		
Fagara capensis											*		*							
Hermannia sp.																*				
Jasminum angulare										*										
Kedrostis nana var.														*	*			*		*
schlechteri																				*
Lampranthus coccineus																				*
Liliaceae (sp.indet.)																	*	*	*	
Maytenus undata										*										
Mesembryanthemaceae (sp.indet.)						*		*												
Panicum deustum	*		*		*	*	*	*	*	*	*	*		*	*	*		*	*	*
Pelargonium lateripes												*								
Ruschia sp.																			*	
Schkuhria sp.						*														
Scilla ebracteata		*	*	*						*			*		*	*	*	*		*
Senecio radicans																				*
Senecio sp.					*															*
Solanum sp.					*															
Stipa dregeana	*		*	*	*	*		*	*			*	*	*						
Viscum rotundifolium					*		*						*				*		*	

Sansevieria aethiopica and *S. hyacinthoides* could not readily be distinguished in the veld and their combined mass was recorded. The same applies to *Commelina africana* and *C. benghalensis* (Table 3).

Portulacaria afra and *Sansevieria* spp. occurred in all plots.

A further 11 species occurred on more than half of the plots: *Asparagus racemosus, Azima tetracantha, Capparis sepiaria* var. *citrifolia, Commelina* spp., *Crassula perforata, Euclea undulata, Maytenus heterophylla, Panicum deustum, Rhoicissus digitata, Sarcostemma viminale* and *Schotia afra.*

The total biomass/plot and the mass/plot of *Portulacaria afra, Schotia afra, Azima tetracantha* and *Capparis sepiaria* var. *citrifolia* were subjected to an analysis of variance to determine any significant differences in the vegetation within and outside the elephant camp. The only significant difference was in total biomass/plot ($p < 0,05$). Within the elephant camp the average mass/plot of *P. afra, S. afra* and *A. tetracantha* declined and that of *C. sepiaria* var. *citrifolia* increased, compared with the same species outside the elephant camp (Table 4).

Table 4

Mean plant biomass/plot (kg) in and outside the elephant camp

	Mean plant biomass/plot (kg)		
	Outside	Inside	F Value
Total plant biomass	367,9	170,4	*7,002
Portulacaria afra	260,2	116,9	3,80
Schotia afra	41,6	18,0	1,82
Azima tetracantha	9,8	3,9	1,45
Capparis sepiaria. var. citrifolia	12,1	18,1	0,48
Euclea undulata	15,3	7,9	–
Sansevieria spp.	4,4	4,5	–

*$p < 0,05$

There was an average of 21,2 species/plot outside and 20,6 species/plot within the elephant camp. This difference is statistically insignificant ($0,5 > p > 0,25$).

Discussion

At all sampling points the total biomass/plot within the elephant camp was less than that outside, except at point 5 where it was 157 kg outside and 180 kg within the elephant camp. At points 1, 2 and 3 the total biomass/plot within the elephant camp was considerably less than half of that outside. The biomass/plot of individual species varied greatly (Table 4) and although there was a tendency towards lower biomass/plot within the camp, the differences were not statistically significant.

The average total biomass/plot within the elephant camp was only 45 per cent of that outside, which indicates a severe reduction of the vegetation within the camp (Fig. 5). The amount eaten by the elephants therefore exceeded regeneration.

Fig. 5. Aerial photograph illustrating the condition of the vegetation inside the elephant camp.

A. Food preferences of the elephant

The average mass/plot of *Portulacaria afra, Schotia afra, Azima tetracantha* and *Euclea undulata* respectively within the elephant camp were less than half of the value outside (Table 4). However, *Capparis sepiaria* var. *citrifolia* showed an average increase of 50 per cent within the elephant camp, while the values for *Sansevieria* spp. remained virtually constant (Table 4). This indicates that *P. afra, S. afra, E. undulata* and *A. tetracantha* are utilized extensively by the elephants, whilst *C. sepiaria* var. *citrifolia* is avoided. *Sansevieria* spp. may also be avoided, but may be a minor food species.

Portulacaria afra is the most important food species in the elephant camp. Archibald (1955) found that two faeces samples collected in the Spekboomveld consisted of 37 per cent and 62 per cent *P. afra* respectively. In 1835 Pringle called *P. afra* in this area: " . . . . favourite food of the elephant . . . . " (Pringle 1966).

