REPUBLIC OF ZAMBIA

REPORT ON THE 2015 AERIAL SURVEY OF ELEPHANTS IN ZAMBIA

Ministry of Tourism and Arts
Department of National Parks and Wildlife
Research Unit
P/B 1
Chilanga
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The 2015 aerial survey of wildlife in Zambia was commissioned by Zambia Wildlife Authority (Now Department of National Parks and Wildlife)

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Project Manager: The Nature Conservancy, Zambia

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Cover Picture: Bull Elephant in Flat Dogs Camp, South Luangwa, September 2015

Report Compiled by G Colin Craig

VULCAN

The Nature Conservancy Zambia

REPORT ON THE 2015 AERIAL SURVEY OF ELEPHANTS IN ZAMBIA

SUMMARY

An aerial survey of Elephants and other wildlife took place over the elephant range in Zambia from 4th to 26th of September 2015. A total area of 84859 km^2 was sampled at an average intensity of 7.99%. Four ecosystems were covered: Kafue (45030 km^2), Luangwa (32819 km^2), Sioma Ngwezi (4482 km^2) and Lower Zambezi Valley (2528 km^2).

The estimates of numbers of elephants and elephant carcasses are summarised in the tables below, first by species category and then by ecosystem.

	NATIONAL ESTIMATE	95% RANGE
ElephantBull	1851	1412 - 2291
ElephantFamily	19909	15407 - 24410
All Elephants	*21760*	*17237 - 26283*
EleCarcass 1	8	1 - 23
EleCarcass 2	19	2 - 44
EleCarcass 3	96	23 - 169
EleCarcass 4	905	678 - 1133
All Elephant Carcasses	*1029*	*788 - 1269*

ECOSYSTEM	ELEPHANT ESTIMATE	CARCASS ESTIMATE
Kafue	6688	505
Luangwa	13898	169
Sioma Ngwezi	48	278
Lower Zambezi	1125	76
Overall	*21760*	*1029*

The country total of 21760 is similar to the estimate for 2009. The only evidence for change was seen in Sioma Ngwezi National Park, where there has been a steep population decline since 2004.

The number of elephant carcasses is higher than would be expected from natural mortality alone in all areas except the Luangwa valley. This indicates recent or continuing illegal hunting. In the case of Sioma Ngwezi the carcass estimate provides strong supporting evidence of a poaching-driven decline. In Kafue and the Lower Zambezi valley the carcass numbers are still, just, within the limits where the mortality is sustainable, although imprecision in the results does not permit a more pessimistic view to be ruled out.

Overall the result is hopeful in coming nowhere near the worst, and quite widespread, expectations of decline. Illegal hunting is shown to remain a threat, however.

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1. INTRODUCTION

The 2015 aerial survey of wildlife within the elephant range (Fig. 1) in Zambia was conducted between 4 September and 26 September 2015. While the main objective was to estimate numbers and distributions of elephants and elephant carcasses, sightings of other species (including domestic livestock) were recorded as well as sightings of human settlements and activities. Other species are the subject of a separate report. This report deals with elephants, as a part of the Great Elephant Census, which is an initiative to obtain a continental estimate of elephant numbers.

The survey was conducted according to standard practice (Norton Griffiths, 1978) in Cessna 182 and 206 aircraft flying at a nominal height of 300 feet above the ground, with a total nominal transect strip-width of 300m. Details of methods are provided in Appendix I.

