Elephant numbers in Kafue National Park, Zambia

*Robert A.R. Guldemond, Emily R. Lehman, Sam M. Ferreira, Rudi J. van Aarde**

Conservation Ecology Research Unit, Department of Zoology and Entomology
University of Pretoria, Hatfield 0028, South Africa
*corresponding author: rjvaarde@zoology.up.ac.za

Abstract

Aerial surveys of Kafue National Park in Zambia suggest that 3729 ± 1602 (SE) elephants were present in the park in 2001 and 1555 ± 447 in 2004. Elephant numbers may have declined between these surveys, but the wide confidence limits do not allow us to define a trend in population. A comparison of our estimates with the outcomes of earlier surveys suggests a decline over the past 14 years. However, both movements of elephants between the park and game management areas and differences in the extent of the areas surveyed confounded comparisons of the census results. To allow for comparisons, future survey designs should include both the park and the game management areas.

Additional keywords: aerial survey, estimate precision, game management areas, population growth

Résumé

Des études aériennes du Parc National de Kafue, en Zambie, suggèrent que 3729 ± 1602 éléphants vivaient dans le parc en 2001 et 1555 ±447, en 2004. Les chiffres pourraient avoir baissé entre ces deux études, mais les grandes marges de confiance ne nous permettent pas de définir un e tendance pour cette population. Une comparaison de nos estimations avec les résultats d'études antérieures suggère un déclin depuis 14 ans. Cependant, les déplacements des éléphants entre le parc et les aires de gestion de la faune, et des différences de superficie entre les aires étudiées rendent caduques les comparaisons entre les résultats des recensements. Pour permettre de telles comparaisons, les futures études devraient inclure le parc et les aires de gestion de la faune.

Mots clé supplémentaires : recensement aérien, precision d'estimation, aires de gestion de la faune, la croissance de population

Introduction

A worldwide ban on elephant products (Stiles 2004) assisted the anti-poaching programmes the Zambian Wildlife Authority launched or sanctioned to deal with their waning elephant populations (Lewis 1989; Jachmann and Kalyocha 1994). One of these regions was Kafue National Park and its surrounding game management areas. The number of elephants present in the region apparently declined. Since the mid-1980s, though, control of poaching has been high on the management agenda (Lewis 1989; Lewis and Alpert 1997). Such management may have led to an increase in Kafue's elephant numbers. Here we provide details of two recent estimates of population size to evaluate trends in elephant numbers in the park.

Study area

Kafue National Park is situated in south-central Zambia between 14°03'–16°43' S and 25°13'–26°46' E; it covers an area of 22,480 km^2 (Mwima 2001). There are no fences between the park and the adjacent game management areas (fig. 1). Yearly rainfall ranges from 600 mm in the south to 1200 mm in the north of the park (NPWS/JICA 1999), with the rainy season extending from October to April (Mwima 2001). Mixed woodlands (Kalahari sandveld, miombo and mopane), *Baikiaea* forests, termitaria vegetation and seasonally flooded grasslands are the key features of the landscape (NPWS/JICA 1999).