Capparis sepiaria var. *citrifolia* is a woody, thorny shrub with leathery leaves and may be avoided by the elephants for this reason. Archibald states that the roots of *C. sepiaria* var. *citrifolia* are eaten by the elephant. If this is the case, the results of this survey indicate that it either occurs to a very limited degree or that its effects are minimal.

Azima tetracantha is also a thorny shrub and it was therefore not expected to be a major food species. Archibald did not regard it as such. Van der Schijff (1959) mentions *A. tetracantha* as a food species of elephant in the Kruger National Park. Field (1971) demonstrated that *A. tetracantha* is an important food species in the Queen Elizabeth National Park (now Rwenzori National Park) in Uganda and that it comprised up to 36 per cent of the diet of elephants in the short grass-thicket region. Minerals (silica-free ash) were consistently high in *Azima* leaves and this may have contributed to its palatability.

The constant average mass/plot of *Sansevieria* spp. within and outside the camp indicate that they are probably not major food species. However, Archibald states: "Individual species that contribute most to the elephant diet are *Portulacaria afra* and *Sansevieria thyrsiflora* (sic) . . . . ". In his study Field found that *S. dawei* was one of the minor food species. Dougall and Sheldrick (1964) state that *S. ehrenbergii* is eaten by elephant in the Tsavo National Park in Kenya, but they regard it as of minor importance only. Buss (1961) found that *Sansevieria* and *Aloe* combined represented less than 2 per cent of the stomach contents of 71 elephants in the Murchison Falls National Park (now Kabalega National Park) in Uganda. However, 10–30 per cent of the stomach contents of four bulls destroyed near the Weiga River in the same Park consisted of *Aloe* and *Sansevieria*. Buss states: "It is widely believed that elephant chew the leaves of aloe and sansevieria for moisture, spitting out the masticated fiber in balls . . . . George A. Petrides . . . informed me that these discarded 'chews' were common in the Northern Frontier District of Kenya where it is very dry. It appeared that the leaf material eaten by the four Weiga River bulls had not been chewed more than the other food materials in their stomachs, and at the many sites I observed on the Butiaba Flats where elephants had fed on these plants, I found no masticated fibrous balls that suggested this type of feeding. Since there was no shortage of water . . . there was no necessity for these bulls to eat the aloe and sansevieria for the moisture only". The sufficient drinking water available in the elephant camp at Addo and the succulent nature of *Portulacaria afra,* the major food species, probably obviate the necessity of eating *Sansevieria* spp. for their moisture content.

Aloe africana was recorded in five of the plots outside the elephant camp, but in none of the plots within the camp and although *A. africana* is fairly common in the Spekboomveld outside the camp, no specimens were noticed within the camp. This indicates that this aloe is readily eaten by the elephants.

Viscum rotundifolium was recorded in five plots, all outside the elephant camp, which may indicate that it is a preferred species. However, the host plant may be the preferred species and the *V. rotundifolium* may not necessarily be sought after.

Panicum deustum was recorded in eight plots outside and eight within and *Stipa dregeana* in five plots outside and five within the elephant camp. Nowhere did the mass/plot exceed 1 kg and grass is therefore a minimal proportion of the diet of the elephants. Where sufficient grass is available, it is an important source of food. Archibald found that in the Bontveld in the Park the faeces of elephants consisted of 50–75 per cent grass. In his study in Uganda, Field found that grasses and sedges comprised 31–74 per cent of the diet in the short grass-thicket region, while in the tall-grass region it was 45–93 per cent. Buss found that grass was present in 99 per cent of the 71 stomachs he investigated and that it comprised 25–100 per cent of the mass. Napier Bax and Sheldrick (1963) regard grass as an important part of the diet in the Tsavo National Park in Kenya. Van Wyk and Fairall (1969) state that preliminary observations in the Kruger National Park indicate that grass comprises *c* 50 per cent of the diet of elephant.

Laws (1970) also regards the optimum diet as consisting of about 50 per cent grass and states: " . . ... and increasing proportion of grass in the diet is correlated with an increasing degree of habitat change from bush or woodland to grassland, poorer condition as measured by kidney fat indices or the height-weight relationship (Laws, Parker and Johnstone 1970), and increasing extent of population regulatory mechanisms such as delayed maturity and longer calving interval (Laws 1969). It is inferred that while grass is probably essential to provide bulk cellulose for energy, the protein requirements of such a coarse feeder, especially in the dry season when the fibre content of the whole grass plant is high, can only be met by browse and herbs. The optimum diet probably includes no more than 50% grass except at the beginning of the wet season when the protein content of grasses is known to be higher, the remainder browse and herbs".

