

Elephant Population Estimates

Population Estimates for Etosha National Park

Year	Estimate	Survey	Month
1966	200	CE	Mar
1967	500	C	Mar
1968	450	W	Sep
1969	300	CE	Apr
1970	494 ¹	CE	Feb
	116	C	Nov
1971	124	C	Feb
1972	447	C	Mar
	547	C	Apr
	433	C	Jun
	419	CEW	Jul
	863	CEW	Sep
	686	CEW	Oct
1973	292	CEW	Feb
	477	CEW	Mar
	281 ¹	CE	Apr
	715	CW	Jun
	1,293	Park	Sep
1974	904	Park	Feb
	835	Park	Jul
1975			
1976	1,170	Park	Jul
1977	836	Park	Mar
1978	826	Park	Mar
	1,298	Park	Mar
	1,739 ¹	Park	Sep
1979	1,876	Block Ct	Mar
1980	723	W	Jun
1981			
1982	2,202	Total Ct	Jul
1983	2,800	W+Park	May

	1,437	Park	Dec
1984	1,158	Total Ct	May
	2,464 ¹	Total Ct	Sep
	2,081	Total Ct	Dec
1985	1,244	Total Ct	May
	1,186	Total Ct	Aug
	702	Transects	Dec
1986	650	Mixed	May
	1,400	Ground	Aug
	1,200	Ground	Dec
1987	1,500	Ground	May
	2,021	Total Ct	Aug
	1,100	Ground	Dec
1988			
1989			
1990	1,469 ¹	Transects	Aug
1991			
1992			
1993			
1994			
1995	1,188 ¹	Transects	Aug
1996			
1997			
1998	2,206 ¹	Transects	Aug
1999			
2000	2,100 ¹	Transects	Sep
2001			
2002	2,417 ²	Transects	
2003			
2004	2,057 ³	Transects	Sep

Table 1: Etosha Estimates All estimates from Lindeque (1988) unless otherwise indicated: ¹ Estimates from DSS (2002a); ² Estimate from Erb (2004) – DSS; ³ Estimate from Kolberg (2004)

Combined Estimates for Etosha and the North-Western Population

Several analytical steps have been carried out in this table –

- i. The highest estimate for the Etosha population in each year has been carried forward from the previous table;
- ii. A 5-year moving average has been applied to the data to interpolate missing values and to smooth stochastic variation from one year to the next;

- iii. The estimates for the north-western population are tabulated (taken from the next table);
- iv. For those years in which an estimate exists for both the Etosha population and the north-western population the ratios of the two have been calculated;
- v. These ratios clearly demonstrate trends – in the years prior to 1970, the numbers of elephant outside the park were relatively high, during the period 1975-1982 of SADF illegal activity numbers of elephant outside the park were low in comparison to those in the park and in the years after 1982 there has been as a steady increase in elephant numbers in the north-west in relation to the numbers in the park;
- vi. The missing values in the sequence of data for north western population have then been interpolated by applying the ratios calculated above for the different time periods to the 5 year average values for Etosha;
- vii. A 5 year running average has then been calculated for the north-west population;
- viii. The total of the combined populations appears in the final column.

Year	Highest	5 year avg	NW Pop	Ratio	NW pop reconst	5 year avg	Combined population	Adjusted estimates
1966	200	200						
1967	500	383		0.673	258	258	641	802
1968	450	389	211	0.469	211	251	639	799
1969	300	485	283	0.943	283	288	773	966
1970	494	557	300	0.607	300	315	872	1,090
1971	679	726		0.536	389	348	1,073	1,342
1972	863	847		0.464	393	359	1,205	1,506
1973	1,293	955		0.392	374	337	1,292	1,615
1974	904	1,053		0.320	337	300	1,354	1,692
1975	1,037	1,048	190	0.249	190	263	1,311	1,639
1976	1,170	1,137	207	0.177	207	228	1,365	1,707
1977	836	1,332	207	0.248	207	211	1,542	1,928
1978	1,739	1,521	200	0.115	200	223	1,744	2,180
1979	1,876	1,706	250	0.133	250	232	1,937	2,422
1980	1,985	1,979		0.127	251	240	2,219	2,774
1981	2,093	2,191	250	0.120	250	236	2,427	3,034
1982	2,202	2,309	250	0.114	250	226	2,535	3,169
1983	2,800	2,161	178	0.064	178	235	2,396	2,995
1984	2,464	2,022	203	0.082	203	245	2,267	2,834
1985	1,244	1,986		0.149	295	265	2,251	2,814
1986	1,400	1,793	301	0.215	301	301	2,094	2,617
1987	2,021	1,631		0.214	348	331	1,962	2,452
1988	1,837	1,676		0.212	355	333	2,009	2,511
1989	1,653	1,679		0.210	353	345	2,024	2,530
1990	1,469	1,546	307	0.209	307	357	1,903	2,378
1991	1,413	1,438		0.253	363	360	1,798	2,248
1992	1,357	1,357	406	0.296	406	391	1,747	2,184
1993	1,300	1,300	370	0.340	370	431	1,731	2,164

