TRENDS OF THE ELEPHANT POPULATION IN NORTHERN BOTSWANA FROM AERIAL SURVEY DATA

[1]Debbie St.C. Gibson, [2]G Colin Craig and [3]Rapelang M Masogo

[1] Present address: P0 Box 25476, Windhoek, Namibia
[2] Present address: Ministry of Environment and Tourism, P Bag 13306, Windhoek, Namibia
[3] Department of Wildlife and National Parks, P0 Box 131, Gaborone, Botswana

SUMMARY

Aerial surveys of elephants in northern Botswana have been taking place since the early 1970s. While it is not possible to use all of the data from these surveys, they provide evidence to suggest that since 1987 the population of elephants in northern Botswana has increased to its present level of around 80,000 animals at a rate of around 6% per annum. Their range, which has expanded south and westward, changes seasonally but is largely outside protected areas (Figure 1).

This paper summarises the methods and results of aerial surveys since 1973 and presents a history of the elephant population in Botswana with estimates of recent trends provided by survey data.

RESUME

ll est évident que la population d'éléphant du nord du Botswana a connu une croissance pour atteindre son niveau actuel de 80000 têtes avec environ un taux de croissance de 6% l'an. Leur zone de distribution s'est accru du sud vers l'ouest, avec des changements saisonnniers.

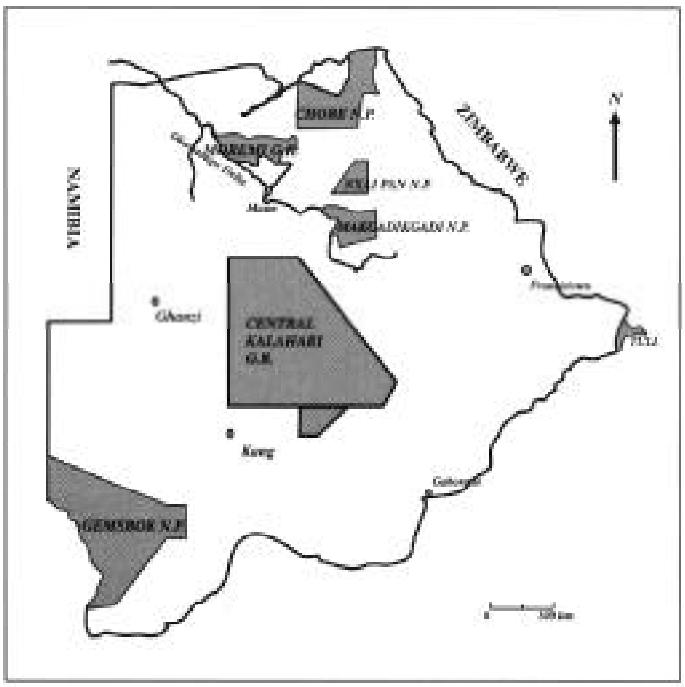

Figure 1. Map of Botswana showing protected areas (shaded)

INTRODUCTION

Botswana supports one of the largest populations of elephants in Africa Most occur outside protected areas in the north (Figure 1) where they form part of a larger population spreading from Zimbabwe through Botswana to Namibia. In addition, a population of up to 1,000 animals is found in and around the Northern Tuli Game Reserve, a small private reserve in the east of the country.

Most of the information about the size and distribution of the elephant population in northern Botswana comes from aerial surveys which have been taking place since the early 1970s. It is not possible to use the data from all of these surveys to obtain estimates of overall population trends because of variations in coverage and quality. A summary of these surveys is included in this paper, however, because they could be used, for example, for obtaining information about elephant numbers within specific areas (such as Chobe National Park) and about their distribution.

Historical trends in elephant distribution

In the past, surface water occurred more widely throughout Botswana than it does today and wild animals, including large species such as the elephant and rhino, were able to survive even in the Kalahari, at least during the rainy seasons. Elephant were probably distributed almost throughout the country and there may have been as many as 400,000 animals (Campbell, 1990) at the beginning of the 19th century. It is thought that the country began to dry up from about 1870 (Campbell, 1990) but before this happened, elephants had been reduced to low numbers by uncontrolled commercial hunting for ivory. By the beginning of the present century the elephant population had been reduced to a remnant population inhabiting only the north of Botswana, and elephants had become very rare even in what is now Chobe National Park. Measures imposed in 1893 to reduce this trend included establishing hunting quotas, and implementing a system whereby foreigners had to buy a licence and local people had to have written permission to hunt elephants (Campbell,

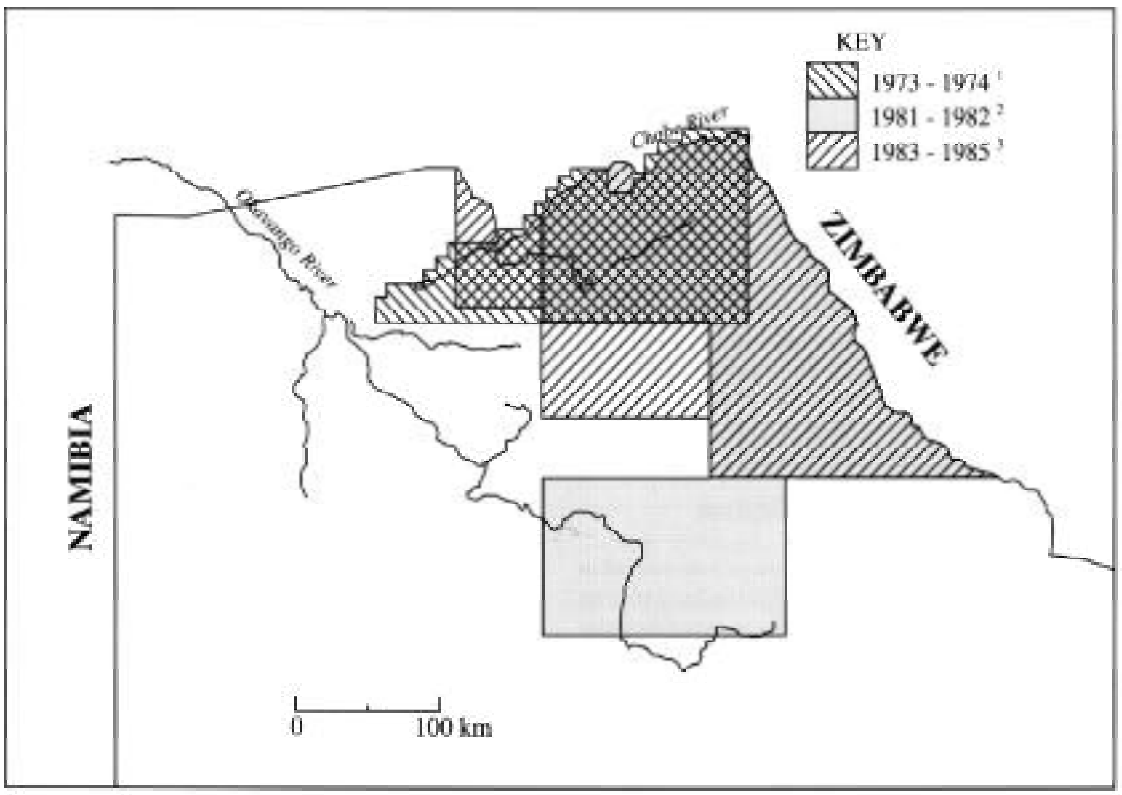

Figure 2. Areas surveyed for elephants from 1973 to 1985 ([1]Sommerlatte, 1976; [2]Melton, 1985; [3] Work, 1986).