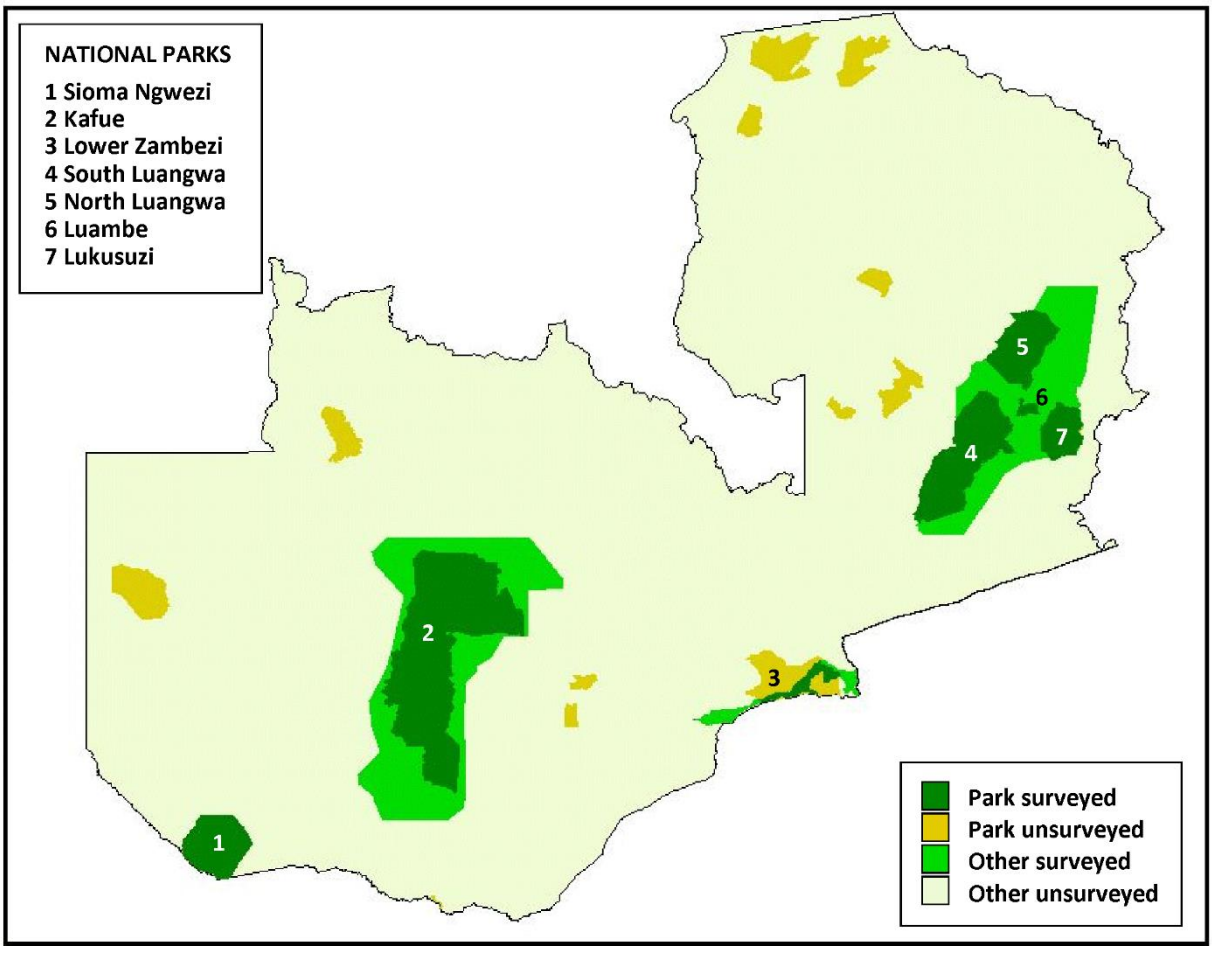


Figure 1 Areas Surveyed in September 2015
Wholly or partially surveyed parks are numbered
Other areas surveyed are Game Management Areas

2. RESULTS AND DISCUSSION

2.1. Reporting format

Tables provide the estimated number per stratum with its 95% confidence range. This "range" refers to the range within which there is a 95% probability that the true number falls (i.e. it is the 95% confidence interval). Strictly, for most species this is actually the range within which 95% of independent *estimates* made by the same method would fall. The true value is likely to be higher on average because of undercounting bias.

The numbers actually seen by the observers are also provided. "No. in" is the number of animals seen within sampling strips and "No. out" is the number seen outside of the sampling strips. Where animals were seen only outside of the sampling strips no estimate can be given but the information can be used to show that the species occurs and where it occurred.