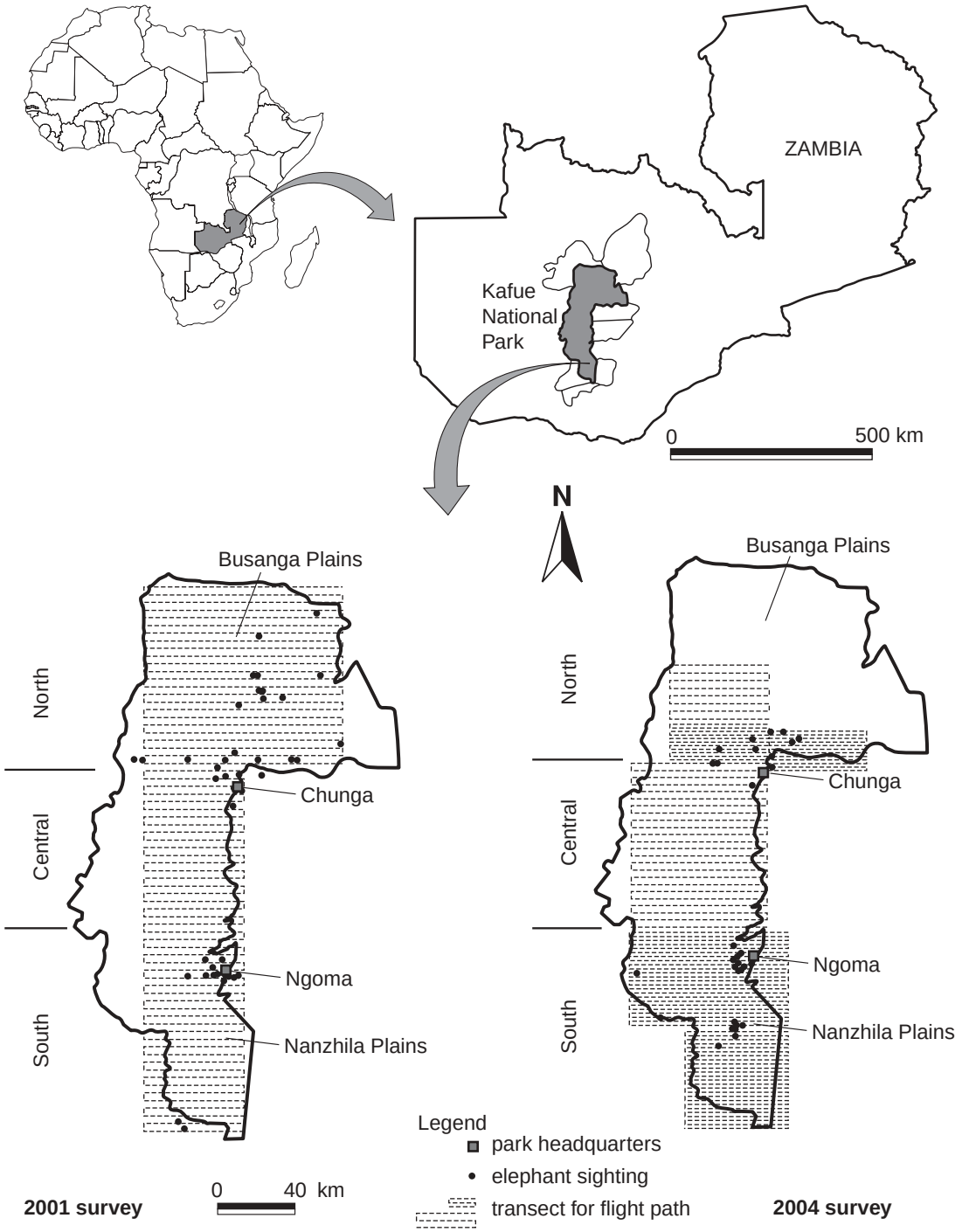

Figure 1. Kafue National Park and surrounding game management areas are situated in south-central Zambia. Transects overlying the park indicate the flight paths for the 2001 (left) and 2004 (right) elephant surveys. The south, central and northern strata used for each year are illustrated. Elephant sightings centred on the southern (Ngoma) and northern (Chunga) headquarters, the Nanzhila Plains in the south and the Busanga Plains in the north.

Materials and methods

We opted for aerial surveys that allow for rapid assessment of large numbers of animals spread over vast areas (Norton-Griffiths 1978). Fairall and Kampamba (2001) reported on our September 2001 survey, but we re-analysed the raw data in our present report. We surveyed the southern sector of the park in September 2004 and the central and northern sectors during the first week of the following November. The onset of the rainy season and aircraft failure did not allow us to complete the 2004 survey of the park's northernmost regions. Here, seasonal movements induced by the onset of the rainy season could violate survey assumptions and potentially bias a population estimate (Caughley 1974).