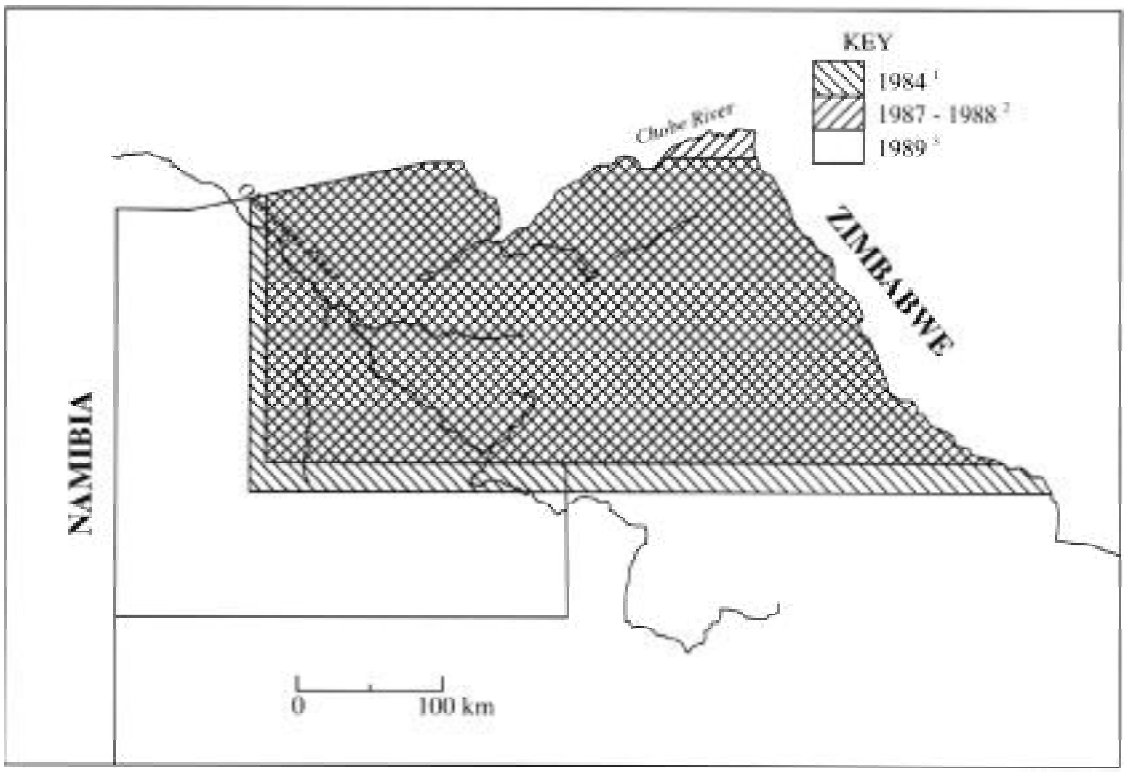

Figure 3. Areas surveyed for elephants from 1984 to early 1989 ([1]KCS, 1985; [2]Gavor, 1987; Calef 1988; [3]Calef 1988).

1990). By about 1930, increases in the population were observed, although numbers were still low (Child, 1968) and their distribution restricted mainly to the north and north-east of Botswana In the late 1950s, a rapid increase in elephant numbers was observed with the population perhaps being augmented by immigration from neighbouring countries (Child, 1968). Hunting increased until it was banned in 1983 (Melton, 1985) in response to concerns that tusk weights were declining.

AERIAL SURVEYS IN BOTSWANA

By the late 1960s damage to vegetation was evident in the Chobe National Park (Child, 1968) in the north-east of the country. This was attributed to an overabundance of elephants and an aerial survey (Figure 2) was undertaken in 1973 (Sommerlatte, 1976) to estimate the size of the elephant population. This was complemented by studies of vegetation in part of the area and concentrated on Chobe National Park and its surrounds.

Spinage (FGU-Kronberg, 1987) reports surveys of the Okavango Delta and Chief's Island by Astle and Graham (1976) and Biggs (1979). More extensive surveys were done by the Department of Wildlife and National Parks (DWNP) (Melton, 1985) in 1981 and 1982 (Figure 2).

None of these surveys covered the same areas (although there was some overlap) and much of the area in which elephants were known to occur was omitted from them (eg. the Okavango Delta). This prevented comparisons or trends from being obtained and consequently, in 1983, surveys were designed specifically to obtain "a good estimate of elephant numbers" (Work, 1986). However, as can be seen in Figure 2, these did not improve coverage greatly and neither were they completed during a single season.

The next surveys, completed in 1984 and 1985 (KCS, 1984 and 1985) came close to the required coverage (Figure 3) although the Chobe river front was omitted despite the fact that this area was known to be particularly favoured by elephants during the dry season.

In the 1980s, the focus of wildlife management changed from the state of the vegetation to concerns about the effects of illegal hunting on the status of wildlife populations in northern Botswana. The DWNP (Calef, 1988 and 1990, Gavor, 1987) therefore carried out extensive aerial counts in 1987 and early 1989 (Figure 3).

In September 1989, a programme of countrywide surveys (Bonifica, 1992) was started and the entire elephant range in northern Botswana has been covered at least once a year since then (Figures 4 and 5).

METHODS

Survey methods

Aerial surveys in Botswana have generally used the standard technique of aerial transect sampling (Norton Griffiths, 1978). Briefly, this entails counting animals along transects placed at a predetermined distance apart to give the required sampling intensity. A pair of observers in the aircraft count animals seen between markers (rods or lines attached to the lift struts of the aircraft). The markers are separated at a distance that gives a predetermined "strip width" on the ground when flying at the chosen height above ground.

It is important that a constant height above ground level (a.g.l.) is maintained using a radar altimeter although some surveys have been attempted using the pressure altimeter and subtracting the altitude of the ground to calculate the height above ground. Much of Botswana is featureless and accurate navigation is difficult. However, position on the transects was maintained using an OMEGA navigation system. After 1991 GPS satellite navigation systems were used, enabling very accurate navigation.

