

Abundance and distribution of elephants in the Luangwa Valley, Zambia

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Summary

Elephant density over 40 000 km² of the Luangwa Valley was estimated as 2.17 km⁻² to give a population size of around 86 000 in that area, a tally that would probably top 100 000 if unsurveyed areas within the drainage had been included. Seasonal movement is largely restricted to a migration on to the riverine strip during the wet season and reciprocal dispersal across the valley thereafter. The mean annual range of movement is about 25 km.

Introduction

- The Luangwa Valley of Zambia is a broad trough formed by down-faulting that has preserved Karroo strata on the valley floor. It is through this stratum, not the basement rock, that the Luangwa River has carved a bed. The softness of the rock and the flatness of the floor of the trough have combined to produce a mature meandering river flanked by flood plains and oxbow lakes. Vegetation of the alluvial zone is a mosaic
- ◆ of riparian forest, grassed dambos, thicket, mopane (*Colophospermum mopane*) woodland, *Combretum/Terminalia* woodland, flood plain and flood pan grassland and *Kigelia/Combretum* woodland. Away from the river on the Karroo strata the vegetation is dominated by leguminous miombo woodland. Astle, Webster & Lawrence (1969) describe the land systems of the valley in detail.

- ◆ Within the valley are four national parks. The largest is the South Luangwa National Park (SLNP) which comprises around 9000 km², followed by the North Luangwa National Park (NLNP) which is about half the size. The land surrounding the national parks is designated as Game Management Areas but settlement and agriculture are not restricted within them.

Zambia has only one rainy season each year, about 90% falling between December and April.

The information presented in this paper forms a small portion of the results of a joint survey of the area by the Government of the Republic of Zambia and the Food and Agricultural Organization of the United Nations.

*John Goddard died in the Luangwa Valley on 8 July 1971.

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Methods

Abundance

In January 1973 elephants were surveyed from a Cessna 185 aircraft over 40 000 km² of the middle and upper Luangwa Valley. The elephants were counted on sub-parallel 100-m wide strips from an altitude of 61 m at 150 kph. Available flying time was allocated disproportionately between blocks. A relatively precise estimate was needed for the SLNP, a standard error of under 10% of the estimate being aimed at; rather less precision was sought for the Munyamadzi Corridor and the NLNP; even less was required for the areas east of the river adjacent to the parks; and only a rough indication of numbers was needed for the head of the valley and the area south of the SLNP. Sampling intensity was allocated according to this declining scale of priorities.

For a given expenditure of effort a survey in January will return a more precise estimate than at any other time of the year. The concentration of elephants on the alluvial zone allows a simple division of the area into high-density and low-density strata. Results of a previous survey by Goddard in January 1971 were used to define strata in the SLNP and NLNP. Outside these two parks the boundary between the two strata was set roughly as the boundary of the alluvial zone.

Sampling units were subdivisions of longer transects and were defined as the area observed from 61 m altitude as recorded on a radar altimeter, on a 100-m strip during 2 min of flying. At 150 kph each of the two observers scanned 0.5 km² in this interval, the number of elephants he counts in that area being one sampling-unit replication. The data were analysed by Jolly's (1969) 'equal-size units' method, which should return an unbiased estimate of elephants seen per unit of area but (since the survey design violates the requirement of random sampling) with a standard error of dubious reliability.

Distribution and seasonal movement

The NLNP and SLNP were surveyed by Goddard in October 1970 and in January, March and May 1971. Parallel east-west flight lines spaced at 3-km intervals were traversed at 190 kph from an altitude of 91 m. Elephants were counted out to the limit of visibility on both sides of the aircraft and their positions mapped.

After Goddard's death in July 1971 a further survey was run by Van Lavieren (1971) to complete the sequence. He used a strip width per observer of 200 m which was increased to 300 m in areas of good visibility. Data from these five surveys are presented here in highly summarized form. The two national parks were divided into 10 × 10 km grid squares and the number of elephants seen in each was divided by the aggregate length of flight lines within that square to give an index of relative density. These indices were then summarized further by dividing them into two classes only, those above and those below the mean for a particular survey.

