SURVEY EXPERIMENTS AND AERIAL SURVEY OF ELEPHANTS IN THE SOUTH LUANGWA NATIONAL PARK AND THE LUPANDE GAME MANAGEMENT AREA, ZAMBIA, 1993.

Hugo Jachmann

Luangwa Integrated Resource Development Project, PO Box 510249, Chipata, Zambia

INTRODUCTION

The Luangwa Valley Ecosystem, covering a total of 144,000km^2 in Zambia's Eastern Province, runs from the Nyika highlands in the north to the Zambezi Valley in the south. It is one of the last unique wilderness areas remaining in Africa. The South Luangwa National Park (SLNP) covers some 9,050 km^2 and is located in the central part of the Luangwa Valley. Together with the adjacent Lupande Game Management Area (LGMA) covering approximately 5,000 km^2 to the east of SLNP (Figure 1) they form the operational area of the Luangwa Integrated Resource Development Project (LIRDP). LIRDP is a community-based resource management project, mainly funded by the Norwegian Government (NORAD) and The Netherlands Government (DGIS).

As a result of commercial illegal hunting for ivory and rhino horn, from the mid-1970s to the late 1980s, the populations of both rhinos and elephants have been severely reduced, with the rhino now close to extinction. In the LIRDP area, the elephant population declined from approximately 35,000 in the early 1970s to 2,400 in 1988, while during this same period the rhino population was reduced from several thousand to a mere remnant (Bell *et al.,* 1994; Jachmann 1993a, 1994). With the onset of the law-enforcement operations of LIRDP in 1988, illegal hunting rates declined to a level of approximately 10 elephants killed per year. As a result, from 1988 to 1993, the elephant population increased from 2,400 to approximately 6,000, partly due to immigration and partly due to natural recruitment (Jachmann, 1993a, 1994).

In 1993, two aerial counts were carried out using different survey designs in order to estimate numbers of elephants and some of the other large herbivores, for use as feedback for law-enforcement operations and to provide baseline data for use in the preparation of a management plan, scheduled for 1994.

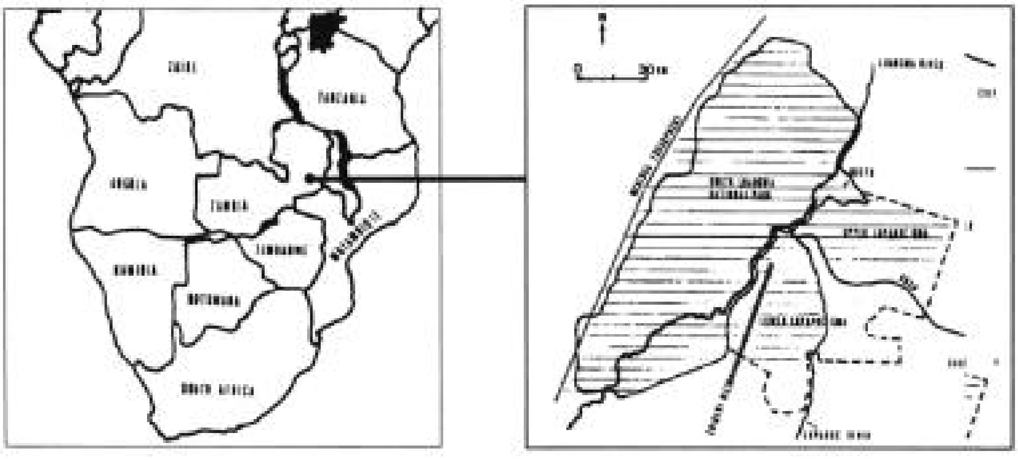

Figure 1. Location of South Luangwa National Park and the Lupande Game Management Area in the central Luangwa Valley in Zambia's Eastern Province. Horizontal lines are flying paths on 5km gird lines.

STUDY AREA

The survey area incorporated the SLNP, including the small Nsefu Sector (200 km^2) on the east bank of the Luangwa River, and the LGMA, divided into the Upper Lupande and Lower Lupande hunting blocks (Figure 1). With the exception of the Chideni Hills in the Lower Lupande area and some hills in the eastern part of the Upper Lupande area (eastern escarpment), most of the survey area was flat and only slightly undulating towards the Mchinga escarpment.