Later surveys have common standards of height above ground level (300 feet), strip width (200m per side or less) and information to be recorded. Records are made of the positions (grid coordinates from the GPS) at which sightings are made, the number of animals in each group and whether the group is a family group or a group of bulls. Other wild mammal species, domestic livestock and ostriches are also recorded. Heights above ground are read from the radar altimeter every minute of latitude (0.01670) (on very long transects this is reduced to a reading every two minutes) for later calculation of sample area and notes of open water and fires are also kept.

Jolly's Method 2 for sampling units of unequal size (Jolly, 1969) has been used consistently to obtain estimates and variances.

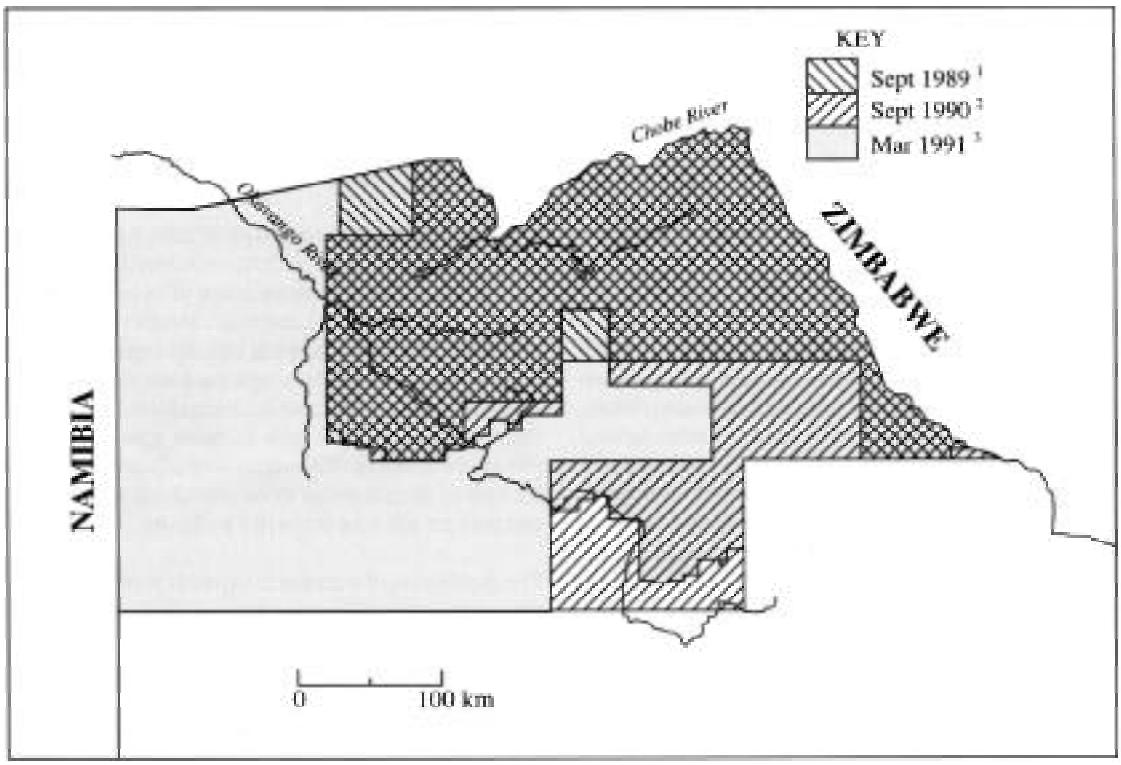

Figure 4. Areas surveyed for elephants from Sept 1989 to April 1991 ([1]Bonifica ,1992; [2]Bonifica, 1992; [3]Bonifica, 1992).

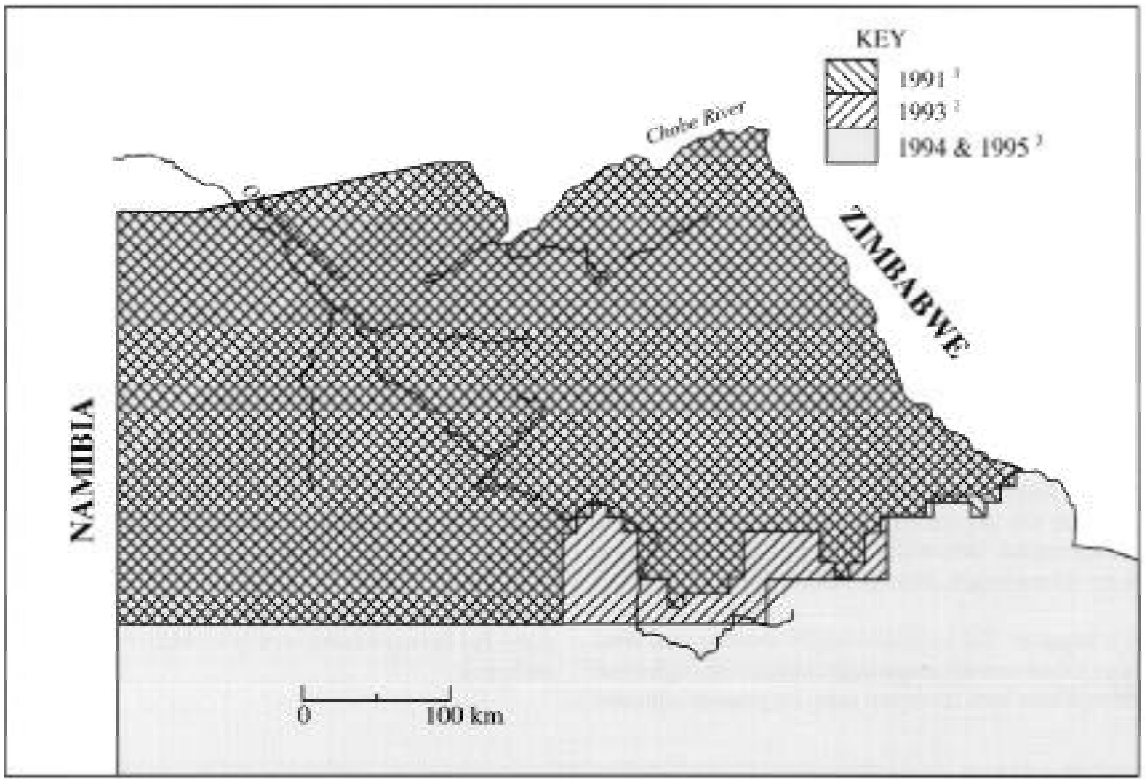

Figure 5. Areas surveyed for elephants from Sept 1991 to Sept 1995 (1 Craig, 1991; [2]ULG, 1993; [3]ULG, 1994; DWNP, 1995; Craig, 1996).

