Review article

Distribution and status of the African elephant *Loxodonta africana* in South Africa, 1652-1992

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Hall-Martin, A.J. 1992. Distribution and status of the African elephant *Loxodonta africana* in South Africa, 1652-1992. *Koedoe* 35(1): 65-88. Pretoria. ISSN 0075-6458.

The historical decline of African elephants to a low of 120 animals in 1920, and their subsequent recovery to over 10 000 is described for the major populations of South Africa. Population growth rates of 6,8 % and 6,7 % per annum are derived from census and estimates for the Kruger National Park and the Addo Elephant National Park respectively. The reasons for elephant population control in the Kruger National Park, and the impact of elephants on both the Kruger and Addo environments, are discussed. The translocation of young elephants to found new populations is mentioned. The consequent increase of elephant range and numbers in the next decade to a possible maximum of 31 000 km^2 and 13 000 animals, is envisaged.

Key words: African elephant, *Loxodonta africana*, population density, translocation, culling, census, ivory trade.

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Introduction

The decline in the continental population of the African elephant *Loxodonta africana* over the past decade (Douglas-Hamilton 1989) has elicited grave concern in many quarters. The status of the African elephant, and the role of the ivory trade in its demise, was a major issue at both the 7th (Lausanne) and 8th (Kyoto) Conferences of the Parties to CITES. In South Africa, however, the species has shown a steady increase since reaching a dangerously low level in 1920 (Hall-Martin 1980). This review oulines the population growth of elephants in South Africa since 1920, the management of elephant populations, and highlights the translocation of young elephants to establish new populations as a means of ensuring a continuing increase in elephant range and numbers.

Historical overview of elephant numbers and distribution

The recorded distribution of elephants in South Africa begins with a report of their occurrence at Mossel Bay on the Cape south coast by Vasco da Gama, a Portuguese navigator in 1497 (Skead 1980). The continuous record of modern history of South Africa, however, dates from 1652. In that year a provisioning station for ships sailing from Europe to the East Indies was established by the Dutch East India Company in Table Bay, later known as Cape Town. At that time elephants occupied much of the territory (Fig.1) later to become South Africa (Skead 1980, 1987; Smithers 1983).

The arid central Karoo plains, Bushmanland and the Kalahari are, however, unlikely to have supported large or permanently resident populations. The historical record shows lit-

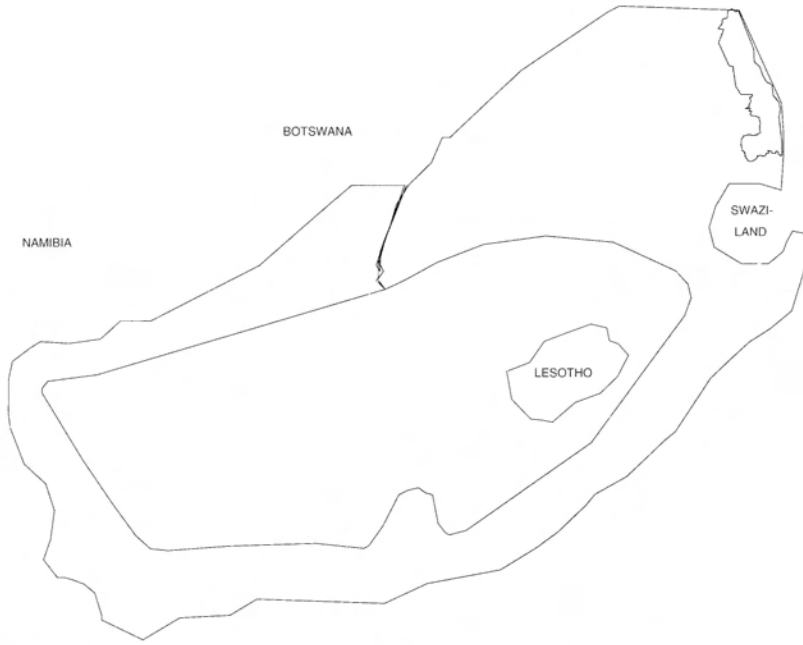

Fig. 1. Schematic distribution of the African elephant in South Africa ca. 1650 (location of the Kruger National Park is shown in outline)

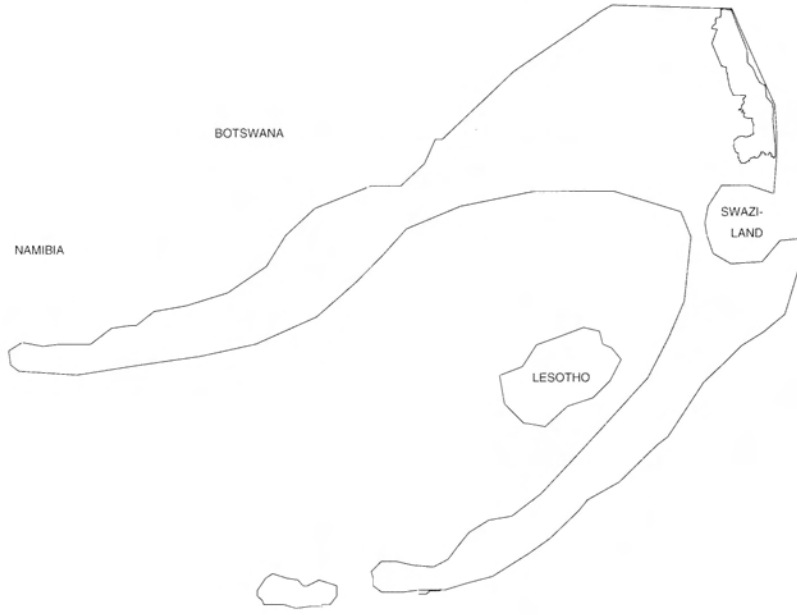

Fig. 2. Approximate distribution of the African elephant in South Africa ca. 1800.

Fig.3. Distribution of the African elephant in South Africa ca. 1920.

Fig. 4. Distribution of the African elephant in South Africa, 1991 (A and B indicate regions where many small, translocated populations occur on privately owned land).

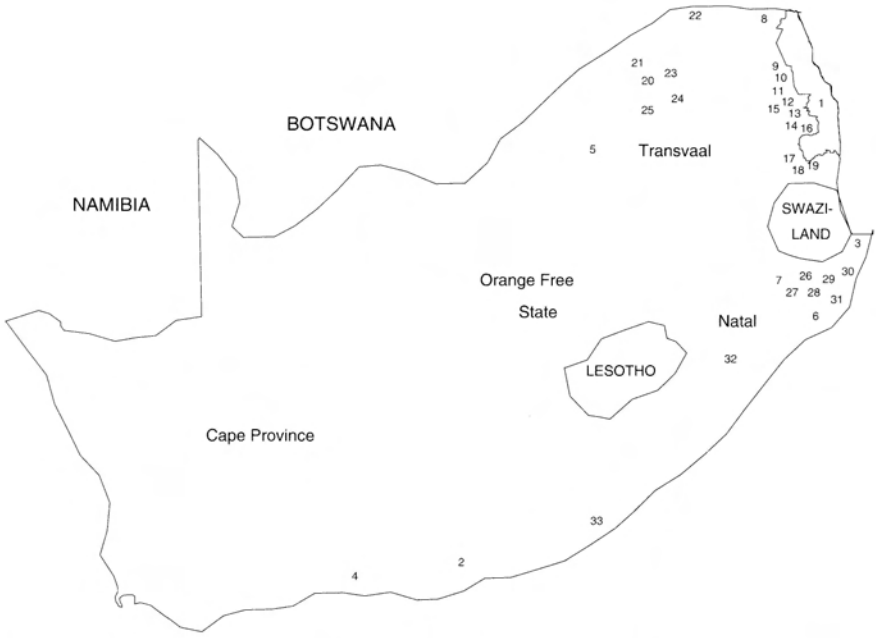

Fig. 5. Localities of all natural and translocated African elephant population in South Africa, June 1991.

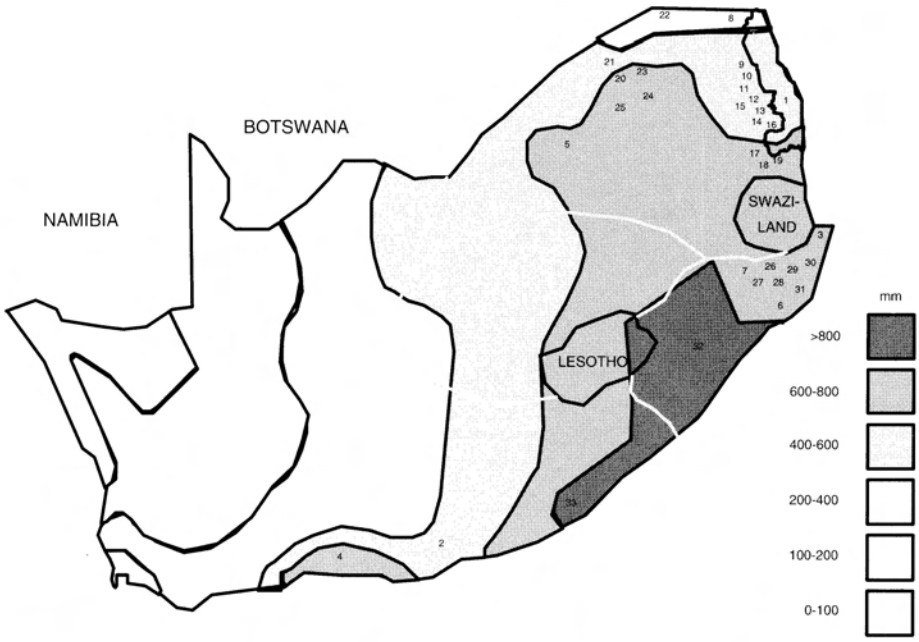

Fig. 6. The distribution of African elephants in South Africa in 1991 relative to generalised mean annual rainfall isohyets.

tle evidence that the grasslands of the interior, now known as the Highveld of the Orange Free State and southern Transvaal were particularly rich in elephants either. The savanna and woodland regions of the Transvaal and the high rainfall areas on the East Coast as far south as the Cape of Good Hope, however, supported large elephant populations (Smithers 1983).