B. Influence of the elephant on the vegetation

Archibald wrote in 1955: "At present the only conspicuous signs of deterioration of vegetation in the park are to be seen around bore-holes, where constant rubbing and trampling prevent even the spekboom from regenerating".

The results of the present survey indicate that conspicuous changes in the vegetation have already occurred after 17–18 years of intensive and continuous utilization by the elephant. Not only has the total biomass decreased considerably, but the composition of the vegetation is changing by the reduction of the food species *Portulacaria afra, Schotia afra, Euclea undulata* and *Azima tetracantha,* while *Capparis sepiaria* var. *citrifolia* is increasing. *Aloe africana* no longer occurs within the elephant camp.

The population of 62 elephants in the camp represented a density of 2,7 elephants/km^2, which is high in comparison to other parks.

Petrides and Swank (1965) state that elephants require a relatively small amount of nutrients per unit body mass and Pienaar, van Wyk and Fairall (1966) state: "Because of limited food requirements per unit biomass of elephants, there is a danger of overuse and damage to the range if these animals are replaced by an equal biomass of smaller herbivores which have greater caloric-intake requirements per unit of weight. It seems safe to assume therefore that án optimum carrying capacity figure for any given range in terms of elephant biomass would already (grossly) exceed the safe carrying capacity of the same range for an equal biomass of any smaller grazing or browsing species or group of species."

Reports from various parks indicate that elephant can have a profound influence on the vegetation.

Buechner and Dawkins (1961), indicate that luxuriant wooded grasslands, *Terminalia* woodlands, *Cynometra* rainforests and riparian forests in the Kabalega National Park, Uganda, are in the process of conversion to treeless grassland through the combined action of elephant and fire. The basic cause of these changes seems to lie in an extraordinary increase in the population of elephant. In an area of 4 000 km^2 which included the section of the park south of the Victoria Nile, the average number of elephant was 7 000–8 000, the lowest count being 4 414 and the highest 12 389 (Buechner, Buss, Longhurst and Brooks 1963), giving an average population density of *c* 2 elephants/km^2.

Laws *et al* (1970) also studied the elephant population and vegetation in this area and concluded that the damage described by Buechner *et al* had increased. The elephant population density of 2,9 elephant/km^2 had been reduced to 2,7 elephant/km^2 by 1967, but Laws *et al* conclude: "The analysis of the elephant populations indicates that they are at densities in excess of the carrying capacities of the habitat . . . . ". This Park has an annual precipitation of 1 000–1 250 mm (Buechner *et al*).

Wing and Buss (1970) studied the influence of the elephant on the Kibale Forest Reserve, Uganda, an area of 550 km^2 with an average annual precipitation of 1 500 mm. The population density is about one elephant per km^2 and the authors conclude: "Probably the elephants influence the species composition considerably with their marked preference for certain species and apparent distaste for others. However, the elephant surely are a long way from overusing the forest habitat when only about 20% of all the trees and large shrubs in it show some degree of usage."

In the Ruwenzori National Park, Uganda, with an area of 1 979 km^2 and an annual precipitation of 600–1 200 mm, the elephant population fluctuates between 2 250 in the dry season and 3 000 in the wet season (Field 1971), the corresponding population densities being 1,1 elephant/km^2 and 1,5 elephant/km^2 respectively. Field states: "Studies of woodland dynamics show a decline in the large trees which corresponds to the increase in elephant. In some cases trees have been almost eliminated. Damage to trees indicates that a most important factor in their decline is the elephant. There is some evidence that the trees are eliminated selectively".

Elephant returned to the Serengeti National Park, Tanzania, in the late 1950's after an absence of decades (Lamprey, Glover, Turner and Bell 1967). There are two distinct populations in the Park: a northern population with a density of 0,3 elephant/km^2 and a southern population with a density of 0,1 elephant/km^2 which both remained stable during 1962–68 (Watson and Bell 1969). In the northern section elephant damage was confined to large *Acacia* and *Commiphora* trees, while in the southern section *Acacia xanthophloea* trees along the Seronera River were being destroyed at an estimated average rate of 7 per cent/annum. The average annual precipitation in the Serengeti National Park is *c* 800 mm (Schaller 1972).