The vegetation of the alluvial complex consists predominantly of deciduous dry woodland with *Colophospermum mopane* on shallow alkaline clay soils and *Combretum/Terminalia* on freely draining soils. In the north of SLNP and part of the Nsefu Sector there are several vast grassland plains with *Setaria eylesii* and *Hyparrhenia rufa*. The vegetation of the escarpment and plateau areas is dominated by miombo woodland with *Julbernardia* and *Brachystegia* species.

The dry season runs from mid-April to mid-November. Approximately 700-800mm of rain falls mainly from December to March.

METHODS

Survey Design

The survey area was not stratified on account of a limited budget and small groups of elephants, more or less evenly distributed over most of SLNP (confirmed by ground observations). In addition, the minimal gain in precision from stratified counts does not usually outweigh the extra expense and the loss in information on the distribution of the population under study.

The first aerial count was carried out in the early dry season (4-7 June) and covered the entire project area. Transects were accurately flown with the aid of a global navigation unit, whereby the beginning and end of a transect were determined by distinct features in the landscape. In SLNP, transects were flown east to west between the Luangwa River and the Mchinga escarpment. In the Lower Lupande transects were flown east to west between the Luangwa and Lupande Rivers, and in the Upper Lupande, transects were flown east to west between the Luangwa River and the eastern boundary of the GMA (Figure 1).

The second count was carried out in the late dry season (16-18 October), and incorporated SLNP only. The Nsefu Sector had been covered during a separate survey, funded by the World Wide Fund for Nature (WWF), carried out annually in the month of October (A. Pope, pers. comm.). During the second count in SLNP, some of the other large herbivores were also counted (e.g. buffalo, eland, giraffe, hartebeest, kudu, roan, waterbuck and zebra), while in the small Nsefu Sector, all species larger than impala were counted (A. Pope, pers. comm.).

Flying paths were along 5km grid lines (Figure 1), with a sampling intensity of 6%. For the WWF sponsored survey of the small Nsefu Sector, flying paths were 1km grid lines with a sampling intensity of 20% (circumstantial stratification!).

Flying Procedures

For both surveys, a Cessna 206 aircraft was used, flying 100m above ground level (AGL), maintained with the use of a barometric altimeter. Height control was not as satisfactory for the hilly parts of the Lupande GMA as for the mainly flat parts of SLNP. However, elephant densities in the hilly areas of the GMA were extremely low, limiting this potential source of error.

Strip widths were set at 140m to each side, with a total transect width of 280m calibrated as indicated by Norton-Griffiths (1978). Flying speed was maintained at an average of 110 knots, giving a searching speed of 57km^2/hour.

During the first survey, the aircraft was manned by a pilot, a navigator and two experienced observers. During the second survey, hc wever, the aircraft was manned by an additional two observers. In order to correct for visibility bias and estimate the bias related to observer experience, the double-count procedure was followed (Caughley, 1974; Graham & Bell, 1988). During the second survey, four observers were used, out of a total of 12, each with a different level of experience.

For the small Nsefu Sector, a Cessna 182 aircraft was used, flying at 100m AGL, maintained with a radar altimeter. Strip widths were set at 100m to each side and flying speed was an average of 95 knots, giving a searching speed of 35km^2/hour (A. Pope, pers. comm.).

Analyses

Live elephants and dead elephants were counted. Dead elephants were categorised as fresh carcasses (skin still visible) and skeletons (bones only), retaining the division used in former aerial surveys covering the LIRDP area.

Visibility bias
During the second survey, the double-count method was used to correct for visibility bias. On both sides of the aeroplane, two observers, one experienced and one less experienced, independently and without collusion, counted groups of nine large herbivores. At the beginning of a session, all watches were set to agree to a second. With each observation, species, time and group size were indicated. If both observers sitting in line recorded a sighting at exactly the same time, it was assumed that it had likely been of the same group (Graham & Bell, 1988).

The corrected number of animals was calculated using an adaptation of the Petersen Estimate (Seber, 1982), Y=yl y2/m, where: Y is population size, yl is the number of animals seen by the front observer, y2 is the number of animals seen by the rear observer and m is the number of animals seen by both observers.