No reliable estimate has ever been made of the numbers of elephants which may have existed in South Africa, but it is quite likely to have been of the order of 100 000 animals before 1652. The decline in the South African elephant population took place in three phases. Between the years 1652 and 1790 the decline of the species was largely caused by the increase in settlement and human population growth, with the ivory trade playing only a small part. The onset of this process of elephant decline was commented upon early in the historical record by Kolbe in 1731 and Mentzel in 1787 (Skead 1980), and is reflected in Fig. 2. From about 1790 to 1870 the main force eliminating elephants was the growth of the ivory trade and the emergence of professional ivory hunters on a large scale (Skead 1987). These hunters operated as far north as the Zambezi Valley and their ivory was moved southwards to the ports of Durban and Port Elizabeth. By about 1870 the large elephant populations had been wiped out. From 1870 to 1920 the shooting of elephants was due, in large measure, to crop protection, especially in the eastern Cape where the Provincial authorities attempted to exterminate the last large elephant population at Addo in 1920 (Stokes 1941; Hall-Martin 1980). Crop protection mortality was still the major cause of the continuing decline of elephants in the Tembe area until as recently as 1983 (Bosman & Hall-Martin 1986).

As a result of development, the ivory trade, and crop protection, the distribution of elephants was reduced to four remnant populations permanently resident within the borders of the country. These reached their lowest numbers in 1920 (Stevenson-Hamilton 1947; Hall-Martin 1980) when there were about 120 animals. The remnant populations were at Knysna on the Cape south coast, Addo in the Eastern Cape Province near Port Elizabeth, the Sihangwane (Tembe) area of northern Natal, and the Olifants Gorge area of the eastern Transvaal in an area which was proclaimed a game reserve in 1898 and in 1926 became the Kruger National Park (Fig.3).

Present distribution of elephants in South Africa

The four remnant elephant populations of South Africa occupied a range of no more than 100 000 ha in total in 1920. Since then elephant distribution has changed dramatically as numbers and populations increased due to conservation and management practices initiated by the National Parks Board. The Board's elephant conservation policy is based on protection, management, utilisation and translocation. Between 1979 and 1991 new populations of elephants were established by the translocation of 388 young elephants, largely from the Kruger National Park, to areas where the species had earlier been exterminated (Table 1). By 1991 the elephant range of South Africa had grown to about 2,6 million ha. (Fig.4), and elephants were to be found in 33 discrete populations or ranges (Fig.5). Two small populations (18 animals) were also established in Swaziland and one population in Namibia through translocations from the Kruger National Park (Hall-Martin 1992). Over 93 % of translocated calves survived, and stable reproducing populations have been created.

The present distribution of elephants in South Africa in relation to rainfall is shown in Fig.6, and the actual size of each range is given in Table 1. All new elephant populations have been established within the historical range of the species; most translocated populations occur in areas of above 600 mm mean annual rainfall. The new populations in the 400-600 mm rainfall regime have mostly been established naturally by emmigration from the Kruger National Park. The absence of elephants above the 800 mm rainfall isohyet, with the exception of Knysna, is due to these higher rainfall areas on the east coast having the highest human population density and

high agricultural potential. The exclusion of elephants here is to some extent a further example of the fundamental competition for the best habitat between man and elephants — as seen also in other areas in Africa (e.g. Parker & Graham 1989).

The total elephant range of South Africa in 1991 (25 893 km^2) comprises about 2,1 % of the total surface area of the country. Most of the available occupied elephant range (75 %) in South Africa is accounted for by the Kruger National Park which also accounts for 85 % of the country's elephants. The other ranges are either state-owned with different legal status (13 %) or privately owned (12%).

The difference between the above figure for elephant range in South Africa and that quoted by Douglas- Hamilton (1989) is largely due to the translocation of elephants to several game reserves and privately owned ranches in 1990 and 1991 (Table 1). In sharp contrast to the Pan-African trend where elephant numbers and range are shrinking (Douglas-Hamilton 1989; Parker & Graham 1989; Caughley *et al.* 1990) the range available to elephants under legal protection and secure management in South Africa has increased by 274 300 ha (11 %) under State control, and by 119 430 ha (5 %) in private ownership since 1979.

Elephant numbers and trends

The status of the major elephant populations in South Africa is determined annually during the dry season by means of a total count carried out by helicopter in the Addo Elephant and Kruger national parks and either helicopter or fixed-wing aircraft on private reserves (Dublin 1989). In the case of the Kruger National Park there is a mean 1,4 % variation from year to year between the expected and actual count which can be attributed to census technique, weather and other factors. The census at Addo Elephant National Park is more precise (as virtually all animals in the population are individually known). The number of elephants in Tembe, which is a mosaic of forest and dense woodland where aerial counts are not successful, are estimated on the basis of known animals, evidence of movements from tracks and droppings and helicopter counts. In the smaller, recently established elephant populations numbers are determined from aerial census, the known numbers of animals translocated and known mortalities.

The estimates and counts quoted range over the period August 1990 to June 1991. Because the census work is carried out as routine operations in the national parks and on some of the private nature reserves, no detailed descriptions of the procedures followed have been published recently in the formal literature. However, internal reports (e.g. Ostrosky 1988a; Whyte 1990) are produced for every census carried out. The earlier surveys carried out in the Kruger National Park were, however, published (Pienaar *et al.* 1966).

The status and potential maximum size of the present populations of African elephant in South Africa — under management regimes similar to that of the Kruger National Park — are shown in Table 1.

Kruger National Park (KNP)

Estimates of the numbers of elephants in Kruger were made at irregular intervals between 1903 and 1964 (Table 2). During the early years the Park Warden Col. James Stevenson-Hamilton made estimates on the basis of known herds and individually known groups of bulls. By the 1950s rough road counts together with estimates or 'guesses' were being used. The first aerial survey, using a fixed-wing aircraft and covering only part of the park was carried out in 1960 (Pienaar *et al.* 1966). The first comprehensive total count by helicopter of elephant and buffalo was carried out in 1967 and has been repeated every year since with the exception of 1979 when insufficient funds were available. The census totals for the period 1967-1980 can be found in Hall-Martin (1984). All totals for the period 1967-1990 are included in Whyte (1990).

The Kruger National Park elephant and buffalo count was carried out from 1967 to 1973

Table 1
Current elephant status in South Africa (1990/1991)

Region	Map No.[1]	Area (km^2)	% Area	Pop^n Estimate	% Pop^n	Density (km^{-2})	Max Pop^n [2]
National Parks							
Kruger NP	1	19 485	75,60	7 278	84,73	0.38	7 500
Addo Elephant NP	2	87	0,34	162	1,89	1,84	220
Subtotal		**19 572**	**75,94**	**7 440**	**86,61**	**0,38**	**7 720**
National parks or game reserves							
(proclaimed under legislation of independent or self-governing states within South Arica)							
Tembe Elephant Park	3	299	1,16	80	0,93	0,27	119
Pilanesberg NP	5	580	2,25	41	0,48	0,07	174
Letaba Ranch	9	400	1,55	31	0,36	0,07	120
Manyeleti GR	14	27	0,10	10	0,12	0,04	86
Makuya NP	8	185	0,72	40	0,47	0,22	65
Mthethomusha GR	17	80	0,31	8	0,09	0,10	30
Andover GR	13	71	0,28	10	0,12	0,14	27
Subtotal		**1 642**	**6,37**	**220**	**2,56**	**0,12**	**621**
Provincial Game Reserves							
Hluhluwe/Umfolozi GR	6	900	3,49	146	1,70	0,16	360
Itala GR	7	300	1,17	23	0,27	0,08	120
Subtotal		**1 200**	**4,66**	**169**	**1,97**	**0,14**	**480**
Forestry Reserves							
Knysna Forest	4	300	1,17	4	0,05	0,01	30
Subtotal		**300**	**1,17**	**4**	**0,05**	**0,01**	**30**
Private Nature Reserves							
Klarerie Private NR	11	628	2,44	395	4,60	0,63	238
Timbavati Private NR	12	785	3,05	190	2,21	0,24	297
Tshukudu Game Ranch	15	50	0,19	2	0,02	0,04	19
Sabi-Sand GR	16	572	2,22	60	0,70	0,11	217
Kwalata Game Ranch	20	80	0,31	7	0,08	0,09	30
Phinda Resource Res.	31	135	0,52	20	0,23	0,15	54
Venetia Mine	22	350	1,36	5	0,05	0,02	105
Rhinoland Safaris	21	68	0,26	6	0,06	0,09	25
Touchstone Game Ranch	23	75	0,29	10	0,12	0,13	26
Vosdal Game Ranch	24	115	0,45	3	0,03	0,03	34
Mabula Lodge	25	80	0,31	8	0,09	0,10	24
Subtotal		**2 938**	**11,40**	**706**	**8,22**	**0,28**	**1 069**
Other privately owned land (< 50 km^2)							
Phalaborwa Mining Co.	10	41	0,16	14	0,16	0,34	14
Mtibi Game Ranch	18	25	0,10	3	0,03	0,12	10
Lowhills	19	30	0,12	3	0,03	0,10	11
Welcome Game Ranch	26	21	0,08	5	0,06	0,23	8
Mahlatini Game Ranch	27	15	0,06	5	0,06	0,33	6
Rietboklaagte	28	25	0,10	3	0,03	0,12	10
Sutton Game Ranch	29	20	0,08	4	0,04	0,20	8
Pumalanga	30	25	0,10	3	0,03	0,12	10
Karkloof Falls Safari Park	32	14	0,05	2	0,02	0,14	11
Mpongo Park	33	25	0,10	8	0,09	0,32	37
Subtotal		**241**	**0,96**	**50**	**0,58**	**0,21**	**125**
Total		25 893		8 589		0,33	10 045