We used GIS techniques to place strip transects systematically across most of the park, some of which overlapped with the adjacent game management areas (see fig. 1). During 2001, coverage within the survey area was 21%. For this survey, we placed markers on the windows of a Cessna 210 to represent 420 m on the ground on each side of the aircraft. The aircraft flew at 160 km h^{-1} and maintained a height of 160 m above the ground. No radar altimeter was available. The landscape of the park is relatively flat and we thus assumed that the height measured using a conventional altimeter was relatively constant. Two observers, one positioned on each side of the aircraft, recorded elephant data and relayed information via intercom to a survey coordinator.

The 2001 survey consisted of 70 transects and the 2004 survey of 113. Following our correction of strip width, the 2001 survey covered 21% of the survey area (fig. 1).

During 2004, we sampled predetermined strata at various intensities based on the expected elephant distribution noted in the 2001 survey. We surveyed areas where we expected large numbers of elephants in 81 transects at 43.2% (transects spaced at 1 nautical mile) and those where we expected low numbers in 32 transects at 21.6% (transects spaced at 2 nautical miles) (fig. 1). For this survey, we placed markers on the Cessna 210 wing struts to represent 400 m on the ground on each side of the plane flying 100 m above the ground. We maintained a flying speed of 175 km h^{-1} during surveys, using an aircraft-fitted global positioning system to track our flying path. The pilot maintained height using a radar altimeter. For both surveys, we used standard techniques (see Norton-Griffiths 1978) to calibrate and verify strip width.

During the 2004 survey, each of the two observers used a Canon EOS 10D digital SLR camera to take multiple images of elephants found along transects. From these we counted the numbers of elephants that we saw in each transect.

Analyses

The clumped distribution of elephant sightings required us to use a stratified analysis to get a more precise population estimate (Caughley 1977). We therefore distinguished between the southern, central and northern sectors of the park. We based our population estimates for each of these sectors on method II of Jolly (1969) for transects of unequal sizes using a sample design without replacement of transects.

Fairall and Kampamba (2001) used all the elephant sightings they made up to 2000 m on each side of the flight path during September 2001. Their estimate of 2194 elephants had wide confidence limits (95% confidence interval: 768–3620, confidence limit = 65%) and was based on the assumption that they saw all the elephants within such a wide strip. Their effort to correct for this by analysing distance data in a distance-sampling design yielded an estimate of 2141 with an even wider confidence limit (95% confidence interval: 983–4662, confidence limit = 86%). In an effort to reduce confidence limits and minimize the influence of distance on estimates, we opted to recalculate this 2001 estimate. For this we used only the data collected between 80 and 500 m on either side of the aircraft and Jolly's method II (1969).

We used estimates to calculate densities for each of the three sections of the park and used these to extrapolate section-specific population sizes. The population sizes were the product of densities and area, while the variances in population sizes came from the products of variance in density and area squared (Glen et al. 2004). Our estimate of population size for the park is the sum of the values for each of the three sections for each survey year. Variances for these estimates were the sum of all the section-specific variances (Spiegel 1975). We calculated population growth rate (see Caughley 1977) using estimates extracted from the literature for the park's elephants over the last 14 years.

Results

During the 2001 survey, 1096 elephants were recorded at 42 locations while we recorded 582 elephants on

38 occasions during the 2004 surveys. Sightings were clumped and most elephants were seen in either the south or the north sections during 2001 and 2004 (fig. 1). Most were in the proximity of the park's southern and northern headquarters, as well as on the Nanzhila Plains.

Our estimate (± SE) of 3798 ± 1635 elephants for the 2001 survey area is higher than that estimated by Fairall and Kampamba (2001). Our approach did not reduce the 95% confidence interval (our estimate: 6408; Fairall and Kampamba's (2001) estimate: by Jolly's method 2852 and by distance estimate 3679), but had a confidence interval of 84.4%, which is similar to that of the distance estimate (86%) and higher than that of Jolly's estimate (65%). Our extrapolation yielded an estimate of 3729 ± 1602 elephants for the park in September 2001 (table 1).