In October 1972 the abundance of elephants inside the parks was measured relative to that outside. In eight areas lines were flown (175 kph from 91 m) across the park boundary from a point approximately 10 km inside the park to 10 km outside. Sampling areas were chosen where the interface between park and game management area cut through the same vegetation type. Each line within the park was an extension of a line outside, the surveys of the two segments being paired according to time of day, direction of the sun, vegetation type and observer fatigue. Elephants were counted

to the limit of visibility on one side of the aircraft, their density index being calculated as the number seen per 10 km of flight line.

Data from one sampled area, on the southern boundary of the NLNP, are excluded from the results. It returned estimates of density in that part of the Munyamadzi Game Management Area that were greatly in excess of those from the adjoining portion of the national park. The reason is probably to be found in the rise of land elevation as the national park is approached and entered. Consequently lines are not matched by habitat and the results were therefore rejected.

Results

Abundance

Elephant numbers estimated for each stratum in January 1973 are listed in Table 1. These are summarized by block in Table 2 for the blocks mapped in Fig. 1.

Table 1. Estimated elephant numbers in January 1973

Block/strata	Area (km ²)	% sampling intensity	Elephant density/km ²	Elephant numbers	Standard error of numbers	Standard error as % of numbers
North/a	2560	2	1.56	4000	1210	30
North/b	7110	1	1.00	7100	2510	35
NLNP/a	1120	6	7.87	8800	1170	13
NLNP/b	3340	2	2.66	8900	3310	37
Corridor/a	480	8	4.00	1900	480	25
Corridor/b	1920	2	2.51	4800	1350	28
SLNP/a	2560	10	7.07	18100	1350	7
SLNP/b	6860	3	1.97	13500	2290	17
Lukusuzi	2630	2	1.56	4100	1390	34
East 1/a	450	5	2.30	1000	470	47
East 1/b	1550	1	0.50	800	490	62
East 2/a	600	8	1.15	700	190	27
East 2/b	1650	2	0.75	1200	650	54
East 3/a	490	8	7.78	3800	910	24
East 3/b	1660	1	2.75	4600	1660	36
East 4/a	700	5	0.82	600	380	63
East 4/b	1470	2	0.06	100	90	90
South	2500	1	0.87	2200	1780	81

These data suggest that the 39 650 km² surveyed within the Luangwa Valley contained about 86 000 elephants at an overall density of 2.17 km⁻². Dodds & Patton (1968) give the total area drained by the Luangwa and its tributaries as 145 600 km². If the valley area not included in the survey contains a density of elephants of about 0.2 km⁻², a conservative guess, the elephant population of the drainage exceeds 100 000 elephants.

In Table 3 the 1973 estimate of 31 600 elephants in the SLNP is compared with previous estimates. These have been modified from the original estimates to correct for differences in block boundaries. The surveys up to 1969 used the Munyamadzi River as a northern boundary. Data from the 1973 survey allowed calculation of a correction factor of 0.9 by which previous survey estimates have been multiplied to correct for their larger area of coverage.

Superficially the set of estimates suggest the elephants have been increasing at a

Table 2. Estimated elephant numbers summarized by blocks

Block	Elephant density/km ²	Elephant numbers	Standard error error	Standard error as % of numbers
North	1.15	11100	2790	25
NLNP	3.97	17700	3510	20
Corridor	2.79	6700	1430	21
SLNP	3.35	31600	2650	8
Lukusuzi	1.56	4100	1390	34
East 1	0.90	1800	680	38
East 2	0.84	1900	680	36
East 3	3.91	8400	1890	23
East 4	0.32	700	390	56
South	0.87	2200	1780	81
Total area	2.17	86200	6240	7