[1] For reserve location refer to map numbers indicated in Figure 5
[2] Estimated maximum sustainable population given the available land resources in 1991

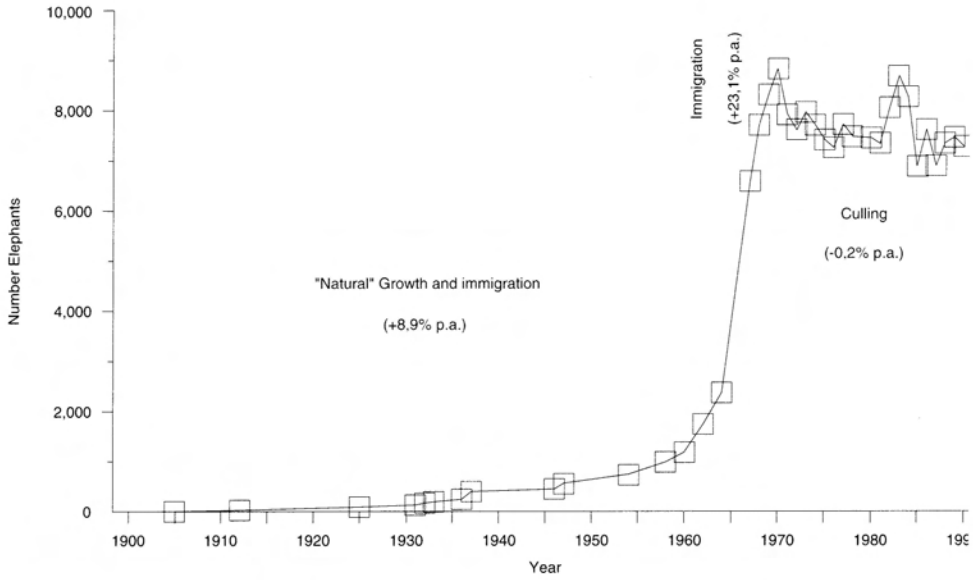

Fig. 7. Trend of the African elephant population in the Kruger National Park, 1900-1990.

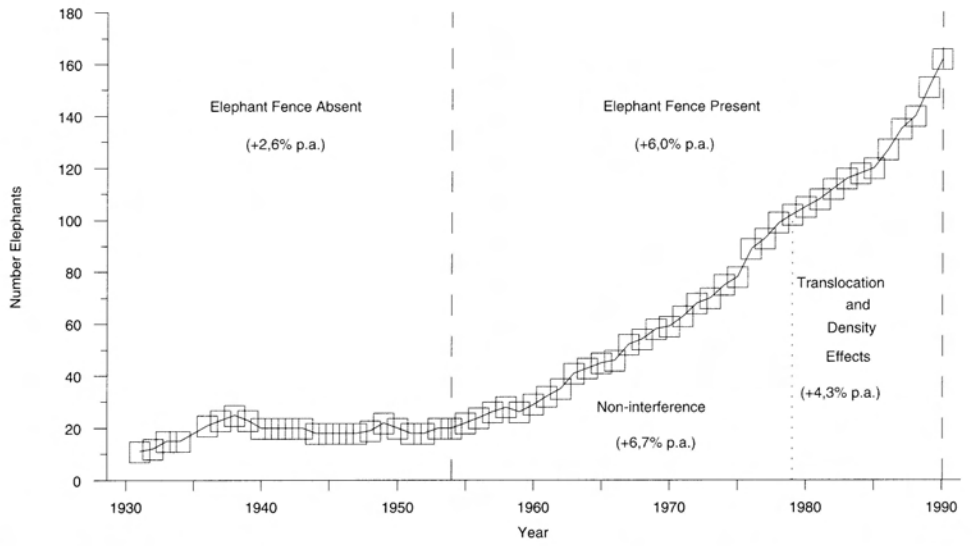

Fig. 8. Trend of the African elephant population in the Addo Elephant National Park, 1930-1990. Three phases characterised by no perimeter fence, non-interference, and translocation and musth-related mortality in males are indicated.

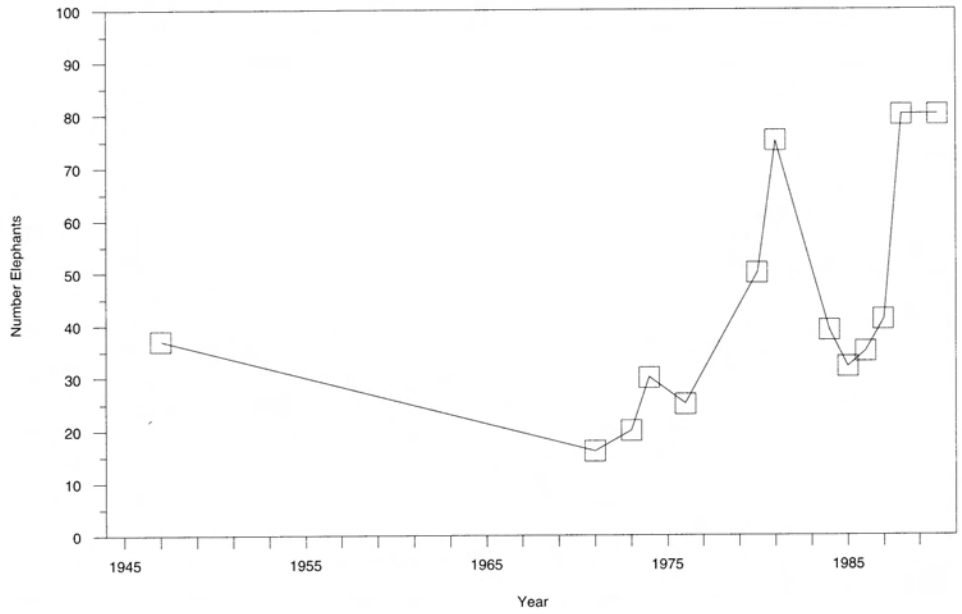

Fig. 9. Trend of the African elephant population in the Tembe Elephant Park, 1945-1990.

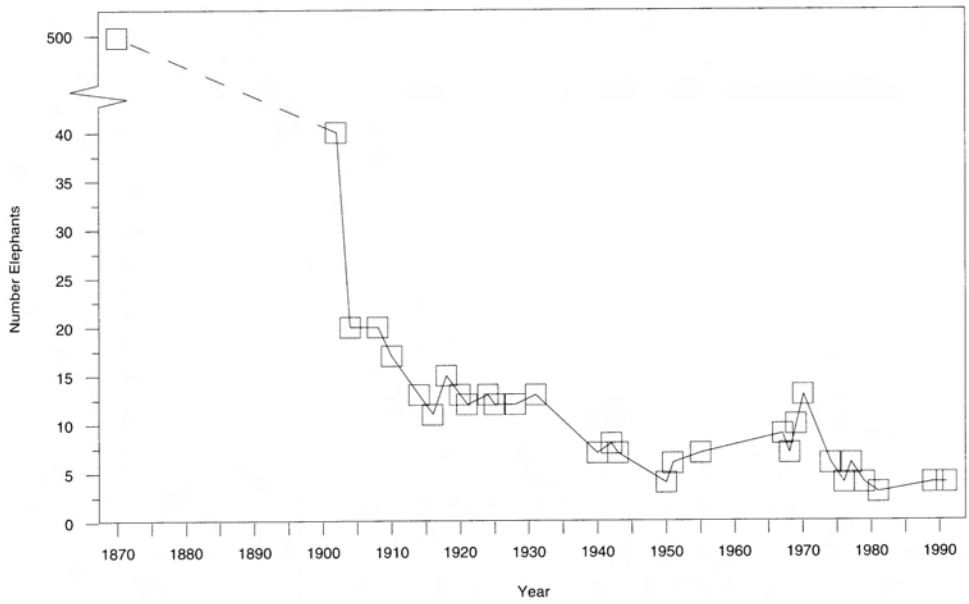

Fig. 10. Trend of the African elephant population in the Knysna Forest, 1870-1990.