Results are broken down by parks and game management areas (GMAs) within systems. The Sioma system is represented only by Sioma Ngwezi National Park. The Luangwa system has four parks and the surrounding GMAs. No elephants or carcasses were seen in Lukusuzi National Park but it is nevertheless included in the tables, as it was surveyed. National and system totals come directly from the analysis of the original sampling strata. Parks and GMAs are from a secondary GIS analysis (Appendix Id).

Full results for strata, including variances, are given in Appendix III.

2.2. Observations of Wildlife

2.2.1. Elephants - numbers

Estimates of elephants are tabulated below Tables give the estimate, its 95% confidence range, the number seen (both in and out of the sample strips) and the density. Density is expressed per 100 km^2 to reduce the number of necessary decimal places. The total for all areas surveyed is in bold at the bottom of each table. This is the sum of the estimates for each of the four systems, italicised in the table. These in turn are the sums of the component parks and GMAs. Integer estimates are given for simplicity, which causes some rounding errors in the totals.

Locations of actual sightings of elephant bulls and family groups are presented in the maps that follow the tables. Mapped locations include animals seen both in and out of the strips.

Following results and maps for elephant family groups and bulls, are the estimates for carcasses. Some discussion is included here to highlight the main results tabulated and mapped. Overall discussion and conclusions are in section 3.

Table 1. Estimates of all elephants

AREA	Pop. est.	95%Range	No. In	No. Out	No./ 100km²
Kafue National Park	4813	2548 - 7078	476	567	21.65
Kafue GMAs	1876	262 - 3490	158	56	8.24
Sub-total Kafue Ecosystem	*6688*	*3945 - 9432*	*634*	*623*	*14.85*
South Luangwa National Park	3302	2108 - 4496	358	201	38.19
North Luangwa National Park	4673	2885 - 6461	474	245	99.94
Luambe National Park	54	6 - 131	6	5	15.7
Lukusuzi National Park	0	-	0	0	0
Sub-total Luangwa Parks	8030	5889 - 10170	838	451	49.34
Luangwa GMAs	5869	2761 - 8976	534	211	42.12
Sub-total Luangwa Ecosystem	*13898*	*10343 - 17454*	*1372*	*662*	*42.35*
Sioma Ngwezi National Park	*48*	*6 - 126*	*6*	*15*	*1.07*
Lower Zambezi National Park	973	384 - 1562	102	43	84.98
Lower Zambezi GMAs	153	16 - 325	16	134	11.06
Sub-total Lower Zambezi Valley	*1125*	*512 - 1739*	*118*	*177*	*44.5*
Zambia Elephant Range Overall	**21760**	**17237 - 26283**	**2130**	**1477**	**25.64**

Table 2. Estimates of Elephant Bulls

AREA	Pop. est.	95%Range	No. In	No. Out	No./ 100km²
Kafue National Park	147	46 - 248	17	11	0.66
Kafue GMAs	25	2 - 60	2	2	0.11
Sub-total Kafue Ecosystem	*172*	*65 - 279*	*19*	*13*	*0.38*
South Luangwa National Park	403	194 - 612	40	22	4.66
North Luangwa National Park	437	200 - 675	44	20	9.35
Luambe National Park	0	0 - 0	0	5	0
Lukusuzi National Park	0	-	0	0	0
Sub-total Luangwa Parks	840	525 - 1155	84	47	5.16
Luangwa GMAs	659	359 - 960	66	10	4.73
Sub-total Luangwa Ecosystem	*1500*	*1093 - 1906*	*150*	*57*	*4.57*
Sioma Ngwezi National Park	*8*	*1 - 23*	*1*	*0*	*0.18*
Lower Zambezi National Park	86	22 - 150	9	3	7.51
Lower Zambezi GMAs	86	9 - 202	9	6	6.22
Sub-total Lower Zambezi Valley	*172*	*39 - 304*	*18*	*9*	*6.79*
Zambia Elephant Range Overall	**1851**	**1412 - 2291**	**188**	**79**	**2.18**