Data sources

Most of the surveys attempted to follow standard procedures (summarised in Table 1). However, constraints of equipment and time in some cases reduced their quality. For instance, not keeping a constant height above ground level due to the lack of a radar altimeter (Sommerlatte, 1976) or an inability to complete an entire survey within a reasonable time or even within the same season (Work, 1986), have prevented the use of estimates in more detailed analyses. In other cases, the data quality has been reduced because the surveys did not cover an adequate amount of the elephant range in northern Botswana (eg. Melton, 1986) or because it was not possible to ascertain exactly what area was covered or even the techniques used, say for calibrating strip widths (eg. KCS, 1984).

Because of this, early survey data are not considered adequate for inclusion in analysis of trends for the elephant population in northern Botswana, although they are of general interest. There is now a reasonable set of data collected from 1987 from which elephant population estimates and trends were examined (Table 2).

Distribution maps

Elephant distributions were mapped from survey data by summarising numbers of animals seen into cells of 0.1 by 0.1 degrees making up a raster image of 94 cells across by 93 cells high (9.4 by 9.3 degrees). Numbers of animals seen were corrected for sampling intensity to give a predicted density for each cell. The image was then filtered using a moving average. This removed unimportant differences in value between adjacent cells to create a more coherent picture of distribution. Cell values were adjusted to preserve the total of all cells (equal to the overall estimate) and the numbers per cell were converted to density.

The distribution of densities is too wide to permit it to be displayed meaningfully using linear density increments and the cells were therefore shaded according to log (density).

Analysis of population trends

Exponential regression was used to describe population increase of the northern Botswana elephant population (Caughley and Birch, 1971). This presents population

Work, D.R. (1986) Summary report of aerial surveys conducted in 1983, 1984 and 1985, Typed manuscript.

Table 1. Summary of the equipment and field parameters used during aerial surveys of northern Botswana from 1973 to 1995.

Year (ft)	Location (m)	Area (km^2) Height/Nav	Height a.g.l.	Strip Width	Equipment	Author
1973/74	Chobe plus surrounds (Figure 2)	22,500	490-660	800	press alt/?	Sommerlatte 1976
1981/82	NE Bots (not all in 1 season) (Figure 2)	54,977	250	500	radar alt/ GNS	Melton 1985
1983 dry	NE Bots (partial) (Figure 2)	4,125	300-350	?	radar alt/ GNS	Work 1986
1984 wet	NE Bots (partial) (Figure2)	42,971	300-350	?	radar alt/ GNS	Work 1986
1984 Apr/May	N. Bots excluding Chobe R. (Figure 3)	72,000	300	600	radar alt/ GNS	KCS 1984, 1985
1984 Oct/Nov	N. Bots excluding Chobe R (Figure 3)	72,000	300	400	radar alt/ GNS	KCS 1984, 1985
1985 wet	NE Rots (partial Chobe) (Figure 2)	2,230	300-350	?	radar alt/ GNS	Work 1986
1987 Jan/Feb	N. Bots (Figure 3)	119,774	300	500	radar alt/ GNS	Gavor 1987, Calef 1988
1987 May/Jun/Jul	N. Bots (Figure 3)	119,774	300	500	radar alt/ GNS	Gavor 1987, Calef 1988
1989 Jan/Feb/Mar/Apr	N. Bots (Figure 3)	132,016	300	500	radar alt/ GNS	Calef 1990, 1993
1989 Sep	N. Bots (Figure 4)	60,878	300	500	radar alt/ GNS	Bonifica 1992
1990 Apr	N. Bots (Figure 4)	140,387	300	500	radar alt/ GNS	Bonifica 1992
1990 Sep	N. Bots (Figure 4)	67,206	300	500	radar alt/ GNS	Bonifica 1992
1991 Mar	N. Bots (Figure 4)	150,448	300	500	radar alt/ GNS	Bonifica 1992
1991 Sep	N. Bots (Figures)	154,919	300	?400	radar alt/ GNS	Craig 1991
1993 May	N. Bots (Figures)	143,943	300	?400	radar alt/ GNS	DWNP 1993
1993 Sep	N. Rots (Figure 5)	166,236	300	340	radar alt/ GNS	ULG 1993

Table 1 Continued

Year	Location	Area (km²)	Height a.g.l. (ft)	Strip Width (in)	Equipment Height/Nav	Author
1994 Apr	Countrywide (Figure 5)	573,694	300	400	radar alt/ GNS	ULG 1994
1994 Sep	Country wide (Figure 5)	579,049	300	400	radar alt/ GNS	ULG 1994
1995 Apr	Countrywide (except E Bots) (Figure 5)	?	300		radar alt/ GNS	DWNP 1995
1995 Sep	Countrywide (except E Bots) (Figure 5)	122,922	300	?	radar alt/ GNS	Craig 1996

change in terms of proportional or percentage change per unit time and is the easiest to justify in the absence of evidence of more complex patterns of change. Linear regressions of the natural logarithms of survey estimates versus time (Caughley, 1977) between 1987 and 1995 were used to determine the rate of population increase and its 95% confidence limits.

Modelling approach to estimating rate of increase and its precision

There are differences in sampling intensity and precision among the various estimates. As a result, the use of regression analysis is not strictly valid. The possible range of results was therefore modelled using a Monte Carlo simulation (eg. Sokal and Rohlf, 1995) as follows: for every survey result, a normal distribution was constructed using the estimate and its standard error. A possible estimate was drawn at random from each of these distributions to provide a set of results simulating possible estimates for the whole period in question. A regression coefficient was derived from the set. This was repeated a million times and the results were used to calculate a mean regression coefficient and its variance.

RESULTS AND DISCUSSION

Distribution

Surveys suggest that in 1984 the elephant range was a fairly restricted area in the north of Botswana (Figure 6). Since then the range has expanded substantially (Figure 7). Most elephants in northern Botswana now occur outside protected areas and there are very marked differences between their wet and dry season ranges. Their wet season range is large (about 100,000 km²) and extends almost throughout the north (Figure 8). It shrinks to about 60,000km² in response to the drying-up of seasonal pans and streams when the animals concentrate (Figure 9) near the major rivers in northern Botswana (the Chobe, Linyanti and Kwando rivers) and in the Okavango Delta. Densities in some areas can be extremely high at this time of the year - for example 7/km² and 4/km² along the Linyanti and Chobe rivers respectively. In the wet season, when elephants disperse, densities in these two areas are reduced to 2/km² and 0.5/km² respectively, although there are a few other areas in which there appear to be high densities throughout the year. When pans persist well into the dry season following a good rainy season, however, elephants may remain widely dispersed throughout the year.

Surveys show general population movements but may miss important minor details: following particularly good

Table 2. Estimates of elephant numbers in northern Botswana from 1987 to 1995 using aerial surveys.