For seven of the nine large herbivore groups counted, a visibility correction factor was estimated. A multiple-linear regression analysis was performed, with the correction factor as the dependent variable. Mean group size, unit weights (Coe *et al.,* 1976) and number of observations for each species were the independent variables. Unit weights, based on age-weight data and population structure, were used as an indication for the average size of individuals of a particular species. The number of observations of each species was used as the independent variable relating to abundance. Tests of the multiple-regression assumptions were performed and met in all cases. The resulting regression coefficients were compared and tested with t-statistics to determine which of the independent variables had the most influence on the relationship.

Final analysis followed Jolly's Method 2 for unequal sized sampling units (Norton-Griffiths, 1978).

Observer experience bias
For each session, the true total number of visible animals in the transects were calculated using the Petersen Estimate. Then, for each observer, the percentage of animals seen as compared to the total number of visible animals was calculated. With the percentage of animals seen by each observer for each separate session as the dependent variable, a multiple-linear regression was performed, using aerial survey experience (hours), current survey experience (hours) and flight duration (session in hours) as the independent variables.

RESULTS

Live Elephants

The survey carried out in June 1993, gave an estimate of 5,263±1,081 elephants for SLNP (including Nsefu) and 666 ± 258 for the LGMA (Jachmann, 1993a). The second count, in October 1993, provided an estimate of 4568+ 649 for SLNP, using a visibility correction factor for elephants of 1.06, and 702 ± 202 for the Nsefu area (A. Pope, pers. comm.) resulting in a total of 5,270 ± 680 elephants for SLNP (including Nsefu), as shown in Table 1.

Table 1. Summary of aerial survey results.

Area	Date	Estimate	S.E.	%	95% C.I. Lower	95% C.I. Upper
SLNP (+Nsefu)	June	5,263	1,081	20.5	3,144	7,382
SNLP (+Nsefu)	October	5,270	680	12.9	3,937	6,603
Lower LGMA	June	438	192	43.8	9	867
Upper LGMA	June	228	172	75.4	0	707

For the October survey, population estimates were corrected for visibility bias, using an adaptation of the Petersen Estimate through a double-count procedure.

Dead Elephants

No fresh carcasses were observed during the surveys. However, in June, the total number of old skeletons in the project area was estimated at 169, while the October survey gave an estimate of 379. The high count during the October survey is mainly due to the improved visibility of skeletons in burned areas. The average carcass ratio for 1993, calculated as a percentage of the combined total number of carcasses and live animals counted, was 4.4%. It should be noted, however, that most of the skeletons observed were a collection of scattered and bleached bones of elephants killed more than four or five years ago.

Visibility Correction Factor

The estimated visibility correction factors ranged from 1.06 for elephants to 2.05 for hartebeest. The multiple-regression model, relating mean group size, individual size and abundance to the sighting probability of the various species counted, was not significant. However, the multiple correlation coefficient was 0.8398, and the model explained 71% of the variation.

Although none of the independent variables had a significant t-statistic (Table 2) the variables of abundance and mean group size had a much greater influence on the sighting probability than the size or the actual biomass of the individuals of a particular group of herbivores. Thus larger group sizes give a higher sighting probability, while an increasing abundance of a particular species enhances the formation of a searching pattern by the observers.

Table 2 Estimated regression coefficients, standard deviations (SD), percentage standard error (SE), computed t-values (t) and significance levels (p).

Variable	Coefficient	SD	%SE	t	p
Mean Group Size	-0.039886	0.029959	75.11	-1.331	N.S.*
Individual Size	0.000080	0.000310	387.50	0.256	N.S.
Abundance	-0.016895	0.009517	56.33	-1.775	N.S.
Intercept	1.986229				

*N.S.= Not Significant

Observer Experience Bias

A multiple-regression analysis was performed using the percentage of animals seen by each observer as the dependent variable, and the Total Survey Experience (TSE) in hours, the number of hours counted in the Current Survey Experience (CSE) and the Flight Duration (FD) of a single session as the independent variables. Although the model had a reasonably good fit, with a multiple correlation coefficient of 0.7045 and a significant F-statistic ($p<0.05$), it explained only 50% of the variation. This implies that several other variables such as eye sight of the observer, capability to concentrate for long periods and familiarity with the area, also play an important role.