Table 3. Estimates of Elephants in Family Groups

AREA	Pop. est.	95%Range	No. In	No. Out	No./ 100km^2
Kafue National Park	4666	2403 - 6929	459	556	20.99
Kafue GMAs	1851	237 - 3464	156	54	8.13
Sub-total Kafue Ecosystem	*6516*	*3775 - 9258*	*615*	*610*	*14.47*
South Luangwa National Park	2900	1724 - 4075	318	179	33.54
North Luangwa National Park	4236	2464 - 6008	430	225	90.59
Luambe National Park	54	6 - 131	6	0	15.7
Lukusuzi National Park	0	-	0	0	0
Sub-total Luangwa Parks	7190	5072 - 9307	754	404	44.18
Luangwa GMAs	5209	2116 - 8302	468	201	37.39
Sub-total Luangwa Ecosystem	*12399*	*8867 - 15931*	*1222*	*605*	*37.78*
Sioma Ngwezi National Park	*40*	*5 - 116*	*5*	*15*	*0.9*
Lower Zambezi National Park	887	301 - 1472	93	40	77.47
Lower Zambezi GMAs	67	7 - 194	7	128	4.84
Sub-total Lower Zambezi Valley	*954*	*354 - 1553*	*100*	*168*	*37.72*
Zambia Elephant Range Overall	**19909**	**15407 - 24410**	**1942**	**1398**	**23.46**

The largest population of elephant is in the Luangwa Ecosystem with particularly high densities in the central region of the valley along the Luangwa River (Fig 5). Significant numbers were also found in the Kafue system (Table 1). In the Lower Zambezi system only the valley floor was surveyed. This has a small population (1125) in contact with that across the river in Zimbabwe. The density is high in the park, however (0.85/km^2), only North Luangwa has a higher density.

Comparing Tables 2 and 3 reveals a much lower proportion of elephant bulls in Kafue as opposed to other areas. This could imply a reduction of the bull population or a larger proportion of bulls with the family groups.

Sighting distribution maps follow. Distribution along the major rivers is clear. In North Luangwa there was a wider distribution away from the river than in South Luangwa (Fig. 5). The Kafue elephants are divided into north and south groups by a distribution gap in the middle (Fig. 4). Also interesting in Kafue is that during the survey elephants were making use of the south bank of Lake Itezhi Tezhi, but not the north shore.