Date	Estimate	95% Range		
1987 (January)	50,440	40,352	-	60,528
1987 (June)	40,530	26,750	-	54,310
1989 (February)	66,051	45,554	-	86,548
1989 (September)	59,896	42,806	-	76,987
1990 (April)	49,064	37,276	-	60,878
1990 (September)	55,835	35,635	-	76,036
1991 (March)	64,916	44,864	-	84,968
1991 (September)	68,771	50,571	-	86,971
1993 (May)	73,901	44,052	-	103,751
1993 (September)	79,033	65,364	-	92,701
1994 (April)	54,927	41,082	-	68,772
1994 (September)	78,304	61,477	-	95,131
1995 (April)	81,041	64,371	-	97,711
1995 (September)	77,916	59,918	-	95,925

rainy seasons, extremely long-distance movements of small numbers of elephants have been recorded. For example, in February 1997 a pair of elephants moved from the north through the Central Kalahari Game Reserve until they were shot as problem animals by the Department of Wildlife and National Parks (DWNP) staff in the Kang area of south-west Botswana. They had traveled a distance of more than 44)0km. Shortly after this another elephant, which may also have originated in the north, was shot south of the Gemsbok National Park close to the South African border, and nearly 1,000km from the Chobe river (Nagafela, 1998). Tracking the progress of the animals which villagers reported had passed derived this information. While elephants have been known to move very long distances elsewhere in Africa (eg. Thouless and Dyer, 1992) in response to season, the significance of the movements reported here is that the animals traveled through regions that have not been occupied by elephants for perhaps a hundred years.

Family groups of elephant appear to have slightly different ranges from bull groups and tend to occur in habitats with easier access to water than do bulls (Figures 10 and 11). Bulls are generally more widely dispersed, especially around the periphery of the range.

The number and trend of elephant populations

The estimated rate of increase from the regression is 6.0% per annum (Figure 12). Although this is statistically significant ($t = 4.3165$, $P<0.01$), there is a wide range of uncertainty around the actual estimated value, with a 95% probability that the rate of increase is between 2.9% and 9.2%. The estimated rate of increase obtained by the Monte Carlo simulation was 6.05% (range 3.1% to 9.1%). This result is sufficiently close to that from the regression analysis to give confidence that the violations of assumptions involved in using the latter are not serious.

This estimate is fairly close to predictions from other sources for northern Botswana (Calef, 1990, calculated a growth rate of 5.7%) and for adjacent Zimbabwe (rates of between 4% and 5% were estimated by Cumming, 1981 and Craig, 1989). It is also well below the theoretical maximum instantaneous rate of increase for elephants (r_{max}) calculated as, for example, 7.4% per annum (FGU Kronberg, 1988). The latter figure should be taken as a realistic upper limit in preference to the upper confidence limit of 9.2%. It can be expected that

as the time-series of available data lengthens, the precision of the results will increase and it will become possible to state the estimate of the rate of increase with more confidence.

When interpreting such data, the possibility of bias exaggerating the trend should be borne in mind. When monitoring takes place over many years, there can be a drift in procedural standards (eg. transect strip widths have changed; control of height may have improved; accuracy of navigation certainly has improved) which could cause a false trend in numbers. Improvements in techniques are aimed at eliminating bias (especially under-counting) because where there is a bias, that bias may change and produce spurious increases or decreases. However, the endeavour to achieve perfection in this could itself produce an upward trend in estimates. This possibility, however remote, can never be ruled out until there are sufficient data that the detected increase exceeds any possible false trend.

A second caution is that population increase, even if real, does not necessarily imply natural increase through breeding. The northern Botswana population is not closed and net immigration or emigration could occur from neighbouring countries. A measure of the intrinsic rate of increase of the population is not possible until a time-series of estimates of the entire regional population becomes available. Although simultaneous surveys of neighbouring Namibia and Zimbabwe have been carried out, (Craig, 1996), the available data are insufficient to determine an overall trend.

Finally, it is worth repeating that one cannot use estimates of Botswana's elephant numbers prior to 1987 to demonstrate a trend over a longer period. Results before 1987 are not useful and cannot be made useful in an analysis of trends, because no complete and objective surveys were done. Any estimate of trend based on these would be no better than a guess. This emphasises the value of complete, repeated and standardised surveys.

ACKNOWLEDGEMENTS

This paper is published with the permission of the Director of the Department of Wildlife and National Parks, Botswana.

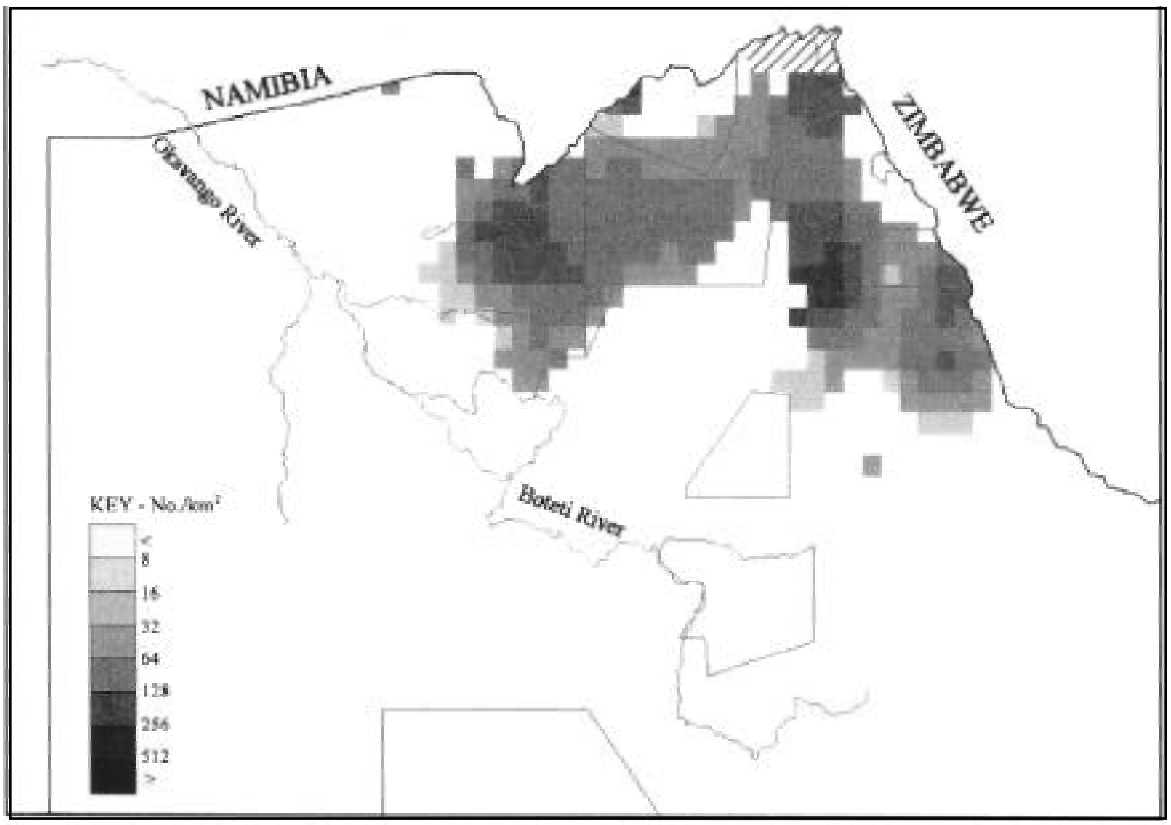

Figure 6. The 1984 distribution of elephants in northern Botswana (hatching shows unsurveyed area likely to contain elephants).