Table 2
Estimates of elephant numbers in the Kruger National Park 1903-1990

Year	Number	Nature of Estimate	Source
1903	0	Local knowledge	Stevenson-Hamilton 1903a, 1903b
1905	10	Local knowledge	Stevenson-Hamilton 1905
1912	25	Estimate	Stevenson-Hamilton 1912
1925	100	Estimate	Stevenson-Hamilton 1925
1931	135	Estimate	Pienaar, Van Wyk & Fairall 1966
1932	170	Estimate	Stevenson-Hamilton 1932
1933	200	Estimate	Stevenson-Hamilton 1933
1936	250	Estimate	Stevenson-Hamilton 1936
1937	400	Estimate	Stevenson-Hamilton 1937
1946	450	Estimate	Sandenbergh 1946
1947	560	Estimate	Pienaar, Van Wyk & Fairall 1966
1954	740	Estimate	Steyn 1958
1958	995	Estimate	Pienaar, Van Wyk & Fairall 1966
1960	1186	Aerial survey	Pienaar, Van Wyk & Fairall 1966
1962	1750	Fixed-wing survey	Pienaar 1963
1964	2374	Helicopter count *	Pienaar, Van Wyk & Fairall 1966
1967	6586	Helicopter count *	Cited in Hall-Martin 1984
1968	7701	Helicopter count *	Cited in Hall-Martin 1984
1969	8312	Helicopter count *	Cited in Hall-Martin 1984
1970	8821	Helicopter count *	Cited in Hall-Martin 1984
1971	7916	Helicopter count *	Cited in Hall-Martin 1984
1972	7611	Helicopter count *	Cited in Hall-Martin 1984
1973	7965	Helicopter count *	Cited in Hall-Martin 1984
1974	7702	Helicopter count †	Cited in Hall-Martin 1984
1975	7408	Helicopter count †	Cited in Hall-Martin 1984
1976	7257	Helicopter count †	Cited in Hall-Martin 1984
1977	7715	Helicopter count †	Cited in Hall-Martin 1984
1978	7478	Helicopter count †	Cited in Hall-Martin 1984
1979	No census		
1980	7454	Helicopter count †	Cited in Hall-Martin 1984
1981	7343	Helicopter count †	Cited in Whyte 1990
1982	8051	Helicopter count †	Cited in Whyte 1990
1983	8678	Helicopter count †	Cited in Whyte 1990
1984	8273	Helicopter count †	Cited in Whyte 1990
1985	6887	Helicopter count †	Cited in Whyte 1990
1986	7617	Helicopter count †	Cited in Whyte 1990
1987	6898	Helicopter count †	Cited in Whyte 1990
1988	7344	Helicopter count †	Cited in Whyte 1990
1989	7468	Helicopter count †	Cited in Whyte 1990
1990	7278	Helicopter count †	Cited in Whyte 1990

* Census using Bell G47 helicopter
† Census using Bell Jet Ranger helicopter

using a Bell 47 helicopter, and from 1974 onwards using a Bell Jet Ranger 206 B helicopter. The pilot is accompanied by a navigator/observer who sits left front, and two observers in the rear seats. The helicopter flies at a height of 600-800′ above ground, and at a speed of 90-100 mph. The census takes 18 days to complete and the total flying time is 125 hours with two pilots taking turns. This flying time includes time taken for placement (i.e. base to point where census begins and return to base) and time spent circling over both elephant and buffalo herds during the count. The flight path is traced on a map (1:100 000) of the park and follows all visible drainage lines; these are usually indicated by denser, taller riverine vegetation. The aircraft is usually positioned midway between the watercourse and the watershed . Where the riverine fringing vegetation is par-

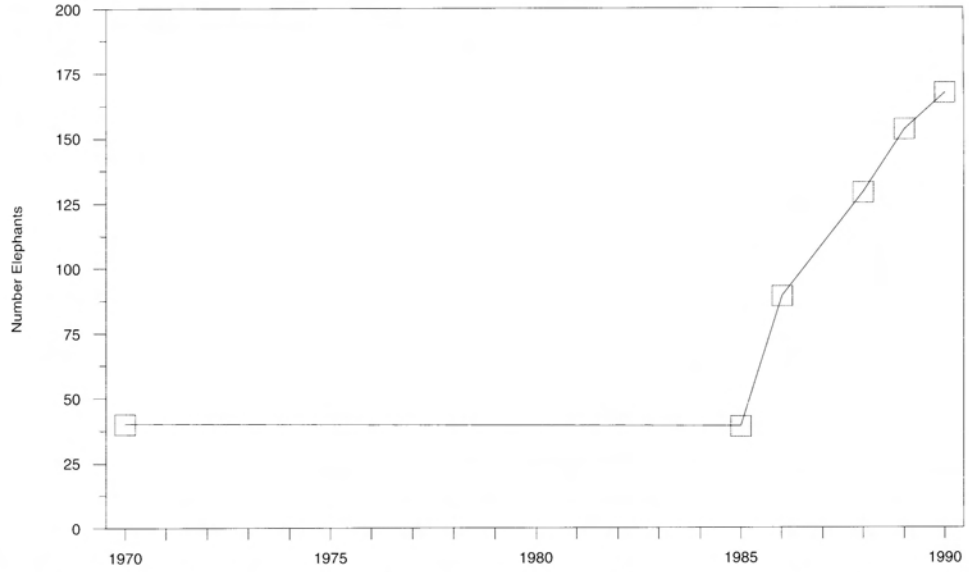

Fig. 11. Trend of the African elephant population in the Timbavati Private Nature Reserve, 1970 - 1990.

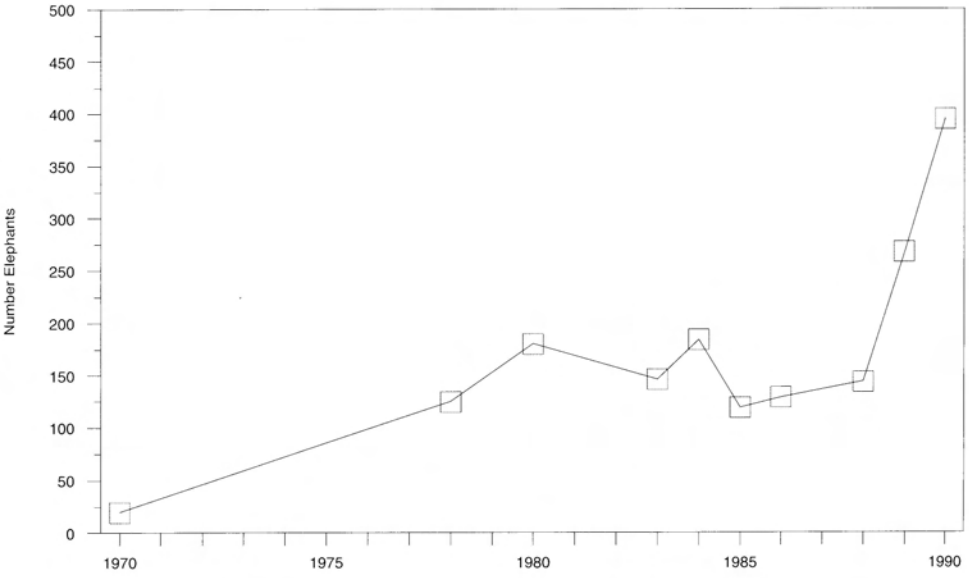

Fig. 12. Trend of the African elephant population in the Klaserie Private Nature Reserve, 1970 - 1990.

Table 3
A comparison between the observed and expected elephant census totals for the KNP (1982 - 1990)

Year	Exp	Obs	Dev (O-E)	%
82	7 890	8 051	161	2,0
83	9 061	8 678	-383	-4,4
84	7 619	8 273	654	7,9
85	7 192	6 887	-305	-4,4
86	7 114	7 617	503	6,6
87	7 270	6 898	-372	-5,4
88	6 824	7 344	520	7,1
89	7 208	7 468	260	3,5
90	7 266	7 278	12	0,2
Mean				1,4

ticularly well developed, or dense enough to hide elephants, the flight path on either the outward or inward leg is set closer to the drainage line. At the top of the drainage line a wide sweep is flown to the watershed to check not only that there are no elephants inthe drainage area counted, but also no elephants close to the watershed in adjoining drainage basins. Such groups are possible candidates to leave the counting area overnight by crossing a watershed and so their position and group composition is mapped and monitored on subsequent flights as well. Because the census is carried out at the height of the dry season, it takes advantage of elephant daily movements. The animals tend to spend the cold winter nights on the watersheds to escape cold air drainage, and they wander down to water in the drainage line during the course of the morning as it warms up, to drink.

Elephant herds can be seen 3-5 km away depending upon the height and density of vegetation. On open plains even solitary bulls can be spotted at distances of 5 km and further. Breeding herds are circled at heights of 100-200′ and while they are counted, calves thought to be less than one year old are recorded. Such calves are easy to distinguish up to about 6 months of age on size and the overlap of the pinnae on the head. Young calves are still hairy, older ones have a more "polished" look. The final basis of calf classification depends upon the experience of the observer. In the case of the 1990 census the average length of service in the park of the observers was 20 years per man and that of the pilots was 16 years per man. The pilots also contribute towards the estimate of the age of a calf but the final decision is left to one nominated observer throughout the duration of the count. The pilots, however, are also expert at estimating ages of calves because they are involved in the selection for capture of up to 140 calves, 2-4 years old, per year. The position of all elephants counted is plotted on a map.

The method has been unchanged since 1967 and results should therefore be comparable. The accuracy of the KNP annual elephant census can be assessed by comparing the number of elephant counted with the expected census total for the same year. The expected census total is calculated by adding the number of calves born since the previous survey, to the previous year's total and subtracting the number of animals culled during the year:

Expected total = previous year's total + calves born - cull

Both the expected and observed census totals from 1982 to 1990 are presented in Table 3. The difference between the two sets of totals for the nine year period is not significant ($X^2 = 85{,}955$; $df = 8$; $p < 0{,}0001$) and the percentage deviation varies from 0,2 % to 7,9 % ($X = 1{,}4$ %).

The variation in the calf crop from year to year (as estimated from the air) can be explained by rainfall during the year of conception and is presumably linked to the body condition of the cows. The relationship between the calf crop counted in any year was shown by Hall-Martin *et al.* 1987 to be described by the expression :
$y = 1{,}403 + 0{,}048$ ($r = 0{,}7748$) where y is the calf percentage and x is the rainfall of the year of conception as a percentage of the long-

Table 4
Numbers of elephant in the Addo Elephant National Park 1931-1990 [1]

Year	Number	Year	Number
1931	11	1961	32
1932	12	1962	35
1933	15	1963	41
1934	15	1964	43
1935	18	1965	45
1936	21	1966	46
1937	23	1967	52
1938	25	1968	54
1939	23	1969	58
1940	20	1970	59
1941	20	1970	59
1942	20	1972	68
1943	20	1973	70
1944	18	1974	75
1945	18	1975	78
1946	18	1976	89
1947	18	1977	93
1948	22	1978	99
1949	22	1979	102
1950	20	1980	105
1951	18	1981	108
1952	18	1982	112
1953	20	1983	116
1954	22	1984	118
1955	22	1985	120
1956	24	1986	127
1957	26	1987	135
1958	28	1988	140
1959	26	1989	151
1960	29	1990	162

[1] Individually known population from 1931 and from 1978 an annual helicopter census as well

term mean rainfall. This is another indication of the consistency of the methods used and the results obtained.