The survey in 2004 yielded an estimate of 1337 ± 451 (95% confidence interval: 452–2221) elephants for the survey area (table 1). The percentage confidence interval was 66.2%. Our extrapolation yielded an estimate of 1555 ± 447 elephants for the park during the 2004 surveys (table 1).

Earlier estimates of the elephant population in the Kafue region were based on either surveys of the park alone or surveys that also included the game management areas (table 2). Estimates ranged widely, and though mostly imprecise, they suggest that elephant numbers in the park decreased by 9.3% per year over the past 14 years ($F_{1,6} = 6.66$, $p = 0.04$) (fig. 2). We noted no trend in the percentage confidence limits over time ($F_{1,2} = 0.23$, $p = 0.67$).

Discussion

Elephant numbers are increasing across most of southern Africa (see Blanc et al. 2005), but this may not hold for Zambia (see table 2 in Blanc et al. 2005). Given the anti-poaching campaigns across the Kafue region (see Lewis 1989), we expect that elephant numbers in Kafue National Park would show signs of recovery, especially when considering that elephants used to occur here in higher numbers (see table 2). The census estimates reported here do not support our expectation (fig. 2). This could be for several reasons, the most important being inconsistent survey designs.

The precision of repeated estimates affects the confidence in calculated population growth rates. For instance, the conditions that give rise to possible estimate biases should always be taken into account (Caughley 1974, 1977). To improve estimates we limited the effect of survey effort (Craig 1993) by using systematic aerial surveys that covered 21–43.2% of the area. It is not clear if this was the case in earlier surveys across the Kafue region. During the 2004 survey we maximized our ability to count the correct number of ele-phants in large herds by using aerial digital photography (Redfern et al. 2002) and kept our search rate per observer relatively low (1.16 km^2 min^{-1}). Even so, we realize that our surveys yielded estimates that do not necessarily represent true population sizes. We recognize that estimates also may be influenced by observer fault (see Watson et al. 1981) and by elephants that may not be available for the sample or if they are, are not detectable (see Beavers and Ramsey 1998).

Table 1. Elephant population and density estimates for the southern, central and northern sectors of Kafue National Park, Zambia, from the 2004 and recalculated 2001 surveys (only elephants seen within the first 500-m survey strip)

	South				Central				North				Total			
	2001[a]	2001[b]	2004[a]	2004[b]	2001[a]	2001[b]	2004[a]	2004[b]	2001[a]	2001[b]	2004[a]	2004[b]	2001[a]	2001[b]	2004[a]	2004[b]
Population estimate	2220	2063	1055	810	11	14	102	163	1566	1651	180	582	3798	3729	1337	1555
Standard	1274	1184	436	335	11	14	81	130	1024	1080	82	266	1635	1602	451	447
Upper 95% CL	4717	4388	1910	1467	34	42	261	417	3573	3768	341	1103	7002	6869	2221	2431
Lower 95% CL	–277	–257	199	153	–11	–14	–57	–91	–441	–465	19	61	594	588	452	679
Density	0.354		0.152		0.002		0.025		0.141		0.049					

We report estimates for the survey areas representing each stratum and, by extrapolation, for the corresponding areas of Kafue National Park.
[a] estimate for the survey area; [b] estimate after proportional linear extrapolation; CL – confidence limit

Table 2. Elephant population estimates for Kafue National Park and adjacent game management areas (GMAs), 1991–2004

Year	Total	Kafue National Park	Kasonso–Busanga GMAs	Lunga–Luswishi GMAs	Mumbwa GMA	Namwala GMA	Sichifula & Mulobezi GMAs	Reference
1991	10263	5927 (2919–8935)	–	125 (0–351)	2538 (0–6486)	–	1673 (0–3789)	Said et al. 1995
1994	3862	3862	–	–	–	–	–	Yoneda and Mwima 1994
1995	3840	3840	–	–	–	–	–	Yoneda and Mwima 1995
1996	4980	4482 (1260–7704)	0	0	124 (0–229)	–	374 (0–1060)	Zyambo 1997
1997	5250	5250	–	–	–	–	–	NPWS/JICA 1999
1999	4104	1453	–	–	2435 (0–3017)	216 (0–627)	–	Jachmann 2000
2001	3729	3729 (588–6869)	–	–	–	–	–	This study
2004	1555	1555 (679–2431)	–	–	–	–	–	This study

Values in brackets refer to the 95% confidence interval. All estimates are based on aerial surveys.