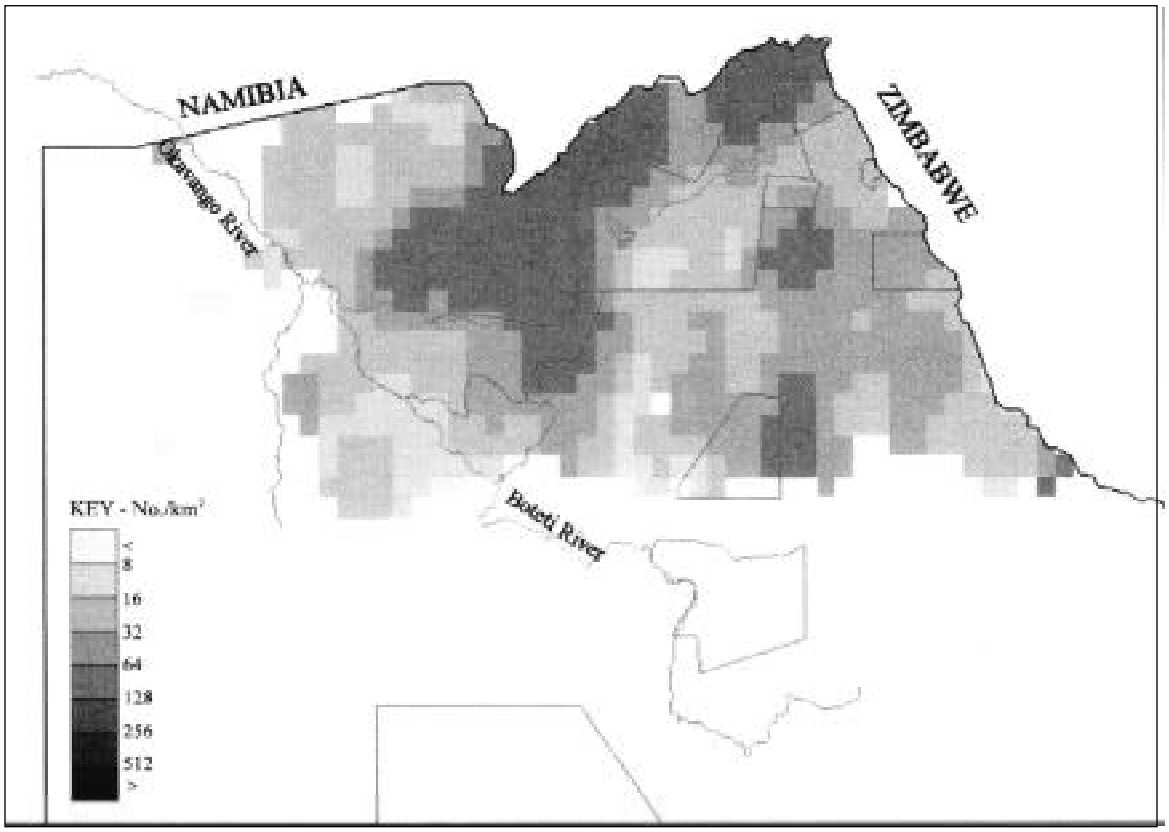

Figure 7. Mean distribution of elephants in northern Botswana from 1989 to 1995.

The contributions of the many participants in surveys over the years are appreciated.

REFERENCES

Astle, W.L. and Graham, A. (1976) Ecological investigations of the UNDP in the Okavango Delta, In: *Symposium on the Okavango Delta,* Botswana Society, Gaborone.

Biggs, R.C. (1979) *The ecology of Chief's Island and the adjacent flood plains of the Okavango Delta, Botswana* MSc thesis, University of Pretoria

Bonifica (1992) *Aerial Surveys,* Final Report to Dept Willdlife and National Parks, Ministry of Commerce, Botswana.

Calef, G.W (1988) Aerial census of large mammals in northern Botswana 1987, *Internal Report, Dept. Wildlife and National Parks, Botswana.*

Calef, G.W (1990) Elephant numbers and distribution in Botswana and north-western Zimbabwe, *Management of the Hwange Ecosystem,* Workshop sponsored by USAID.

Calef, G.W (1993) Numbers and distribution of wildlife and domestic stock in Ngamiland and Chobe Districts January to April 1989, *Internal Report, Dept Wildlife and National Parks, Botswana.*

Campbell A.C. (1990) History of Elephants in Botswana, *The Future of Botswana's Elephants,* Workshop of the Kalahari Conservation Society and Dept. Wildlife and National Parks.

Caughley, G. (1977) *Analysis of vertebrate populations,* John Wiley and Sons Ltd, Chichester, New York, Brisbane, Toronto.

Caughley, G. and Birch, L.C. (1971) Rate of increase, *J. Wildl. Mgmt.* 35(4): 658 - 663.