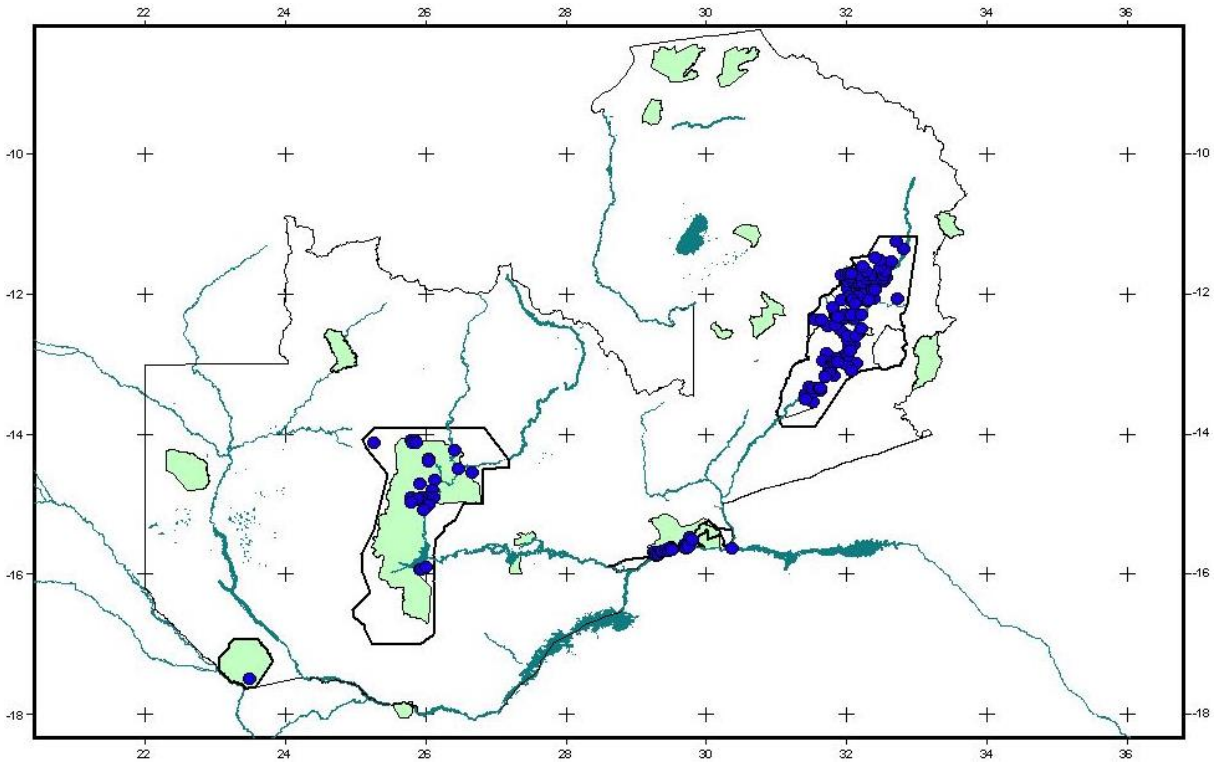


Figure 3 Elephant bull groups - Zambia 2015

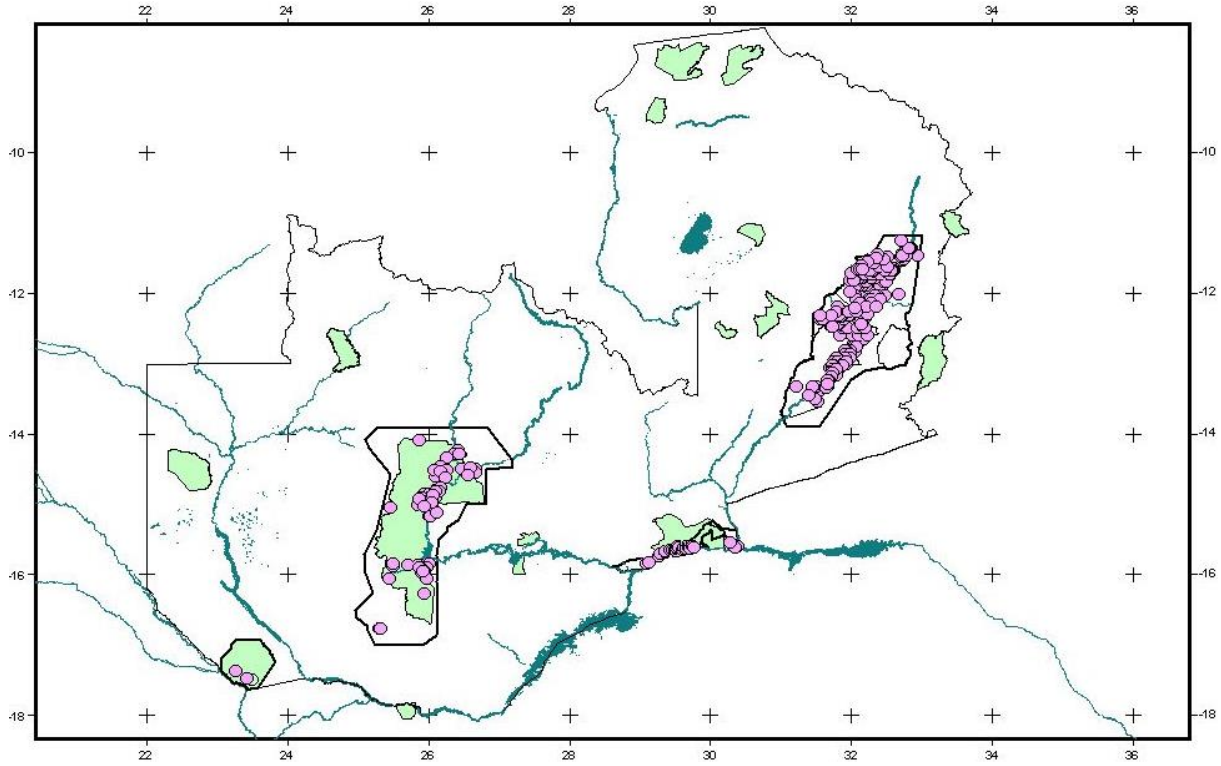