Both the variables, TSE and CSE, had significant positive coefficients (i.e. with increasing survey experience more animals were observed), while the variable FD was almost significant at the 5% level, but with a negative coefficient (i.e. with a longer counting session, fewer animals were observed), (Table 3).

Table 3. Estimated regression coefficients, standard deviations (SD), percentage standard error (SE), computed t-values (t) *and significance levels (p).*

Variable	Coefficient	SD	%SE	t	p
TSE	0.278973	0.105267	37.73	2.650	0.02
CSE	4.005720	1.559011	38.92	2.569	0.02
FD	-7.679495	4.678217	60.92	-1.642	N.S.*
Intercept	77.488110				

*NS.=Not Significant

The overall equation has the following form:

% Animals Observed = 0.28 TSE + 4.01 CSE - *7.68* FD +77.49

Using this formula, we can estimate the optimum FD of a single session, as well as the level of experience necessary to observe, for example, 95% of the visible large ungulates in the survey area. The most experienced observer during the October 1993 survey had a TSE of approximately 100 hours. Using a CSE of one hour, the optimum FD for this particular observer would be about two hours. This implies that a less experienced observer would require a longer CSE, i.e. a long session to get acquainted with the area and animals, or alternatively a shorter FD of a couple of hours, because shorter flights will be uneconomical. For the same reason, the parameter CSE should be no longer than two hours.

If the objective is to attempt to spot at least 95% of the visible large ungulates, the observers should have at least 89 hours of TSE.

DISCUSSION

Population Estimates

The two different survey designs gave almost identical results with regard to elephant population estimates, and it is safe to conclude that in 1993 there were approximately 6,000 elephants in the LIRDP area. The double-count procedure resulted in an additional 6% of elephants observed compared to the regular sample survey, using two experienced observers only. However, for the purpose of counting elephants, the slight gain in precision when using the double-count procedure does not outweigh the extra fuel expenses and the risks involved in low-level flying with six crew on board.

From the early 1970s to 1987, the elephant population in the SLNP and LGMA declined from 35,000 to 15,000 (Bell *et al.*, 1994). A further decline occurred between 1987 and 1988, when a large proportion of the population moved away from the project area. Since 1988, the elephant population in the LIRDP area has progressively increased from 2,400 to approximately 6,000. From 1988 to 1989, the population more than doubled, mainly as a result of elephants returning to the LIRDP area from GMA's to the north and to the south of SLNP. From 1989 to 1993, the population increased by a modest 3% per year (Jachmann, 1994).

From 1990 to 1993, on average 10 elephants were killed by illegal hunters each year (Jachmann, 1993b). This, however, should be considered a conservative approximation, because some elephants killed by poachers may not be detected by patrols. However, during this period, elephant mortality cannot have been much higher than this estimate, because no fresh carcasses have been observed from the air since 1990. Hence the majority of skeletons observed during the most recent aerial surveys are at least four or five years old.

Elephant Distribution and Group Size

Both elephant distribution and group size are a function of habitat condition, i.e. mostly seasonal changes in habitat, and disturbance from illegal hunting (Jachmann, 1980, 1983, 1984). Elephants are social animals and maintain close family bonds. During the wet season, when the food situation improves in the form of abundant fodder and grass, group size increases as a result of lowered food competition. In the Luangwa Valley, during most of the wet season, elephants congregate in the alluvial belt, mainly feeding on grasses.

When grass quality falls, during the late rains and early dry season, elephants disperse over the floor of the valley, utilising woodland species that have high concentrations of sodium and simple sugars, but low concentrations of certain plant secondary compounds (Jachmann, 1989a). Any disturbance through illegal hunting results in a more compressed distribution and therefore larger groups, which avoid the most hazardous areas (Jachmann, 1989b).

During both surveys, the population was more or less evenly distributed over the valley floor, with very few elephants east of the Chideni Hills. The mean group size was 4.2 ± 3.8 in June and 3.8 ± 3.0 in October, with the largest observed group numbering 18 animals. These observations, in combination with the absence of fresh carcasses, confirm that there is currently little to no illegal elephant hunting in the area, and that law-enforcement operations under LIRDP are still very effective (Jachmann, 1993b).