1994	<i>1,244</i>	1,323		<i>0.384</i>	<i>508</i>	478	1,801	2,252
1995	1,188	1,425	508	0.428	508	510	1,936	2,420
1996	<i>1,527</i>	<i>1,606</i>		<i>0.373</i>	<i>598</i>	552	2,159	2,698
1997	<i>1,867</i>	<i>1,788</i>		<i>0.318</i>	<i>568</i>	573	2,361	2,951
1998	2,206	1,971	579	0.262	579	604	2,574	3,218
1999	<i>2,153</i>	2,117		<i>0.289</i>	<i>611</i>	633	2,750	3,437
2000	2,100	2,227	662	0.315	662	675	2,902	3,628
2001	<i>2,259</i>	2,233		<i>0.334</i>	<i>745</i>	725	2,958	3,698
2002	2,417	2,214		<i>0.352</i>	<i>779</i>	763	2,977	3,721
2003	<i>2,237</i>	2,237		<i>0.371</i>	<i>829</i>	803	3,040	3,800
2004	2,057	2,057	800	<i>0.389</i>	800	800	2,857	3,571

Table 2: Combined estimates for Etosha and the North-Western Population. *Interpolated values are shown in red italics.* In the final column, the 'Adjusted estimates' are 25% higher than the calculated values

Estimates for the North-Western Population

Using all available data, estimates have been compiled for the north-western population. In some years where surveys were limited either to Damaraland or the Kaokoveld, and estimate for the total population has been made by using the value from the year before or the year after for the missing part. The notes in each line of the table explain how each estimate has been obtained.

Year	Estimate	Source
1934	1,000	Shortridge (1934)
1968	211	E. Joubert (Supercub survey)
1969	283	E. Joubert (Supercub survey)
1970	300	G. Owen-Smith (2004)
1971		
1972		
1973		
1974		
<i>1975</i>	190	De Villiers (Bantu Affairs)
<i>1976</i>	207	Viljoen (MSc study 1976-1978)
<i>1977</i>	207	Viljoen (MSc study 1976-1978)
<i>1978</i>	200	65 (Viljoen - Western)+ 135 (DSS 2002 - Eastern)
<i>1979</i>	250	192 (DSS 2002 Damaraland only)+ 58 (Balance of 1982 total)
<i>1980</i>		
<i>1981</i>	250	138 (DSS 2002 Kaokoveld only)+ 112 (Balance of 1982 total)
<i>1982</i>	250	214 (Loutit 2004 Damaraland) + 36 (DSS 2002 Kaokoveld)
1983	178	DSS (2002a)
1984	203	54 (Owen-Smith 2004 Kaokoveld) + 159 (DSS 2002 - Damaraland 1983 estimate)
1985		
1986	301	247 (Loutit 2004 Damaraland) + 54 (Owen-Smith 2004 - Kaokoveld 1984 estimate)
1987		
1988		
1989		
1990	307	253 (Loutit 2004 Damaraland) + 54 (Owen-Smith 2004 - Kaokoveld 1984 estimate)
1991		

1992	406	Loutit (2004)
1993	370	Loutit (2004)
1994		
1995	508	Loutit (2004)
1996		
1997		
1998	579	DSS (2002a)
1999		
2000	662	DSS (2002a)
2001		
2002		
2003		
2004	800	Leggatt (pers.comm)
1975-1982 SADF illegal hunting		

Table 3: Estimates for the North-Western Population

Estimates for Khaudum and Nyae Nyae Populations

Survey areas have altered over the period 1977-2004 and the later estimates include areas outside the national park and the conservancy. In some years where only part of the area was surveyed an overall estimate has been made by using the value from the year before or the year after for the missing part. References for all estimates are given at the foot of the table and a simple population model is given.

MODEL PARAMETERS									
				Average rate of growth		4.56	4.56	% / year	
				Starting population (1975)			0	animals	
				Starting immigration (1975)			34	animals	
				Rate of change of immigration			7.14	% / year	
ESTIMATES					MODEL				
					Best fit analysis				
Year	Khaudum	Nyae Nyae	Totals	Selected	Estimate x 1.25	Zero immig	Predicted	Immigration	Difference ²
1975							0	34	
1976							36	36	
1977			64	64	80	80	75	39	22
1978			95	95	119	84	120	42	1
1979			54	54	68	87	169	45	10,236
1980	0		122	122	153	91	223	48	4,999
1981						96	284	51	
1982						100	350	55	
1983						105	424	59	
1984	395	385		780	975	109	505	63	220,983
1985						114	594	68	
1986	377			762	953	120	692	73	67,855
1987	528			929	1,161	125	799	78	130,879
1988		401		929	1,161	131	917	83	59,528
1989						137	1,046	89	