NOT
 110 ÷ 3 = 37 1.0 2.03
 90 ÷ 3 = 30 2.90 2.04
 165 ÷ 3 = 55 1.65 2.01

BASE
 LINE
 +

Corridor
 SLNP

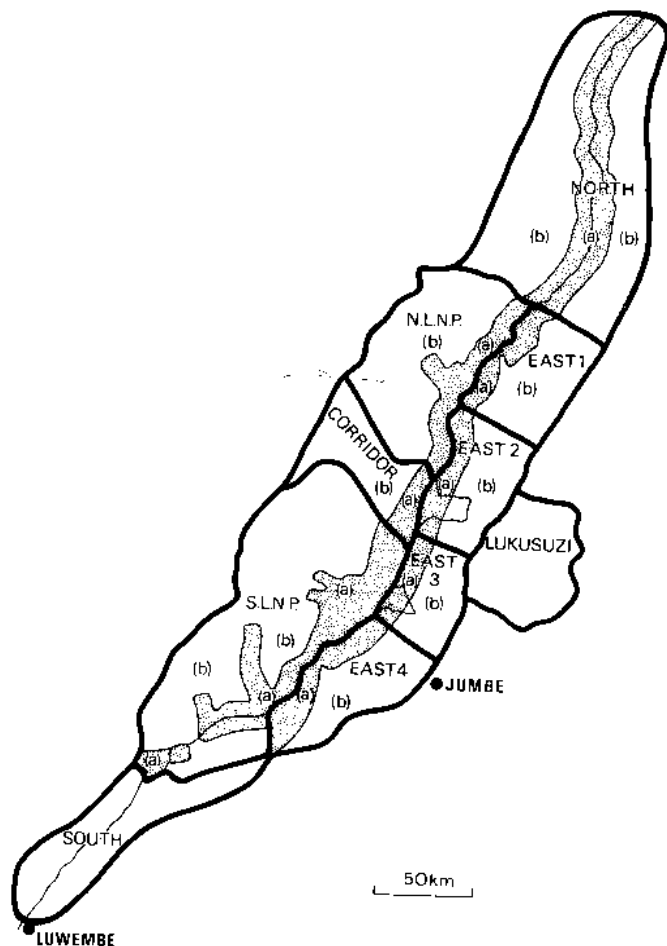
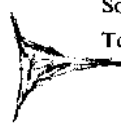


Fig. 1. Map of blocks and the strata within them established for the January 1973 elephant survey. High density strata (a) are stippled.

Table 3. Aerial survey estimates to the nearest thousand of elephants in the South Luangwa National Park

Date	Elephant numbers	Strip width/observer (m)	Reference
July 1965	9000	600	Dean (1968)
Sept. 1965	14000	600	Dean (1968)
June 1966	12000	600	Dean (1968)
Nov. 1966	10000	600	Dean (1968)
June 1967	11000	400	Patton (1967)
Nov. 1969	18000	400	Martin (1969)
Aug. 1971	28000	250	Van Lavieren (1971)
Jan. 1973	32000	100	This paper

1.5 x 10⁴
 ± 2,912
 ± 5,326
 2.5%
 40%
 60%
 17%

rate of 15% per year between 1965 and 1973. This rate is impossibly high, the maximum rate at which an elephant population can increase being around 4% per year (Hanks & McIntosh, 1973). In Fig. 2 the estimates are graphed against transect width per observer to show that, with the exception of one point, estimates regress smoothly on strip width. Thus, a more plausible interpretation is that the spread of estimates is an artefact of visibility bias decreasing as strip width is narrowed. This conclusion is strengthened rather than weakened by the non-conforming point, that from Patton's 1967 survey. On that survey elephants were counted on a 400-m strip at the same time as buffalo *Syncerus caffer* were counted on a strip of 1200 m. Hence an observer's attention was shared simultaneously between two transects. The set of estimates therefore allows no judgment on whether elephants have been increasing, stable or decreasing in the SLNP between 1965 and 1973.