Visibility Bias and Observer Experience Bias

While the simultaneous double-count offers an attractively simple method of investigating observer bias, it is emphasised that only the visible population is accessible to this type of investigation (Graham & Bell, 1988). In every aerial survey, depending upon the species, there is a population of invisible animals, hidden from the observers by obstructions such as tree canopies. This source of bias cannot be estimated. Of the visible population, only some groups are seen, while others are overlooked for a variety of reasons. Operational factors, such as speed and height, affect the proportion seen and must be kept within practical limits. A strong decline in sighting probability with height can be expected among observers counting solitary animals and groups of less than four (Graham & Bell, 1988). Although group size strongly influences sighting probability, it is not so much determined by the actual biomass of the individual members of the group, but by the number of individuals in that particular group.

In summary, the sighting probability is a function of aircraft speed and height, species abundance and group size, and also of vegetation density, light conditions, colour patterns of objects to be counted and several unknown factors. In addition, the observer experience bias experiments show that sighting probability is also a function of the total survey experience of a particular observer and, to a similar extent, the experience gained within a particular survey. The intuitive reaction to this may be that each observer has to form a series of searching patterns, a process that depends upon the capabilities of the observer, the abundance of the species, the state of the vegetation and the number of species to be counted. With an increasing experience level of the observer, this process may develop more rapidly.

In the current survey, the observer with the lowest level of experience spotted only 33% of the total visible population during his first two hours of counting, while the observer with the highest level of experience spotted 95% of the visible population during his first two hours of counting. However, with five more hours of counting, the least experienced observer spotted almost 80% of the total visible population, while a slightly more experienced observer with a total of seven hours only spotted 54% during his first two hours.

From the above we may conclude that besides keeping the operational factors within reasonable limits, observers should have a high level of experience and should be allowed to practise (and form search patterns) for several hours prior to each survey, while the duration of each counting session should be kept within the limit of two to three hours.

ACKNOWLEDGEMENTS

I would specifically like to thank all twelve observers for their bravery, their time and co-operation. Special thanks go to Mr. N. MacGreevy for putting up with a tedious task, and above all to Adam Pope for supplying me with the survey data on the Nsefu Sector. I am indebted to NORAD and the Royal Netherlands Government for providing the funds to carry out these surveys.

REFERENCES

Bell, R.H.V., Jachmann, H., Chimbali, D.M. & Mulonda, E.Y. (In Press) Illegal activity and law enforcement in the central Luangwa Valley, Zambia, from 1979 to 1992. *J. appl. Ecol.*

Caughley, G. (1974) Bias in aerial survey. *J. WildI. Man.* 38, 921-933.

Coe, M.J., Cumming, D.H. & Philipson, J. (1976) Biomass and production of large African herbivores in relation to rainfall and primary production. *Oecologia* 22, 341-354.

Graham, A. & Bell, R.H.V. (1988) Investigating observer bias in aerial survey by simultaneous double-counts. *J. Wildl. Man.* 53, 1009-1016.

Jachmann, H. (1980) Population dynamics of the elephants in the Kasungu National Park, Malawi. *Neth. J. Zool.* 30,622-634.

Jachmann, H. (1983) Spatial organisation of the Kasungu elephant. *Bijdrage Dierk.* 53, 179-186.

Jachmann, H. (1984) The ecology of the elephants in Kasungu National Park, Malawi, with specific reference to management of elephant populations in the *Brachystegia* Biome of southern Central Africa. Ph.D. Thesis, University of Gronignen.

Jachmann, H. (1989a) Food selection by elephants in the miombo biome, in relation to leaf chemistry. *Biochemical Syst. and Ecol.* 17, 15-24.

Jachmann, H. (1989b) Nombre, repartition et deplacements des elephant. de Nazinga. *Nature et Faune* 5, 25-35.

Jachmann, H. (1993a) Aerial survey of elephant in the South Lungwa National Park and the Lupande Game Management Area. LIRDP Project Document No. 10.

Jachmann, H. (1993b) Law enforcement performance in the LIRDP area. January-June 1993. LIRDP Project Document No. 11.

Jachmann, H. (In Press) Tusklessness in African elephants; trend for the future. *Afr. J. Ecol.*

Seber, G.A.F. (1982) The estimation of animal abundance. Charles Griffin, London, UK. 624 pp.

Norton-Griffiths, M. (1978) *Counting animals.* AWE Handbook No. 1.