1990	1,206	237		1,443	1,804	143	1,187	96	380,006
1991						149	1,341	102	
1992						156	1,510	110	
1993						163	1,693	118	
1994						171	1,894	126	
1995	783	302		1,085	1,356	179	2,112	135	570,978
1996						187	2,349	145	
1997						195	2,608	155	
1998	2,224	558		<i>2,782</i>	3,478	204	2,889	166	346,519
1999						213	3,194	178	
2000	1,266	755		<i>2,021</i>	2,526	223	3,526	191	999,453
2001						233	3,886	204	
2002	1,687	<i>861</i>		2,548	3,185	244	4,277	219	1,192,290
2003	3,184	<i>914</i>		4,098	5,123	255	4,701	234	177,838
2004	3,099	967	<i>749*</i>	4,815	6,019	267	5,160	251	736,884
2005						267	5,658	269	
							Total sum of squares		4,898,470

*Kavango & Jaqna

Table 4: Estimates for Khardum and Nyae Nyae Populations. All estimates from DSS (2002a) up to 2002 except 1998 (Craig 1998) 2000 (Craig 2000), 2002 - Erb (2004), 2004 - Kolberg (2004). Interpolated values in italics.

Estimates for East and West Caprivi Populations

Over the period in which surveys have been carried out in the Caprivi (1978-2004), the full Caprivi has been surveyed on only 9 occasions. In order to augment the available data for modelling purposes, the estimates for some years have been interpolated from the ratios between East and West Caprivi and the ratios for survey units within the East and West areas. However, in carrying out the modelling, no 'double' interpolations¹ have been used.

Some simple for the Caprivi population are shown below. The models are based on an assumed starting population in 1977 and an assumed rate of growth. None of these models fit the estimates particularly well. A closer examination of the data suggests that the Caprivi population actually declined from 1977-1989 and a model for these years (on the page following the simple models) confirms that a closer fit to the estimates can be obtained by assuming an exponential decline from 1978-1989. The formula used for Phase 1 of the model is –

$$P_t = 0.01 \times P_0 \times (100 - e^{\alpha(t-t_0)})$$

where – P_t is the population in year t

P_0 is the starting population in 1977 (t_0) and

¹. A 'double interpolation' is one in which only a part of either east or west Caprivi was surveyed and to get the estimate for the whole Caprivi it is necessary firstly to scale up the estimate (say) for West Caprivi based on a part of West Caprivi and, secondly to obtain the estimate for East Caprivi by using the ratio of estimates for the two areas around that time.

α is a constant

After 1989 the population increases at a rate which exceeds the maximum possible intrinsic growth rate for elephant populations and it is necessary to introduce some immigration into the model. In the second phase of the model (1990-2004) the starting population is that generated by the first phase of the model and a typical growth rate for elephant populations (4.56%) is assumed. Immigration begins in 1990 and both the initial immigration and the rate of change of immigration after the first year are set as variables. The best fit is obtained with a large immigration of 1,900 animals in 1990 which tails off very sharply.

The Caprivi estimates and the model results are shown in **Fig.15** in the main part of the report (page 30). It is necessary to note that the data are not particularly robust and that other interpretations of the estimates might be possible. The general impression in the field is that immigration has become very noticeable in recent years rather than in the 1990s.