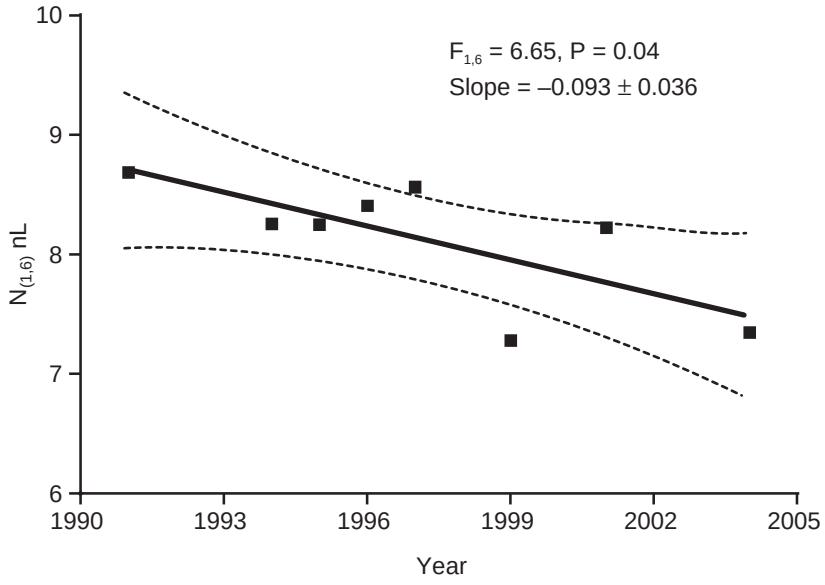

Figure 2. The natural logarithm of the number of elephants (N_t) recorded in Kafue National Park and the surrounding game management areas since 1990. The slopes of the linear regressions provide estimates of the exponential growth in population sizes. Elephant numbers appear to have decreased from 1991 to 2004.

We are concerned with factors underlying the continued decline of elephant numbers estimates (see fig. 2) in the park. Ignoring the confounding influences of survey design, factors such as poaching, changes in ranging behaviour, distributional ranges and vegetation cover may account for the declining estimates. The uneven distribution of elephants across the park, however, is probably one of the most important variables limiting estimates and their precision.

Our surveys suggest that at the end of the dry season elephants in the park occur in two discrete areas. These areas are associated with the two park headquarters, and the clumped distributions we observed may be related to apparent localized protection from poaching. Alternatively, landscape conditions may explain these localities—for instance, historical records suggest that Ngoma Forest adjacent to the present southern headquarters served as an elephant stronghold (J. Hanks, pers comm.).

Population growth of elephants varies (Jaarsveld et al. 1999; Slotow et al. 2005) but cannot exceed 7% per year for long periods (Calef 1988). Aerial counts of elephants at yearly intervals seldom provide data that are precise enough to estimate intrinsic population growth rates. In spite of this, repeated estimates often define growth rates in elephant populations (for example Blanc et al. 2005). Before calculating population growth, managers should carefully consider trends defined by repeated aerial surveys. They may improve the precision of calculated trends by increasing the number of survey efforts or, alternatively, using demographic variables to model potential changes in their elephant populations. Due to the imprecision of surveys in Kafue National Park during the past 14 years, we cannot evaluate whether the long-term decline in numbers continues. In the future, emphasis needs to be placed on survey intensities, with resources channelled to cover the expected distributional range of elephants as part of a national survey strategy, rather than site-specific yearly counts.

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