An indication of the reliability of the Kruger National Park census and the increasing trend of the population can be derived from the fact that the population has been kept fairly stable at around 7 500 animals over a period of 24 years during which time nearly 13 000 elephants have been culled in the park (Hall-Martin 1991a). Immigration of elephants into the park cannot be invoked as an explanation as the park has been fenced off from Mozambique (the main historical source of immigrant elephants) since 1974 (Hall-Martin 1991a). The long-term mean calf crop (percentage of less than one-year-old calves counted in each annual census) is 6,2 % per annum or 476 calves per year. The mean number of elephants culled per year since 1974 (when immigration was effectively ended) is 517 animals. Numbers estimated as born in the park each year (476) can thus be safely revised upwards to at least 517. This reflects an actual increment of 6,8 % per annum of the mean population of 7 642 animals (Hall-Martin 1991a) after natural mortality. Alternatively the observed calf crop could be a lower percentage of an elephant population which is larger than 7 500 animals. Either way these figures indicate a good degree of consistency from year to year.

The elephant population estimates for Kruger are plotted in Fig. 7 and the rate of change is indicated for the period 1900-1960 as 8,9 % which is a reflection of recruitment, immigration and possibly inaccurate early estimates. From 1960-1970 the increase was 23,1 % per annum which is accounted for by recruitment, immigration due to heavy hunting pressure and drought in Mozambique and the implementation of regular, repeatable, accurate censussing. The overall trend 1970-1990 is a decline of 0,2 % per annum which for all practical purposes represents a stable population. A decline of this magnitude could be turned into an increase simply by relaxing the cull in any year, or a bumper calf crop. The variation in estimated calf crops (2,7-11,0 %) indicates that a good crop could easily change this trend.

Addo Elephant National Park (AENP)

Since 1976 the elephant population has been intensively studied and most of the animals are individually known (Hall-Martin 1980). Nevertheless the elephants are counted routinely during the annual game census (eg. Hall-Martin 1991 b) which is done using a Bell Jet Ranger 206 B III Helicopter following parallel flight paths within clearly defined counting blocks or areas. The height above ground, speed and strip width is adapted according to density of vegetation, light conditions and terrain. In general the AENP census is flown at 35-50 mph (ground speed) at about

50-100′ above ground and flight paths are 200-300 m apart. This census is designed for black rhinoceros counting which require a low-flying aircraft to flush them in the dense thicket vegetation. All rhino are known and marked (Hall-Martin 1986) and the accuracy of the count can be monitored. The elephant count is also checked against known animals, and known births and deaths during the year.

The trend of the AENP elephant population from 1931 to 1990 (Table 4) is shown graphically in Fig. 8. From 1930 to 1954 the overall rate of increase was only 2,6 % per annum. This was largely because the elephants left the park regularly to raid crops or to feed on prickly pear (*Opuntia* sp.), and were shot. Only after the completion of the Armstrong fence in 1954 which confined the elephants to the park, was a more positive recruitment rate possible. The rate of increase between 1954 and 1979 when there was no interference with the population was 6,7 % per annum (Fig. 8). The higher rate of increase of 7 % per annum which was quoted by Hall-Martin (1980) was based on a 1954 population of 18 animals and not the 20 as found from subsequent checking of records. This high rate of increase has been tempered in recent years by increasing mortalities among sub-adult males killed by bulls in musth (Hall-Martin 1987) and the disturbance by the translocation of 5 animals to Pilanesberg in 1979. The high mortality recorded (over 6 % of the population was killed between 1977 and 1989) may well be related to the high density and the limited range in the park. This has been slightly alleviated by the recent purchase of land by the Rhino and Elephant Foundation, the Southern African Nature Foundation and the State which has increased the park area by 34 % (Hall-Martin 1991c).

Tembe Elephant Park

The data on the Tembe elephant population is summarised in Table 5 and Fig. 9. The early estimates are guesses based on local knowledge. The figure for 1975 was derived from a helicopter survey and intensive tracking and observation on the ground (e.g. Bosman & Hall-Martin 1986). There were reports of breeding herds in the area in the 1940s, 1954 and 1971 (Ostrosky 1988b) and again in 1973 (Thomson 1978). During 1975/76 intensive reconnaissance found evidence only of bulls and no breeding herds of elephant in the Tembe area (Hall-Martin 1980). All sightings, droppings and spoor records were of bulls. After the 1975 change of government in Mozambique heavy poaching of elephants and illegal settlement in the Maputo Elephant Reserve caused a movement of elephants southwards across the border into South Africa. These immigrants included breeding herds (Klingelhoeffer 1987). In recent years the estimates of numbers of the Tembe elephants have been based on aerial reconnaissance and sightings of known individuals documented by means of a photo-file (Ostrosky 1988b). The apparent decline between 1978 and 1986 is due to the figures being based on minimum helicopter counts (Fig. 9). Later estimates are helicopter counts supplemented by photo-file records.

The Tembe elephant population has been stable because of poaching mortality affecting these animals when they crossed the international border to Mozambique (Bosman & Hall-Martin 1986; Ostrosky 1988a). During the dry season of 1989 the border was sealed with an elephant-proof electrified fence which has stopped elephant movements. This population should now also show a similar rate of increase to other protected populations in South Africa.

Knysna Forest

The only elephant population in South Africa with a less than encouraging recent history is the remnant population in the Knysna Forest. The decline of this population from 1876 - 1981 is shown in Table 6 and Fig.10. In the past these elephants have been a low management priority for the forestry authorities and no specific management or protection action has ever been taken to benefit them (Hall-Martin 1980). Suggestions have also been made that the present range of the population is not adequate elephant habitat (Hall-Martin 1980; Koen *et al.* 1988) but other observers have placed the blame for the decline of this

population on poaching and crop protection shooting by smallholders (Carter 1970). The low point was reached in 1981 when only three elephants — an old bull, an adult cow and a calf could be accounted for (Koen 1981). Recent reports have however confirmed the birth of a calf during early 1989 indicating a slight recovery in the population. To assist this hopeful trend the Minister of Water Affairs and Forestry recently (June 1991) took a decision to start a process of elephant introductions to Knysna. The first two calves in this programme are scheduled to be moved during early 1992 from the Kruger National Park.

Lowveld Private Nature Reserves

The largest elephant populations on private land are those in the Klaserie and Timbavati private nature reserves (Tables 7 and 8). The Transvaal Directorate of Nature and Environmental Conservation carries out an annual aerial census of elephants in these reserves. The population data are plotted in Figs. 11 (Timbavati) and 12 (Klaserie). The fluctuations are most likely explained by movements across the boundary into the Kruger National Park and back again. Such movements by radio-collared animals are well known to researchers in the area. The decline in elephant numbers in Klaserie (Fig.12) after the 1984 drought when many animals moved back into the Kruger National Park is clearly indicated.

Translocated populations

The translocated populations are all stable or increasing slowly as they are mostly too young to breed and they are all far below ecological carrying capacity. The first calf of parents translocated as calves was born in November 1989 in the Pilanesberg National Park. The parents are a bull translocated from Addo at the age of 3-4 years and a cow translocated from the KNP at about 3 years of age. At the time of conception of the calf the bull was about 12-13 years old and the cow was 10 years old. By late 1991 a further five calves were reported in Pilanesberg and three calves born to translocated parents in Natal were reported from Hluhluwe/Umfolozi Game Reserve (Hall-Martin 1992).

Several of the translocated populations represent pioneer groups which will be added to in the future to achieve a more natural age structure of the population over time. The value of the transplanted populations on private land to elephant conservation is not yet significant. This is because most privately-owned ranges are too small to support viable populations in the long-term (Table 1). This problem may well be overcome by the 'conservancy' concept where adjoining landowners are encouraged to take down their fences so as to allow free range to game within the conservancy area.

Elephant population density and carrying capacity

Crude elephant population densities on South African elephant ranges vary from 0,01 elephants/km^2 in Knysna to 1,84 in Addo (Table 1). With the exception of Addo Elephant and Kruger national parks, the elephant populations are still well below estimated carrying capacities of about 0,35 elephants/km^2 in summer rainfall savanna habitats of South Africa. This carrying capacity is determined by the management criteria as applied in the Kruger National Park and is an overall density (Joubert 1986). However, local densities over substantial areas may vary from 0,28 - 0,42 km^2 and may be maintained for periods of several years between culling reductions of populations in particular areas (e.g. Hall-Martin *et al.* 1987). The population size and density recorded for the established populations of Timbavati and Klaserie can be influenced by immigration and emigration — both these reserves adjoin the Kruger National Park and there is a regular two-way movement of elephants. The impact on the habitat can therefore also be intensified at times.