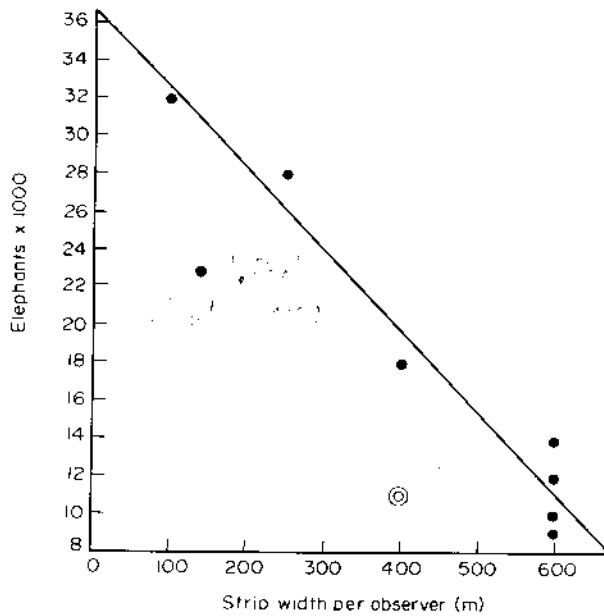


Fig. 2. Visibility bias suggested by a regression of calculated elephant numbers in the SLNP on strip width per observer. The double-circled point is not included in the calculation of the regression.

Distribution and seasonal movement

Figure 3 shows the pattern of seasonal movement within the SLNP. The elephants move towards the alluvial zone about a month before the rains begin. By January the movement is completed at which time the alluvium holds densities of around 7 km^{-2} , densities in the remainder of the park having dropped to 2 km^{-2} . By March, dispersal away from the alluvial zone has already begun and by May elephants have taken up their dry-season dispersion which comes close to an even distribution at $3-4 \text{ km}^{-2}$ throughout the park. Figure 4 indicates a similar pattern of movement in the NLNP. Although the pattern appears to be basically the same east of the river, the January 1973 survey indicated less contrast in densities between the alluvial and Karroo zones on that side of the valley.

The final maps of Figs. 3 and 4 give annual means of the seasonal distributions. They show that there are two main concentrations of elephants in the SLNP and two,

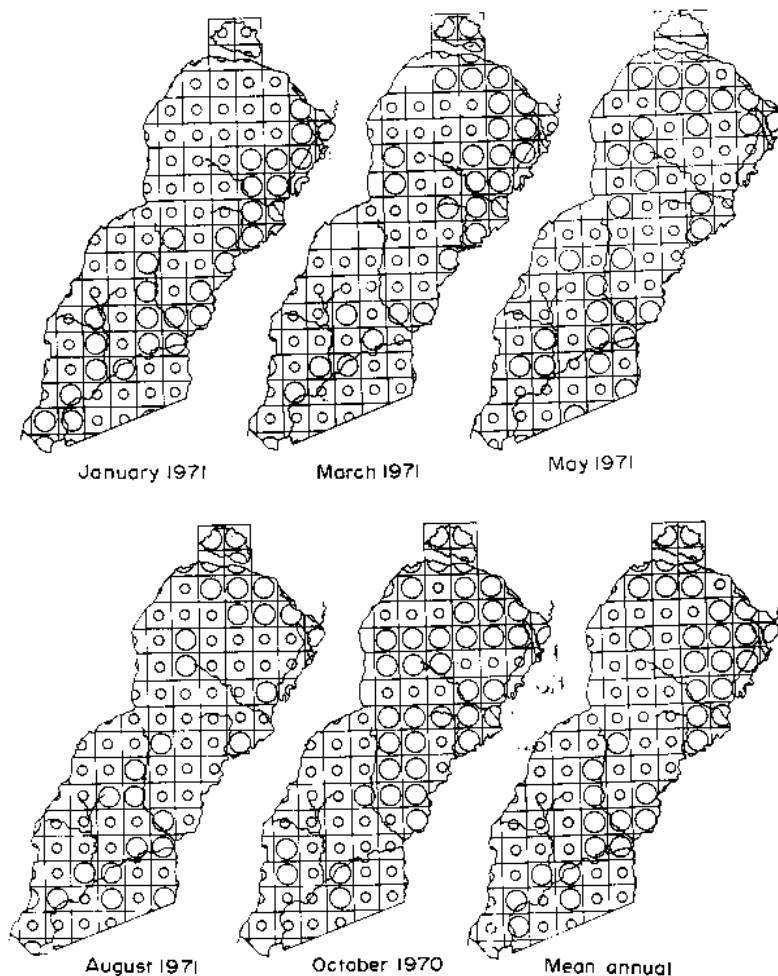


Fig. 3. Elephant distribution in the SLNP by season. Symbols in the $10 \times 10 \text{ km}$ grid squares differentiate density above the mean (large circles) from density below the mean (small circles) for a particular survey. Empty squares were not surveyed.