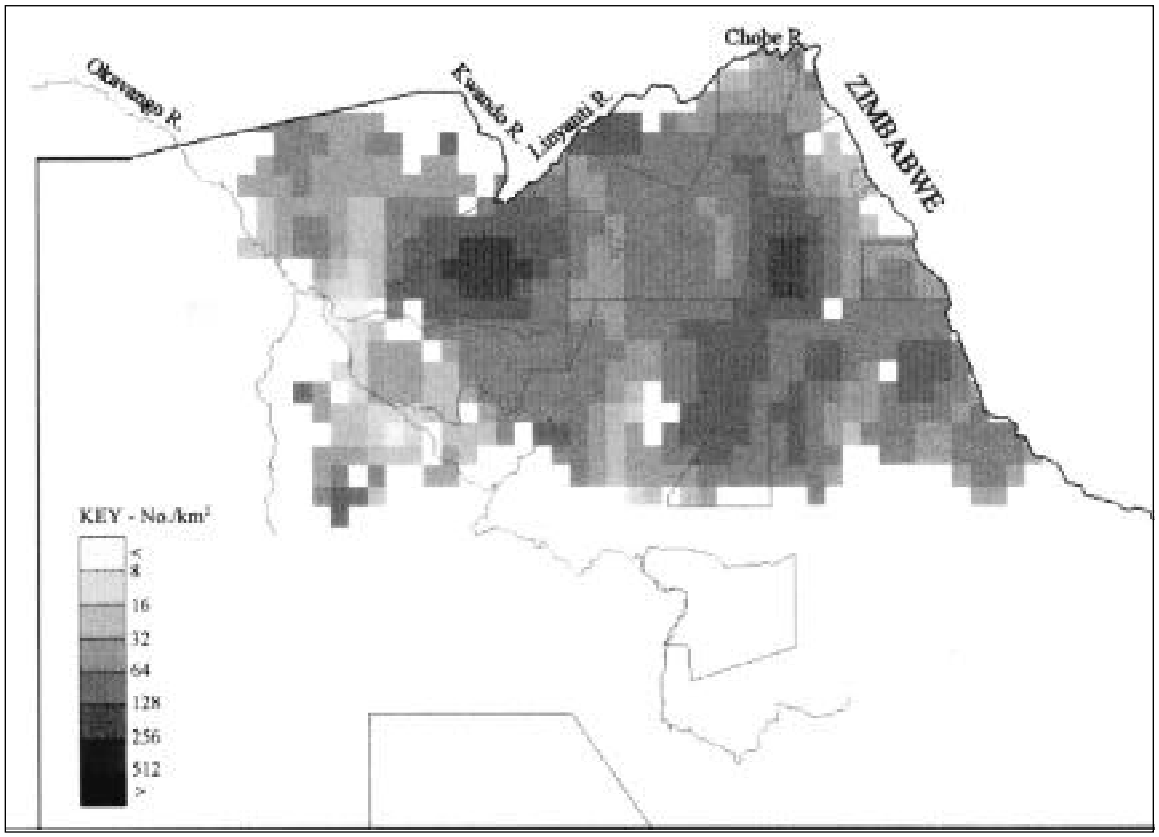

Figure 8. Mean wet season distribution of elephants in northern Botswana.

Caughley, G. and Krebs, C.J. (1983) Are big mammals simply little mammals writ large? *Oecologia* 59: 7- 17.

Child, G.F.T. (1968) An ecological survey of northeastern Botswana, Report to the Government of Botswana, F.A.O. Report No. TA 2563.

Craig G.C. (1989) Population dynamics of elephants, In: Eds R.B. Martin, G.C. Craig and V.R. Booth, *Elephant Management in Zimbabwe,* Dept National Parks and Wildlife Management, Zimbabwe.

Craig G.C. (1991) 1991 dry season survey of northern Botswana, *Report to Dept. Wildlife and National Parks, Botswana.*

Craig G.C. (1996) *ELESMAP Project: Final Technical Report,* CEC project No. B7-5040, Namibia Nature Foundation.

Cumming D.H.M. (1981) The management of elephant and other large mammals in Zimbabwe, In: *Problems in management of locally abundant wild mammals,* Eds. P.A. Jewell and S. Holt, Academic Press, New York.

DWNP (1993) Aerial survey results, *Internal Report, Dept Wildlife and National Parks, Botswana.*

DWNP (1995) Results of a wet season aerial survey of 1995, *Dept. Wildlife and National Parks, Botswana.*

FGU-Kronberg (1987) *Special Report: Review of the aerial monitoring programme,* Report to Dept Wildlife and National Parks, Ministry of Commerce.

FGU-Kronberg (1988) *Estimation procedures for the setting of controlled hunting area quotas,* Report to Dept Wildlife and National Parks, Ministry of Commerce.

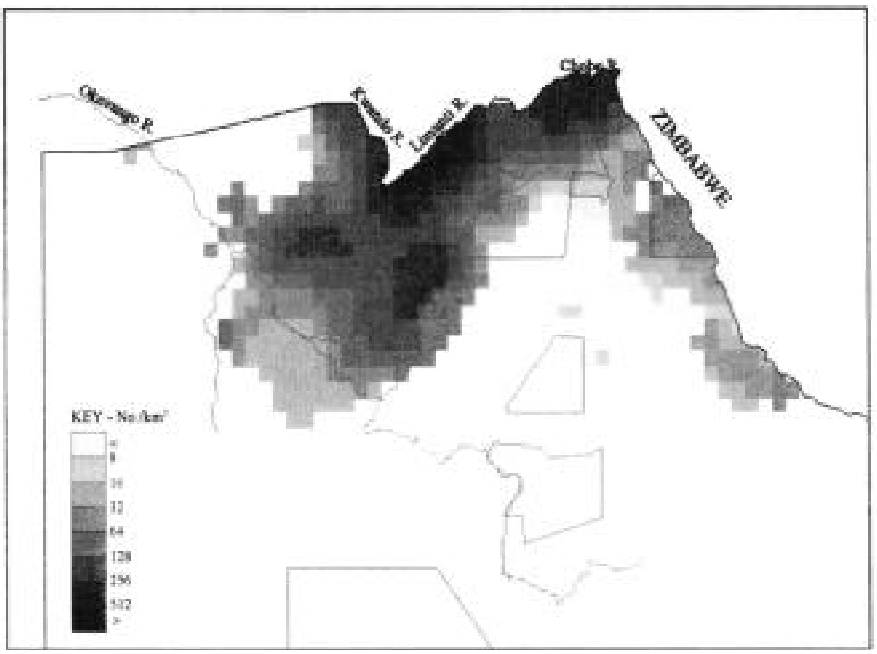

Figure 9. Mean dry season distribution of elephants in northern Botswana.

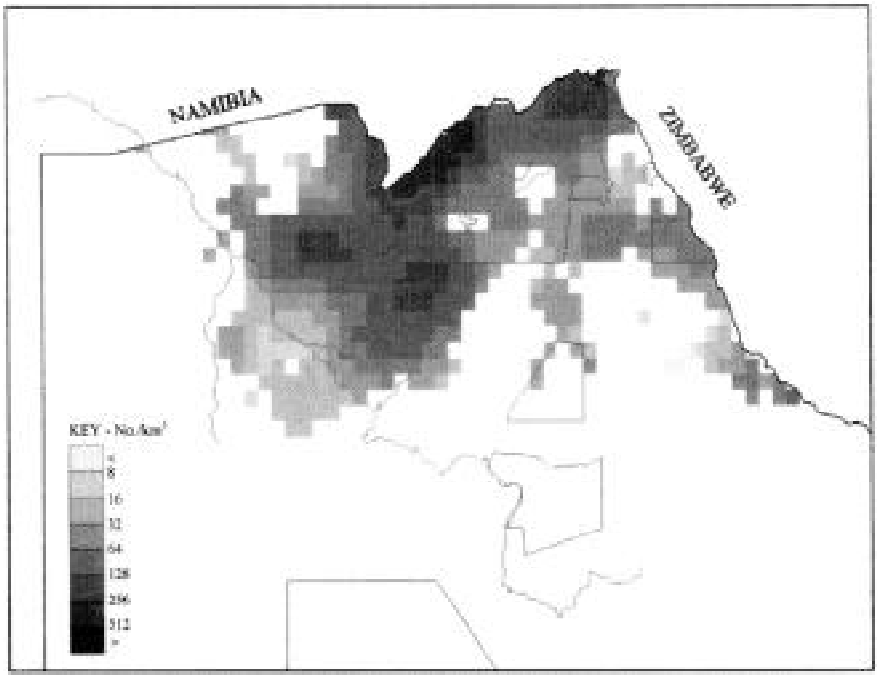

Figure 10. Mean distribution of elephant family groups in northern Botswana.