In the Lake Manyara National Park, Tanzania, an area of 90 km^2 with an average annual precipitation of 750 mm and an elephant population density of 5 elephant/km^2, the damage by elephants is mainly confined to the *Acacia tortilis* woodlands which occupy about 10 per cent of the Park. In two transects the annual mortality of *A. tortilis* averaged 5 per cent and 8 per cent respectively, 95 per cent of the mortality being caused by elephants (Douglas-Hamilton, cited by Laws, 1970). "If the current trend continues at the same rate there will be no living trees in 15 years at the most. However, the rate of damage can be expected to accelerate progressively in time and temporarily in drought years . . . . " (Laws 1970).

Savidge (1968) describes the situation in the Ruaha National Park, Tanzania, an area of *c* 13 000 km^2 with an average annual precipitation of *c* 500 millimetres. Since 1964 "It became apparent that elephants were damaging the trees and other woody vegetation, particularly in areas adjacent to permanent water. This damage . . . has now reached a stage where the continuation of any tree cover is doubtful in extensive areas . . . " (Savidge 1968). Baobabs (*Adansonia digitata*) are also being destroyed and Savidge states: " . . . . as most of this damage has occurred in the last two years, if damage continues at the same rate for another six years, the eastern riverine strip of the park will be devoid of baobabs".

Censuses conducted in 1965/66 reveal that: "the density of elephants over 12 consecutive months never fall below 1,2 per square mile (=0,5/km^2 B.L.P) and for five months of that time was over three per square mile (=1,2/km^2). As these densities were contemporaneous with much of the damage to trees done by elephants in the same area, saturation level of elephants is now known for Ruaha conditions" (Savidge 1968).

In the Tsavo National Park (East), Kenya, *Commiphora-Acacia* woodland is changing to dry grassland due to over-utilization by elephant. (Glover 1963). This Park has an area of *c* 13 000 km^2 and a with scattered large trees. In recent years, however, the bush along the rivers and in some large areas has been destroyed and in its place there are now extensive regions of dryland grasses . . . . The damage has been caused by the overcrowding of elephant near the few permanent rivers and has been maintained and aggravated by great fires . . . ". Napier Bax and Sheldrick (1963) draw the same conclusions: "Most of the park was formerly covered by dense bush, but in the last five years, in some large regions, this has either been almost completely destroyed or else drastically thinned. The damage near the few permanent water supplies has been caused by elephant the rocky nature of the ground having excluded fires. On the eastern side of the park, however, fires . . . . have been the primary cause of loss of bush. Each year fires sweep further into the park and their damaging effect is increased owing to elephants having broken up the thickets".

The Tsavo National Park (East) has an average annual precipitation of less than 500 mm, being even less than 250 mm in the eastern section (Glover 1963). This Park has an area of c 13 000 km^2 and a semi-permanent elephant population of 7 000, but " . . . may be able to carry only some 5 000 elephants in reasonable safety" (Glover 1963), a density of *c* 0,4/km^2.

Sikes (1966) points out that the large elephant population is due to the provision of watering-points first during the construction of the Mombasa-Uganda Railway in the 1900's and recently by the Park authorities. However, the effective control of poaching since 1957 and the increased agricultural activities in the neighbouring areas were also important factors (Laws 1970).

Agnew (1968) states : "Destruction has apparently now ceased, and regeneration is in progress over sections of the park where a marked increase in shrub cover has been recorded in the past year". However, Laws (1970) states: "The relatively little quantitative information is complicated by climatic cycles. Thus Agnew's (1968) findings, based on very limited sampling, have been used to support the view that bush is increasing, though a temporary increase in the shrub cover might be expected at this stage in the rainfall cycle".

Concerning the Kruger National Park, van der Schijff (1957) states: "Olifante . . . oefen 'n belangrike invloed op plantgemeenskappe uit. . . . Onder natuurlike toestande verrig hulle . . . egter 'n belangrike en noodsaaklike funksie. Deur die vernietiging van die ondergroei en die omstoot van bome verhoed hulle dat die bos te dig word. Hierdeur word nie alleen die groei van die gras gestimuleer nie, maar ook die aard van die dieregemeenskap wat in die bepaalde gebied sal voorkom, bepaal. . . . Die droë, dooie bome en takke vorm uiteindelik ook eilande vanwaar nuttige grassoorte en ondergroei gedurende goeie jare weer kan versprei.