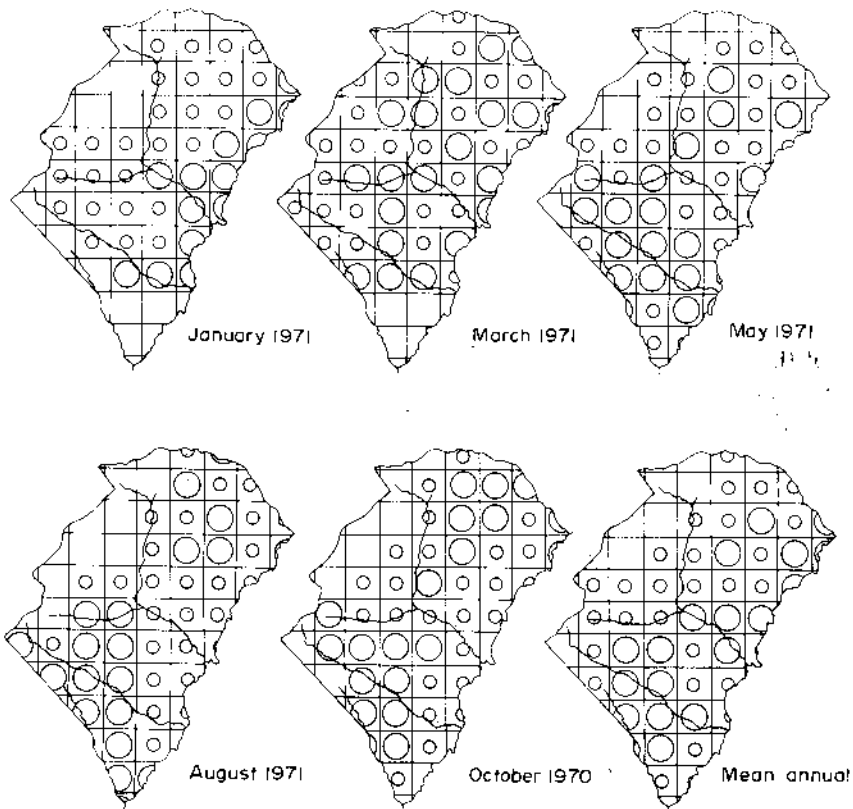


Fig. 4. Elephant distribution in the NLNP by season. Symbols are as for Fig. 3.

or perhaps three, in the NLNP. Laws (1969) interpreted similar semi-discrete concentrations in Tsavo National Park, Kenya, as indicating distinct populations. In an attempt to test this hypothesis for the Luangwa, advantage was taken of a sex-linked gene marker provided by the congenital inability of some females to grow tusks. On 1 November 1972, 205 mature females were examined from the air and scored according to whether or not they were tusked. Ninety-five of these were from the northern concentration of the South Luangwa National Park and 110 were from the southern concentration. The first sample contained 10.3% tuskless females, a percentage very close to the 10.5% reported by Hanks (1971) for females cropped previously in the same area. The southern concentration's frequency of 13.6% cannot be shown to differ statistically from that of the northern concentration ($\chi^2=0.47$, $P=0.5$) and consequently the data do not provide evidence of a genetic difference between concentrations. Such a finding cannot be reversed and interpreted as evidence that these two concentrations share a common gene pool. The question is therefore left open and the term 'concentration' used without attaching a genetic meaning to it.

The January 1973 survey returned estimated elephant densities for the national parks that are generally higher than those from the game management areas outside the parks. Taking unweighted means, density in blocks containing only national park land averaged 2.96 km^{-2} as against 1.21 km^{-2} for blocks excluding all national park land. At face value these figures suggest that densities outside the parks are depressed to about 40% of park densities.