In the Addo Elephant National Park the current population of 162 elephants is at the estimated carrying capacity of the presently fenced area of the park which is 8 767 ha and can support around 2,0 elephants /km^2. The recent land purchases have increased the size

Table 5
Estimates of elephant numbers in the Tembe Elephant Park, Sihangwane area, 1947-1991

Year	Number	Nature of Estimate	Source
1947	35-40	Estimate - local knowledge	A.I. Ferraz and H.C. Lugg *In* :Bruton, Smith & Taylor 1980
1971	16	Estimate	T.P. Dutton *In:* Ostrosky 1988b
1973	15-25	Estimate	Anonymous 1978
1974	20-40	Estimate and aerial survey	Thomson 1978
1976	20-30	Helicopter survey and ground tracking	Hall-Martin 1977
1980	50	Fixed-wing survey and photography	A.J. Hall-Martin *In*: Rautenbach, Skinner and Nel 1980
1981	75	Estimate	Klingelhoeffer 1987
1984	39	Minimum helicopter count	Ostrosky 1988b
1985	32	Minimum helicopter count	Ostrosky 1988b
1986	35	Minimum helicopter count	Ostrosky 1988b
1987	41	Minimum helicopter count	Ostrosky 1988b
1988	80	Minimum helicopter count and known individuals - photo file	Ostrosky 1988b
1990	80	Minimum helicopter count and known individuals - photo file	E.W. Ostrosky 1991 *pers. comm.*

of the park to 11 708 ha. This land will soon be incorporated into the elephant range and lower the effective elephant density to 1,38 elephants/km^2. The higher carrying capacity at Addo is determined by a different climatic system, with almost year round rainfall, and the nature of the vegetation which is a dense, succulent, evergreen thicket (Hall-Martin 1980; Hall-Martin *et al.* 1982). The carrying capacity of Mpongo Park (a private animal park) is also likely to be much higher than the estimate for the drier parts of the country as it is a similar environment to Addo.

Long-term trends

As far as can be predicted, the management policies followed towards elephants in national parks and game reserves in South Africa will ensure ecological stability. Whether this will result in long-term loss of ecological resilience within the system remains to be seen. The damping down of ecological permutations will, however, ensure that more time is won to better understand ecological processes before elephants are allowed, if ever, to have an overpowering impact on the environment.

New elephant habitats

There are several national parks and game reserves (Table 9) with habitat suitable for elephants, which when fenced to a suitable elephant-proof standard, will be restocked. These areas will add a further 563 984 ha to the national elephant range with a carrying capacity estimated at over 2 000 elephants at crude population densities approximately those of equivalent areas. The extent of land in private ownership which is also potentially available for elephants is likely to be less than this, and in smaller, fenced, holdings with less viable populations. The potentially available privately-owned land could accommodate a further 1 000 elephants at crude population densities of around 0,3 - 0,4 elephants per km^2. The potential maximum elephant population for South Africa, therefore, (Table 1 and 9) is about 13 000 animals, or about 2,1 % of the current continental African elephant population.

Elephant management issues

The wildlife management philosophy which has evolved in South Africa has proved to be successful for species as well as for ecosys-

Table 6
Estimates of elephant numbers in the Knysna Forest, 1876-1990

Year	Number	Nature of Estimate	Source
1876	400-500	Estimate of Capt. Harrison, Conservator of Forests	Phillips 1925
1902	30-50	Forestry Dept. Records	Dommisse 1951
1904	20	Forestry Dept. Records	Dommisse 1951
1908	20	Forestry Dept. Records	Dommisse 1951
1910	17	Forestry Dept. Records	Dommisse 1951
1914	13	Forestry Dept. Records	Dommisse 1951
1916	10-12	Forestry Dept. Records	Koen 1981
1918	15-16	Forestry Dept. Records	Koen 1981
1920	13	Record less 5 killed by Maj. Pretorius	Hall-Martin 1980
1921	12	Forestry Dept. Records	Koen 1981
1924	13	Observations of individuals	Phillips 1925
1925	12	Observations of individuals	Phillips 1925
1928	10-13	Observations of individuals	Burton 1968
1931	13	Forestry Dept. Records	Koen 1981
1940	7	Forestry Dept. Records	Roberts 1951
1942	8	Forestry Dept. Records	Roberts 1951
1943	7	Forestry Dept. Records	Roberts 1951
1950	4	Bernard Carp Expedition	Koen 1981
1951	4-8	Forestry Dept. Records	Dommisse 1951
1955	7	Fraser Expedition	Koen 1981
1967	7-11	Forestry Dept. Records	Burton 1968
1968	7	Individuals identified	Keeping, Smuts & David 1968
1969	10	Individuals identified	Carter 1970
1970	13	Forestry Dept. Records	Koen 1981
1974	6	Forestry Dept. Records	Koen 1981
1976	4	Forestry Dept. Records	Koen 1981
1977	6	Forestry Dept. Records	Koen 1981
1979	4	Forestry Dept. Records	Koen 1981
1981	3	Forestry Dept. Records	Koen 1981
1989	4	Birth of calf - press release	*Die Burger* Cape Town 1989.02.24
1991	4	Forestry Dept. Records	G. von dem Bussche, *Pers. comm.*

Table 7
Estimates of elephant numbers in the Klaserie Private Nature Reserve, Eastern Transvaal, 1970-1990

Year	Number	Nature of Estimate	Source
1970	20	Local knowledge	*Research report P.C. Viljoen
1978	125	Aerial census	Research report P.C. Viljoen
1980	180	Aerial census	Research report P.C. Viljoen
1983	146	Aerial census	Research report P.C. Viljoen
1984	184	Aerial census	Research report P.C. Viljoen
1985	119	Helicopter census	Research report P.J. de Villiers
1988	144	Helicopter census	Research report P.J. de Villiers
1989	268	Helicopter census	Research report P.J. de Villiers
1990	395	Helicopter census	Research report P.J. de Villiers

* All research reports are official documents of the Chief Directorate of Nature and Environmental Conservation of the Transvaal Provincial Administration, Pretoria

tems. The basic ingredients are security and a necessary degree of adaptive manipulation of and development of the ecosystem. National parks are fenced, water supplies are maintained, fire is controlled and the numbers of animals (depending upon the species and habitat type involved) are carefully controlled. Management objectives are clearly defined and aimed at the maintenance of biological diversity. In the case of the Addo Elephant National Park the increase in elephant numbers, and consequent impact on the habitat, has been countered by increasing the size of the park. It is hoped that this process can continue for at least the next decade during which land adjoining the park can still be purchased. In the case of the Kruger National Park the ecological impact of an increasing elephant population cannot be alleviated by providing more range, and elephant impact is seen as conflicting with the broader aims of environmental management within the park.

The policy of the National Parks Board of controlling elephant numbers rests on the maintenance of biological diversity as a prime objective of conservation. Any process, such as the impact of an over-abundant elephant population which could impair habitat quality by bringing about large scale rapid vegetation change as has been documented elsewhere in Africa (Laws 1970) as well as in the KNP, is therefore incompatible with basic management objectives (Joubert 1986). The elephant population is, therefore, culled to maintain it at a level which can be carried through drought years without detrimentally affecting the habitat (Hall-Martin 1984). In reality this means limiting the elephant population to 7 000-7 500 animals or a crude population density of about 0,35-0,37 elephants per km^2 (Hall-Martin 1984). The implementation of this policy has resulted in nearly 13 000 elephants being culled in the park since 1967.

The rationale for elephant population control in the Kruger National Park is based on a considerable body of scientific research and a serious weighing of *laissez faire* options against adaptive manipulative management. The impact of elephants on their habitat in the Kruger National Park has been well studied (Pienaar *et al.* 1966; Pienaar 1969; van Wyk & Fairall 1969; Coetzee *et al.* 1979; Engelbrecht 1979; Hall-Martin 1984; Viljoen 1988). The ecological, philosophical and practical considerations governing the policy of controlling elephant numbers in the KNP have been comprehensively reviewed and argued by Pienaar (1969, 1983). The deleterious effect that a large elephant population has on the dynamics of plant communities, individual species of woody plants, water supplies and interactions with other animal species as well as the effects of drought have all been considered (Pienaar 1983; Hall-Martin 1984). In this regard it should be recognised that the rainfall of the area is low by world standards and subject to regular cycles of below and above average rainfall (Gertenbach 1980). The volume of water flowing into the system from outside the park boundaries is also declining due to increased water utilisation by urban developments, industry and agriculture in the catchment areas of the major perennial rivers feeding the park (Pienaar 1985). An increasing elephant population has also been shown to compete for food and limited water supplies with what are considered rare species in the Kruger National Park such as sable *Hippotragus niger*, roan *H. equinus*, tsessebe *Damaliscus lunatus* and eland *Taurotragus oryx* (Pienaar 1969).

Furthermore, the Kruger National Park now supports growing populations of both white rhinoceros *Ceratotherium simum* and the black rhinoceros *Diceros bicornis minor*, both CITES Appendix 1 species which are potentially sensitive to competition for grazing, browse and water with an overabundant elephant population. The numbers of white (1 500) and black (210) rhinoceros in the park, the present rate of increase of 6 % - 9 % for white and 9.0 % for black (Hall-Martin 1986), and the potential carrying capacity of the park for these species makes the Kruger National Park at present the single most important rhinoceros sanctuary in Africa. It is important, therefore, to ensure suitable habitat for these endangered species by controlling the numbers of elephants in the park so

Table 8
Estimates of elephant numbers in the Timbavati Private Nature Reserve, Eastern Transvaal, 1970-1990

Year	Number	Nature of Estimate	Source
1970	40	Local knowledge	*Research report P.J. de Villiers
1985	39	Helicopter census	Research report P.J. de Villiers
1986	89	Helicopter census	Research report P.J. de Villiers
1988	129	Helicopter census	Research report P.J. de Villiers
1989	153	Helicopter census	Research report P.J. de Villiers
1990	167	Helicopter census	Research report P.J. de Villiers

* All research reports are official documents of the Chief Directorate of Nature and Environmental Conservation of the Transvaal Provincial Administration, Pretoria

as to avoid the mortality seen elsewhere among black rhinoceros when excessive numbers of elephants and drought destroyed their habitat (Corfield 1973; Cobb 1980; Parker 1983).