Year	WEST CAPRIVI						EAST CAPRIVI						Total
	Mahango	W Core	Centre	E core	Sum	Sum or Survey	Mudumu	Mamili	Forest	Floodp	Sum	Sum or Survey	
1977	-	-	-	-			-	-	-	-			
1978	-	-	-	-			-	-	-	-		7	7
1979	-	-	-	-			-	-	-	-		16	16
1980	-	-	-	-		1,352	-	32 ¹	1,509 ¹	15 ¹	1,556	1,969	3,321
1981	-	-	-	410 ¹	410	634	-	-	-	-		923	1,556
1982	-	-	-	-		1,652	193	135 ¹	1,936 ¹	-	2,264	2,405	4,057
1983	53	-	-	-	53	690	539	100 ¹	1,550 ¹	-	2,189	2,575	3,265
1984	-	-	-	-		1,384	149	57 ¹	1,768 ¹	41 ¹	2,015	2,015	3,399
1985	0	1 ¹	-	-	1	1,297	310	72 ¹	1,353 ¹	19 ¹	1,754	1,754	3,051
1986	0	-	-	-	0	560	158 ¹	136 ¹	567 ¹	157 ¹	1,018	1,018	1,578
1987	169	868	-	-	1,037	2,937						1,559	4,496
1988	0	-	-	884 ¹	884	1,366	143 ¹	169 ¹	1,075 ¹	-	1,387	1,388	2,754
1989	82	92	-	728 ¹	902	902	387 ¹	179 ¹	335 ¹	240 ¹	1,141	1,141	2,043
1990	319	1,085	-	-	1,404	3,977	534	491	-	-	1,025	1,025	5,002
1991	208	-	-	-	208	2,708	-	-	-	-		719	3,427
1992	-	-	-	-			-	-	-	-			6,630
1993	298	1,209 ¹	-	2,825 ¹	4,332	4,332	405	187	-	-	592	592	4,924
1994	248	1,533 ¹	0	2,953 ¹	4,734	4,734	433	638 ¹			1,071	1,071	5,805
1995	252	-	-	-	252	3,281	821	1,457	-	-	2,278	2,278	5,559
1996	-	-	-	-			-	-	-	-			
1997	-	-	-	-			-	-	-	-			
1998	292 ²	1,227 ²	0 ²	1,549 ²	3,068	3,068	175	1,333 ²	0 ²	0 ²	1,508	1,508	4,576
1999	-	-	-	-			-	-	-	-			
2000	238	-	-	-	238	3,098	-	-	-	-		823	3,921
2001	-	-	-	-			-	-	-	-			
2002	250 ²	-	-	-	250 ²	3,255	-	-	-	-		864	4,119
2003	-	-	-	-			-	-	-	-			5,740
2004	340 ³	1,927 ³	38 ³	2,563 ³	4,868	4,868					3,858 ³	3,858	8,726

2001				6,415		6,548		6,115		5,797	
2002	3,255	864	4,119	6,708		6,887		6,393	5,173	6,004	3,553
2003			5,740 ³	7,013	1,622	7,245	2,265	6,685	893	6,218	229
2004	4,868	3,858	8,726 ⁴	7,333	1,940	7,621	1,221	6,990	3,014	6,440	5,224
2005				7,668		8,016		7,309		6,670	

Table 6: Simpel Population Models for the Caprivi. All data based on DSS (2002a) unless otherwise indicated: ²Craig (1998), ²Sikopo (2002), ³Chase & Griffin (2004), ⁴Kolberg (2005). 'All available data' refers to subtotal constructed using ratios in Table 5.

A two-phase model for the Caprivi elephant population

	ESTIMATES			TWO PHASE MODEL			
	WEST	EAST	Total	Estimate x 1.25	Model	Immigration	0.001 x Diff ²
Starting population 1977				4,510			
Coefficient of exponential decline 1977-1989				0.295			
Rate of growth 1990 onwards				4.56			
Starting immigration 1990				1,900			
Rate of change of immigration %				-87			
First phase: $0.001 \times \text{Difference}^2$				8,372			
$(0.001 \times \text{Difference}^2) / N$				930			
Second phase: $0.001 \times \text{Difference}^2$				16,876			
$(0.001 \times \text{Difference}^2) / N$				2,411			
Year							
1977					4,510		
1978		7			4,449		
1979		16			4,429		
1980	1,352	1,969	3,321	4,151	4,401		62
1981	634	923	1,557	1,946	4,363		
1982	1,652	2,405	4,057	5,071	4,313		575
1983	690	2,575	3,265	4,081	4,245		27
1984	1,384	2,015	3,399	4,249	4,154		9
1985	1,297	1,754	3,051	3,814	4,032		48
1986	560	1,018	1,578	1,973	3,868		3,595
1987	2,937	1,559	4,496	5,620	3,648		3,888
1988	1,366	1,387	2,753	3,441	3,353		8
1989	902	1,141	2,043	2,554	2,956		161
1990	3,977	1,025	5,002	6,253	4,990	1,900	
1991	2,708	719	3,427	4,284	5,465	247	
1992			6,630	8,288	5,746	32	6,458

199 3	4,332	592	4,924	6,155	6,012	4	20
199 4	4,734	1,071	5,805	7,256	6,287	1	939
199 5	<i>3,281</i>	2,278	<i>5,559</i>	6,949	6,574	0	141
199 6					6,874	0	
199 7					7,187	0	
199 8	3,068	1,508	4,576	5,720	7,515	0	3,221
199 9					7,857	0	
200 0	<i>3,098</i>	<i>823</i>	<i>3,921</i>	4,901	8,216	0	
200 1					8,590	0	
200 2	<i>3,255</i>	<i>864</i>	<i>4,119</i>	5,149	8,982	0	
200 3			5,740	7,175	9,392	0	4,914
200 4	4,868	3,858	8,726	10,908	9,820	0	1,183
200 5					10,268	0	

Table 7: A two-phase model for the Caprivi elephant population. Data shown in italics are interpolated. No double interpolations have been used in obtaining the best fit.