When densities are compared by way of matched lines crossing the park boundaries (Fig. 5 and Table 4) the densities outside the park are estimated as 56% of park densities. Analysis of variance of these data (Table 5) indicate, however, that the variation between sampling areas (which contain equal proportions of park and game management area) is of about the same magnitude as the variation between the two land categories. A facile interpretation of the difference between park and game management area densities is ruled out by this finding.

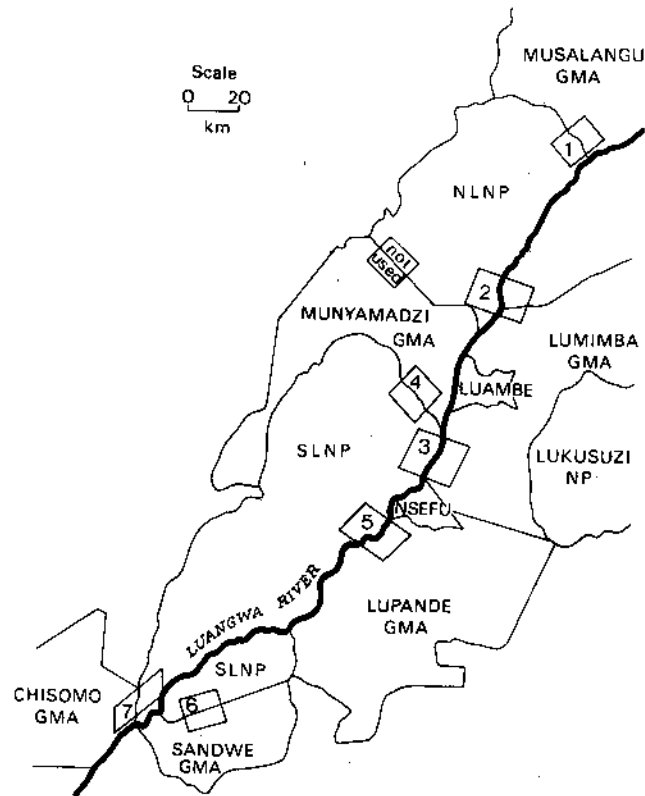


Fig. 5. Map of sampling areas in which densities within parks were measured relative to those outside in the game management areas (GMA).

Table 4. Density indices of elephants either side of national park boundaries

	Sampling area							Mean
	1	2	3	4	5	6	7	
National park index	4.32	4.90	3.05	4.23	11.78	0.08	5.27	4.8
Game management area index	7.46	1.63	1.95	0.63	1.69	0.00	5.54	2.7
Aggregate transect length (km)	236	294	236	222	236	236	148	230

Table 5. Analysis of variance applied to data in Table 4

Source of variation	Sum of squares	Degrees of freedom	Mean square
Land category	15.498	1	15.498
Sampling area	67.066	6	11.178
Deviations	52.807	6	8.801
Total	135.371	13	

Discussion

In the Luangwa Valley, elephants aggregate on the alluvial zone during the rains, probably in response to the flush of annual grasses at that time, and disperse thereafter to provide a more even distribution during the dry season. Movement is almost entirely east-west at right angles to the axis of the valley. For elephants at least the two major national parks in the valley are therefore self-contained ecological units. Within these parks the average range of movement over a year can be calculated as half the distance between the western escarpment and the river, about 25 km.

The January 1973 survey returned a density averaging 2.17 km^{-2} over $40\,000 \text{ km}^2$. Within this area stratum densities ranged between 0.06 and 7.87 km^{-2} , reflecting the general patchiness of distribution which is accentuated at this season by the concentration onto the alluvial zone. Although estimated densities tended to be higher within the national parks, numerous exceptions to this pattern were found.

Although densities reported here are within the range of variation reported from other areas, and the overall density of 2.17 km^{-2} is by no means remarkable, the size of the surveyed area is such that total numbers transcend the ordinary. The estimate of 86 000 elephants in the surveyed area, a tally that would almost certainly top 100 000 if unsurveyed areas within the Luangwa drainage were included, exceeds reported estimates of numbers from other areas of continuous range in Africa.

Acknowledgments

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