While the culling of elephants in the Kruger National Park is clearly a sustainable use of a wildlife resource, the economic benefits derived from the culling played no role whatsoever in the motivation for elephant population control. It is, however, fortunate that the culling operations, for strict management purposes, can be carried out profitably. The gross income derived from the sale of elephant products over the five year period 1985-1989 (when 1788 elephants were culled) averages US$ 1,4 million per year (Hall-Martin 1990). The revenues accrue directly to the National Parks Board and help to offset the costs of security and management. The principle that the financial benefits accruing from culling should not influence the culling quotas within a national park is honoured by the National Parks Board. If the culling of elephants should not be required for ecological reasons, then the Board is committed to placing the processing depot on a care and maintenance basis until such time as it is required.

Studies on the impact of the Addo elephants on their habitat are under way (Barratt & Hall-Martin 1990). These studies have measured changes in the species composition, plant volume, biomass, density and height of the vegetation. Because the vegetation at Addo is a dense, low evergreen predominantly succulent thicket with many multi-stemmed shrubs making up most of the plant cover (Hall-Martin 1980) it is best studied by methods appoximating those described by Anderson & Walker (1974) and Walker (1976). The results of the studies at Addo will include recommendations for the enlargement of the park to accommodate the elephant population at a level where no degradation of the vegetation will be taking place. This is particularly important because Addo also supports a population of 25 black rhinoceros *Diceros bicornis michaeli* (the Kenya/N. Tanzania subspecies) whose dietary requirements show substantial overlap with the elephants. If the financial means to substantially enlarge the park cannot be found, then the culling of elephants in the future appears unavoidable.

In the Transvaal similar studies on the impact of elephants on their habitat outside the Kruger National Park are being conducted by scientists from the Hans Hoheisen Research Centre.

Elsewhere in South Africa elephant management issues are not nearly as important. A limited number of elephant bulls (usually around 10 animals) are shot by safari hunters

on privately owned or community owned land adjoining the western boundary of the Kruger National Park each year. These animals are from populations which are derived from and which are still in regular contact with the KNP population. They are part of a lucrative sport hunting industry which attracts foreign currency, enhances tourism, provides jobs and generally makes an economic contribution to areas neighbouring the park. This "feeding" of elephants into the local economy is just one of the many ways in which the Kruger National Park benefits adjoining communities.

The need for crop protection hunting of elephants in areas adjoining the park is to some extent controlled by the fences around the park. Nonetheless a few animals are shot each year in defence of cultivation. No compensation is paid by the park in accordance with the legal principle that such animals are not the property of the park if they are outside its boundaries. In the case of elephants shot on commercial land for crop protection purposes the community has received the benefit from the sale of the ivory and meat. A system has also been developed whereby crop-raiding elephants are shot by sport hunters who pay a fee for them, this maximises benefits to the community.

Policy and legislation

The African elephant enjoys legal protection in all jurisdictional entities in South Africa. The exact status in each area, and the penalties for infringing on the status of the species, vary somewhat at present. There is, however, an effort underway to ensure uniform penalties for the illegal killing of elephants, or the illegal possession of ivory or trade in ivory throughout the Republic's various jurisdictional areas. Penalties providing for fines of up to R100 000 (US$ 35 000) and/or 10 years imprisonment for the illegal hunting of elephants have been enacted in all four provinces and are also applicable to similar offences in national parks, and in areas under other forms of regional government.

Legislation also provides for all ivory in private and state possession to be registered and marked in accordance with CITES prescriptions. The registration of ivory in this way has been carried out since 1982. Regulations are also in preparation which will provide for mandatory fines of US$ 17 500 or 5 years imprisonment for failure to register ivory. Firearm possession is controlled by strictly enforced legislation and applications to purchase hunting rifles are particularly closely scrutinised. The current state of political flux in the country has, however, resulted in a dramatic increase in the numbers of firearms in illegal private ownership. This influx of weapons is primarily due to political violence but the free availibility of such weapons could potentially impact on wildlife populations. This seems to emphasise the need for a greater input into security of national parks and protected areas.

Hunting of specially protected animals like the African elephant is controlled by legislation and can only be done with a permit. Legal ownership of wildlife rests in the landowner, but the hunting, capture, keeping in captivity, transport of animals are all regulated by legislation. In general, South Africa has followed Western models based on Roman-Dutch law of environmental legislation. The country is also a member of various environmental regulatory treaties such as CITES. Public and NGO support for efforts to control illegal trade and exploitation of wildlife is further indicated by the recent establishment of a TRAFFIC office in South Africa.

Elephant management and the ivory trade.

South Africa holds a reservation against the decision of the 7th Conference of the Parties to CITES to list the African elephant in Appendix I. Despite this reservation South Africa placed a voluntary moratorium on the export of ivory after the Lausanne meeting which is still valid. This was a gesture of support to those countries that asked for a temporary pause in the ivory trade to give them a chance to get the situation under con-

Table 9
National parks and game reserves identified for elephant introduction in South Africa, 1992 - 2000

Area	Size (ha)	Potential Density Elephants /km^2	Potential elephant population
Zuurberg National Park	24 138	1,0	241
Kransberg National Park	30 000	0,3	90
Vaalbos National Park	22 696	0,25	57
Greater Tembe/Ndumo Elephant Park	45 103	0,25	113
Songimvelo Game Reserve	65 000	0,3	195
Greater St. Lucia Wetland Park	150 000	0,35	525
Mkuze Game Reserve	35 000	0,4	140
Andries Vosloo Kudu Reserve	17 000	1,0	170
Groendal Wilderness Area	25 047	1,0	250
Double Drift Nature Reserve	23 000	1,0	230
Madikwe Game Reserve	70 000	0,3	210
Molopo Game Park	8 000	0,25	20
Borakalalo Game Reserve	14 000	0,4	56
Botsalano Game Reserve	6 000	0,25	15
Loskop Dam Nature Reserve	16 000	0,3	48
Atherstone Nature Reserve	13 000	0,3	39
	563 984		2 399

trol. It is also an indication of South Africa's support for the attempts to effect better control of the ivory trade.

Nevertheless it remains the view of South Africa that its sale of ivory and other elephant products was a major contributor towards defraying the costs of elephant protection and conservation. It is hoped to resume ivory sales under strictly controlled conditions in the future. The ivory and other elephant products are a result of effective elephant management which has seen the culling of 13 000 surplus elephants over the past 24 years to protect the integrity of the habitat in the Kruger National Park. Elephant populations in South Africa are increasing steadily, some areas are overpopulated, there is no significant illegal hunting of elephants and there is no justification for regarding the South African elephant population as in any way under threat.

The Kruger National Park population has, however, lost 53 elephants (mostly bulls) since 1983. Of these, a total of 33 were killed since July 1989 when the ivory ban was implemented. No elephants have recently been poached in any of the other South African populations. Prices of illegal ivory in South

Africa are variable and there has been no indication in southern Africa that the illegal trade is dead. The ivory in the illegal trade originates from across South Africa's borders. There is no significant domestic market for ivory and all indications are that South Africa is used as a conduit for moving ivory to markets elsewhere. The effective transport infrastructure and the massive volume of goods moved in containers across South Africa's borders, provide an ideal means of moving ivory through the country. Detection of such shipments is virtually impossible without good intelligence. To this end, therefore, the Endangered Species Protection Unit of the South African Police has built up good links with other police agencies in southern Africa. This unit handled 56 cases between February 1989 and September 1991 involving 125 persons arrested, 282 rhinoceros horns and 334 elephant tusks confiscated. The units record of convictions is good.

Acknowledgements

My thanks are extended to David Barratt and Catherina Hall-Martin for assisting in gathering and co-ordinating the data, and to Petri Viljoen for his contributions on the Kruger National Park elephant census. I am also grateful to Kobie Rautenbach for substantial assistance in preparing this manuscript for publication.

References

ANONYMOUS. 1978. Statement to African Wildlife on the Tongaland elephants. KwaZulu Department of Agriculture and Forestry. *African Wildlife* 32(3): 43.

ANDERSON, G.D. and B.H. WALKER. 1974. Vegetation composition and elephant damage in the Sengwa Wildlife Research Area, Rhodesia. *Journal of the Southern African Wildlife Managment Association* 4(1): 1-14.

BARRATT, D.G. and A.J. HALL-MARTIN. 1990. The effect of indigenous browsers on Valley Bushveld Vegetation in the Addo Elephant National Park. Proceedings "Valley Bushveld Workshop, Thomas Baines Nature Reserve, CSIR.

BOSMAN, P. and A. HALL-MARTIN, 1986. *Elephants of Africa*. Cape Town: Struik.

BRUTON, M.N., M. SMITH and R.H. TAYLOR. 1980. A brief history of human involvement in Maputoland. Pp. 432-459. *In:* BRUTON, M.N. and K.H. COOPER. (eds.). *Studies on the Ecology of Maputoland*. Rhodes University Grahamstown and Wildlife Society Durban.

BURTON C.M. 1968. History of Elephants in the Eastern Cape. Appendix B, Knysna Elephant Symposium, Wildlife Society, Port Elizabeth.

CAUGHLEY,G., H. DUBLIN and I. PARKER. 1990. Projected decline of the African elephant. *Biological Conservation* 54: 157-164.

CARTER, N. 1970. Knysna Elephant Survey, February 1969 - January 1970. Wildlife Society of SA, Eastern Province Branch.

COBB, S. 1980. Tsavo national parks, their first thirty years. *Swara* 3(4): 12-16.

COETZEE, B.J., A.H. ENGELBRECHT, S.C.J. JOUBERT and P.F. RETIEF. 1979. Elephant impact on *Sclerocarya caffra* trees in *Acacia nigrescens* tropical plains thornveld of the Kruger National Park. *Koedoe* 22: 39-60.

CORFIELD, T.F. 1973. Elephant mortality in Tsavo East National Park, Kenya. *East African Wildlife Journal* 11(3&4): 339-368.