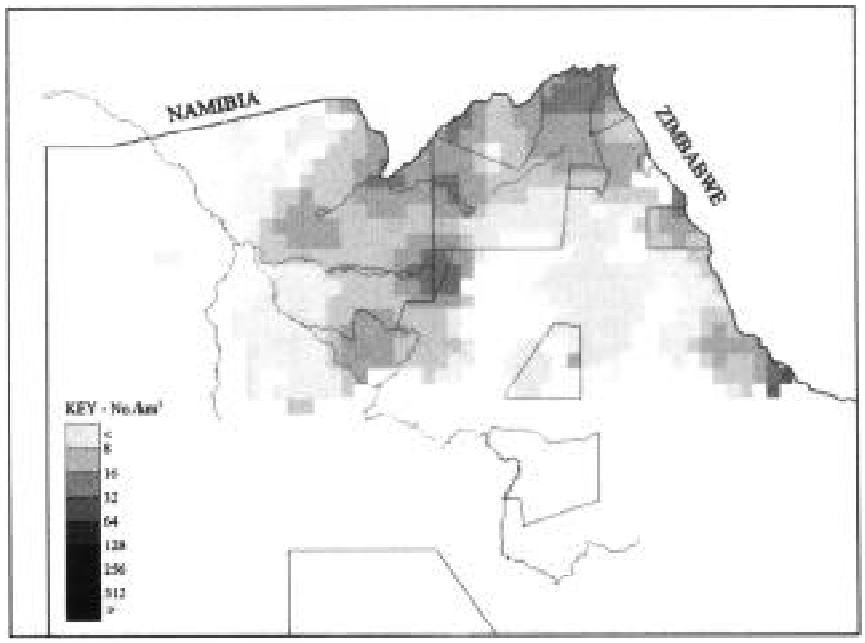

Figure 11. Mean distribution of elephant bull groups in northern Botswana.

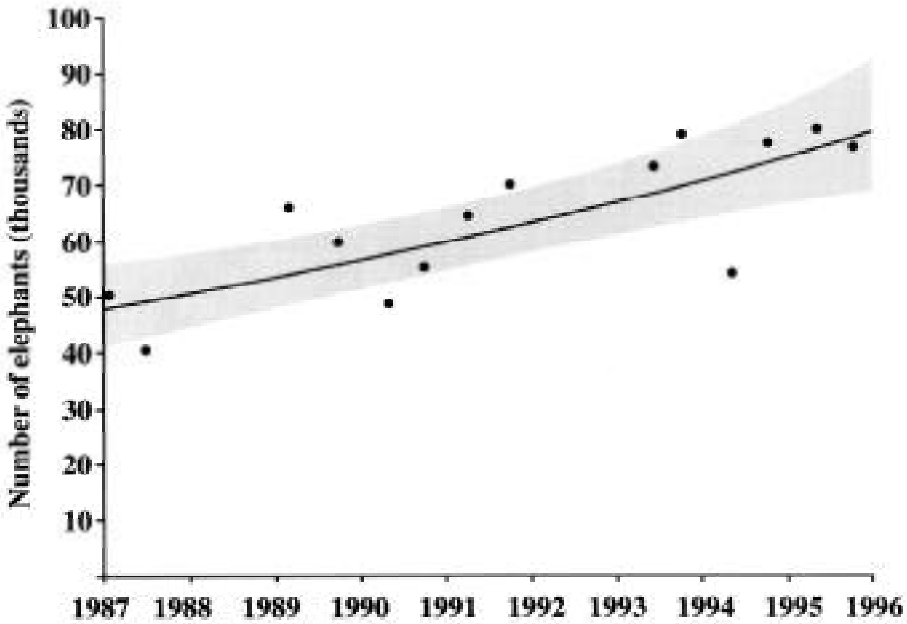

Figure 12. Trend of northern Botswana's elephant population ($y = 10.7732\ e^{0.05826x}$). Shaded area indicates 95% confidence limits for the estimate derived from the regression.

Gavor, I.K.N. (1987) Aerial surveys in the Chobe District: Wildlife Data 1987, *Internal Report, Dept Wildlife and National Parks, Botswana.*

Jolly, G.M. (1969) Sampling methods for aerial censuses of wildlife populations, *E Afri. Agricultural and Forestry Journal - special issue:* 46-49.

KCS (1984) *Aerial monitoring of major wildlife species in Northern Botswana,* Kalahari Conservation Society, report to Dept. Wildlife and National Parks, Botswana

KCS (1985) *Aerial monitoring of major wildlife species in Northern Botswana, The second survey: Oct/Nov 1984,* Kalahari Conservation Society, report to Dept. Wildlife and National Parks, Botswana

KCS (1985) *Aerial monitoring of major wildlife species in Northern Botswana, The third survey: March 1985,* Kalahari Conservation Society, report to Dept. Wildlife and National Parks, Botswana

Melton (1985) The status of elephants in northern Botswana *Biol. Conserv. 31:* 317-333.

Nagafela, N.V. (1998) Annual report of Kgalagadi District, *Internal report, Dept Wildlife and National Parks, Botswana.*

Norton-Griffiths, M. (1978) *Counting Animals,* African Wildlife Foundation, Nairobi, Handbook No. l, pp 139.

Sokal R.R. and Rohlf, F.J. (1995) *Biometry,* W.H. Freeman and Co. New York.

Sommerlatte, M.W.L. (1976) *A survey of elephant population in north -eastern Botswana,* Report to Dept. Wildlife and National Parks, Botswana.

ULG (1993) *Aerial Census of animals in northern Botswana, September 1993,* Report to Dept. Wildlife and National Parks, Ministry of Commerce, Botswana.

ULG *(1994a) Aerial Census of animals in Botswana, wet season 1994,* Report to Dept. Wildlife and National Parks, Ministry of Commerce, Botswana

ULG (1994b) Aerial *Census of animals in Botswana, dry season 1994,* Report to Dept. Wildlife and National Parks, Ministry of Commeree, Botswana.

Work, D.R. (1986) Summary report of aerial surveys conducted in 1983, 1984 and 1985, Typed manuscript.