Dit wil egter voorkom asof die aktiwiteite van olifante in die Krugerwildtuin abnormale afmetings begin aanneem. Die maatstaf vir 'n gunstige olifant-plantegroeiverhouding is geleë in die invloed wat hierdie diere op skaarser boomsoorte uitoefen en nie so seer hulle invloed op die volop soorte nie. Waar seldsame boomsoorte soos *Anthocleistia zambesiaca* (die boskoorsboom) wat deur die eeue heen, in die aanwesigheid van olifante, hulle self kon handhaaf nou skielik in gevaar is om, soos by Shipudza die geval is, deur olifante heeltemal uitgeroei te word, is dit 'n aanduiding dat die verhouding tussen olifante en plantegroei ongunstige afmetings begin aanneem".

Van Wyk and Fairall (1969) studied the situation in the Kruger National Park when the elephant population was only 2 400. They found the worst damage to the vegetation in the areas utilized by elephant during the dry season. The elephant density in those areas was 0,24/km^2. In the Pafuri area of 65 km^2. the only area regarded as overutilized, the elephant population of 86 (Pienaar *et al*) represented a density of 1,3/km^2. Van Wyk and Fairall conclude: ". . . . the highest number of elephants which could be carried in the park, would be 0,75 animals/sq. mile (=0,3/km^2, B.L.P.), if the total destruction of vulnerable areas near water is not to result". The mean annual precipitation in the Park is *c* 500 mm (van Wyk *et al*).

Of the examples mentioned, Kabalega National Park is probably capable of supporting the greatest elephant population density, being primarily luxuriant wooded grasslands with a high annual precipitation; yet Buechner *et al* regard 2 elephants/km^2 high enough to cause changes in the vegetation.

In the Tsavo National Park (East), an area with a low precipitation, Glover regards 0,4 elephant/km^2 as a "safe" population. In the Kruger National Park, also with a low precipitation, van Wyk *et al* regard 0,3 elephant/km^2 as a realistic figure.

In the Addo Elephant National Park the average annual precipitation is *c* 440 mm (Table 4), which is rather similar to the condition in the Kruger National Park and the Tsavo National Park (East). However, while the recommended elephant densities in those two Parks are 0,4 and 0,3 elephant/km^2 respectively, the population density in the elephant camp at Addo has already reached 2,7/km^2 – nine times the density regarded as realistic in the Kruger National Park.

When the Armstrong Fence was completed in 1954, the elephant population in the camp represented a density of 0,8/km^2. On the basis of food requirements of the elephant, Archibald recommended that the population density should not exceed 0,4/km^2. If this is accepted as the criterion for the Park, and evidence from elsewhere tends to support this, the elephant density in the camp was already double what could be termed a realistic level when the camp was completed. The present situation can only be regarded as critical.

Archibald recommended in 1955: ". . . . the enclosure of the elephants in any section of the park should be regarded only as a temporary measure to prevent further annoyance to farmers and also indiscriminate shooting of the elephants. The reasons for this recommendation are that not only does an area of 2 000 to 3 000 morgen of spekboomveld contain insufficient food to support the Addo herd indefinitely, but that the animals require a change of diet and should not be confined to any one plant community. The ultimate objects should be (1) to add judiciously to the area of the park by including such types of plant communities as are not well represented within its present boundaries and which provide useful sources of food for the elephants and other animals, and (2) to erect an elephant-proof fence around the entire reserve".

At present the Armstrong Fence is being extended to enclose the entire Park, which will virtually treble the area accessible to the elephants. If a density of $0{,}3/km^2$ is accepted as reasonable, however, the elephant population of the entire Park should not exceed 30 if damage to the vegetation is not to ensue. The present population is already more than double that figure.

The only two alternative management policies suggested are:

1. Reduction by more than half of the present elephant population and its stabilization at that level; or
2. Substantial enlargement of the Park, preferably to enclose a fair percentage of Bontveld and Mixed Shrub and Grassveld.

Summary

1. After 17–18 years of continuous and intensive utilization by an increasing elephant population, the vegetation in the elephant camp has deteriorated alarmingly: the total biomass has been reduced by more than half and the biomass of the main food species *Portulacaria afra, Schotia afra, Euclea undulata* and *Azima tetracantha* show a downward trend, while the biomass of *Capparis sepiaria* var. *citrifolia* is increasing.
2. *Aloe africana* which is relatively common in the Spekboomveld no longer occurs in the elephant camp.
3. The results of this study and evidence from other parks indicate that a density of 0,4 elephant/km^2 could be regarded as reasonable under local conditions. This indicates that the Park could not support more than 30 elephants without damage to the vegetation.

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