DOMMISSE, E.J. 1951. The Knysna elephants - historical sketch of a world-famous herd. *African Wildlife* 5(3): 195-199.

DOUGLAS-HAMILTON, I. 1989. Overview of status and trends of the African elephant. Report 1 *In*: COBB, S (ed.). *The Ivory Trade and the future of the African Elephant.* Oxford: Ivory Trade Review Group.

DUBLIN, H. 1989. Elephant numbers, distributions and trends in the Southern African region: A review of census methods and recent population data. Typescript 24 pp. EEC/WWF Elephant Programme.

ENGELBRECHT, A.H. 1979. Olifantinvloed op *Acacia nigrescens*-bome in 'n gedeelte van die Punda Milia-sandveld van die Nasionale Krugerwildtuin. *Koedoe* 22 : 29-37.

GERTENBACH, W.P.D. 1980. Rainfall patterns in the Kruger National Park. *Koedoe* 23: 35-44.

HALL-MARTIN, A.J. 1977. South African elephants - pattern for the future. *In*: WWF/IUCN Elephant Survey and Conservation Programme. Newsletter No 2.

HALL-MARTIN, A.J. 1980. Elephant survivors. *Oryx* XV (4) : 355-362.

HALL-MARTIN, A.J. 1984. Conservation and management of elephants in the Kruger National Park, South Africa. Pp 104-118. *In*: CUMMING, D.H. and P. JACKSON (eds.). *The Status and Conservation of Africa's Elephants and Rhino's*. Switzerland: IUCN.

HALL-MARTIN, A.J. 1986. Recruitment in a small black rhino population. *Pachyderm* 7: 6-8.

HALL-MARTIN, A.J. 1987. Role of musth in the reproductive strategy of the African elephant (*Loxodonta africana*) *South African Journal of Science* 83 : 616-620.

HALL-MARTIN, A.J. 1990. Elephant conservation in the Kruger National Park, South Africa. Pp. 89-112. *In: Regional Perspectives and situation Regarding Elephant Conservation and the Ivory Trade*. Background documents for Government of France, Ministers Meeting. Mimeo. IUCN, Gland.

HALL-MARTIN, A.J. 1991a. Elephant conservation in the Kruger National Park, South Africa — from protection to management. *In*: *Proceedings of the*

Kalahari Conservation Society Elephant Workshop. Gaberone: KCS.

HALL-MARTIN, A.J. 1991b. Report on the June 1991 game census in the Addo Elephant National Park. National Parks Board, Skukuza. Typescript.

HALL-MARTIN, A. 1991c. Adding to Addo. *Rhino and Elephant Journal* 5 : 18 - 20.

HALL-MARTIN, Anthony, 1992. Translocation and re-establishment of populations of juvenile African elephants. *African Wildlife Foundation: Elephant and Ivory Information Service* (20) (Special Issue, February): 1-5.

HALL-MARTIN, A.J., T. ERASMUS and B.P. BOTHA. 1982. Seasonal variation of diet and faeces composition of black rhinoceros *Diceros bicornis* in the Addo Elephant National Park. *Koedoe* 25: 63-82.

HALL-MARTIN, A.J., I.J. WHYTE and P.C. VILJOEN. 1987. Census results and culling quotas for the larger herbivore species in the Kruger National Park. National Parks Board, Skukuza. Typescript.

JOUBERT, S.C.J. 1986. Masterplan for the Management of the Kruger National Park. Vol. VI. Mimeo. National Parks Board, Skukuza.

KEEPING, G.B., G.L. SMUTS and J.H.M. DAVID. 1968.Report on Wildlife Society Expedition to Survey the Knysna Elephants. Wildlife Society of SA, Port Elizabeth.

KLINGELHOEFFER, E.W. 1987. *Aspects of the Ecology of the Elephant* Loxodonta africana *and a Management Plan for the Tembe Elephant Reserve in Tongaland, KwaZulu*. MSc Thesis, University of Pretoria.

KOEN, J.H. 1981. A study of the distribution, population composition, movements, etc. of the Knysna elephants. Preliminary Report. Saasveld Forestry Research Station, Typescript.

KOEN, J.H., A.J. HALL-MARTIN and T. ERASMUS. 1988. Macro nutrients in plants available to the Knysna, Addo and Kruger National Park elephants. *South African Journal of Wildlife Research* 18(2): 69-71.

LAWS, R.M. 1970. Elephants as agents of habitat and landscape change in East Africa. *Oikos 21 : 1-15*.

OSTROSKY, E.W. 1988a. Monitoring of elephant movements across the international border between South Africa and Moçambique in the Tembe Elephant Park, Second Annual Report, 1987. Kwazulu Bureau of Natural Resources, Ulundi. Typescript.

OSTROSKY, E.W. 1988b. The Elephant population of the Tembe Elephant Park, KwaZulu: Management Recommendations. KwaZulu Bureau of Natural Resources, Ulundi. Typescript.

PARKER, I.S.C. 1983. The Tsavo story: an ecological case history. In: OWEN-SMITH, R.N. (ed.). *Management of Large Mammals in African Conservation Areas*. Pretoria: Haum.

PARKER, I.S.C. and A.D. GRAHAM. 1989. Elephant decline (Part 1). Downward trends in African elephant distribution and numbers. *International Journal for Environmental studies* 34: 287-305.

PHILLIPS, J.F.V. 1925. The Knysna elephant: a brief note on their history and habits. *South African Journal of Science* XXII: 287-293.

PIENAAR, U. DE V. 1963. The large mammals of the Kruger National Park - their distribution and present-day status. *Koedoe* 6: 1-37.

PIENAAR, U. DE V. 1969. Why elephant culling is necessary. *African Wildlife* 23: 181-195.

PIENAAR, U. DE V. 1983. Management by intervention: The pragmatic/economic option. Pp. 23-36. *In*: OWEN-SMITH, R.N. (ed.). *Management of Large Mammals in African Conservation Areas*. Pretoria: Haum.

PIENAAR, U. DE V. 1985. Indications of progressive dessication of the Transvaal Lowveld over the past 100 years, and implications for the water stabilisation programme in the Kruger National Park. *Koedoe* 28 : 93-165.

PIENAAR, U. DE V., P. VAN WYK and N. FAIRALL. 1966. An aerial census of elephant and buffalo in the Kruger National Park, and the implications thereof on intended management schemes. *Koedoe* 9 : 40-107.

RAUTENBACH, I.L., D.J. SKINNER and J.A.J. NEL. 1980. The past and present status of the mammals of Maputoland. In: BRUTON, M.N. and K.H. COOPER (eds.). *Studies on the Ecology of Maputoland*. Rhodes University grahamstown and Wildlife Society Durban.

ROBERTS, A. 1951. *The Mammals of South Africa*. Johannesburg: "Mammals of SA" Book Fund.

SANDENBERGH, J.A.B. 1946. Kruger National Park, Warden's Annual Report - 1946. Typescript.

SKEAD, C.J. 1980. *Historical Mammal Incidence in the Cape Province. Vol.I*. Cape Town: Dept. of Nature and Environmental Conservation.

SKEAD, C.J. 1987. *Historical Mammal Incidence in the Cape Province*. Vol.II Cape Town: Dept. of Nature and Environmental Conservation.

SMITHERS, R.H.N. 1983. *The Mammals of the Southern African Subregion*. Pretoria: University of Pretoria.

STEVENSON-HAMILTON, J. 1903a. Report on Singwitsi Game Reserve. Transvaal Administration Reports for 1903. Typescript. Sabie Bridge.

STEVENSON-HAMILTON, J. 1903b. Game preservation. Transvaal Administration Reports for 1903. Typescript.

STEVENSON-HAMILTON, J. 1905. Report on the Government Game Reserves for the year ended 30th June 1905. Typescript. Komati Poort.

STEVENSON-HAMILTON, J. 1912. Government Game Reserves. Sabi and Singwitsi. Annual Report 1912. Typescript.

STEVENSON-HAMILTON, J. 1925. Extracts from annual report of the Transvaal Game Reserves. 1925. Typescript.

STEVENSON-HAMILTON, J. 1932 Kruger National Park, Warden's Annual Report - 1932. Typescript.

STEVENSON-HAMILTON, J. 1933. Kruger National Park, Warden's Annual Report - 1933. Typescript.
STEVENSON-HAMILTON, J. 1936. Kruger National Park, Warden's Annual Report - 1936. Typescript.
STEVENSON-HAMILTON, J. 1937. Kruger National Park, Warden's Annual Report - 1937. Typescript.
STEVENSON-HAMILTON, J. 1947. *Wild Life in South Africa*. London: Cassell.
STEYN, L.B. 1958. Jaarverslag van die Opsiener Nasionale Krugerwildtuin vir die tydperk 1 April 1957 tot 31 Maart 1958. Typescript.
STOKES, C.S. 1941. *Sanctuary*. Cape Town: The Sanctuary Production Committee.
THOMSON, G. 1978. Natal's last elephants. *African Wildlife* 32(3 : 42-43.
VAN WYK, P. and N. FAIRALL. 1969. The influence of the African elephant on the vegetation of the Kruger National Park. *Koedoe* 12: 57-89.
VILJOEN, A.J. 1988. Long-term changes in the tree component of the vegetation in the Kruger National Park. Pp. 310-315. *In:* MC DONALD, I.A.W. and R.J.M. CRAWFORD (eds.). *Long-term data series relating to southern Africa's renewable natural resources*. South African National Scientific Programmes. Report no 157.
WALKER, B.H. 1976. An approach to the monitoring of changes in the composition and utilization of woodland and savanna vegetation. *South African Journal of Wildlife Research* 6(1): 1-32.
WHYTE, I.J. 1990. Census results for elephant and buffalo in the Kruger National Park in 1990 and culling quotas for the 1990/91 culling year. National Parks Board, Skukuza. Typescript.