Figure 2 Elephant family groups - Zambia 2015

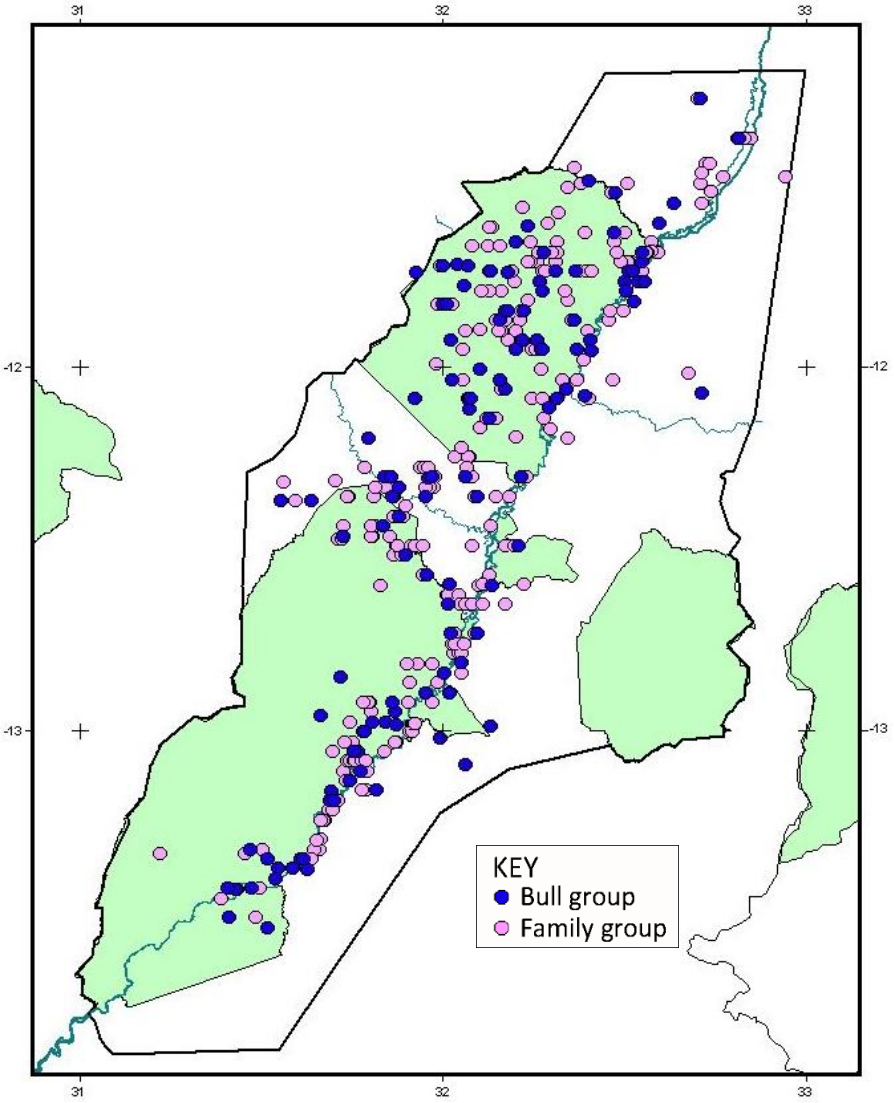


Figure 5 Elephant groups - Luangwa System

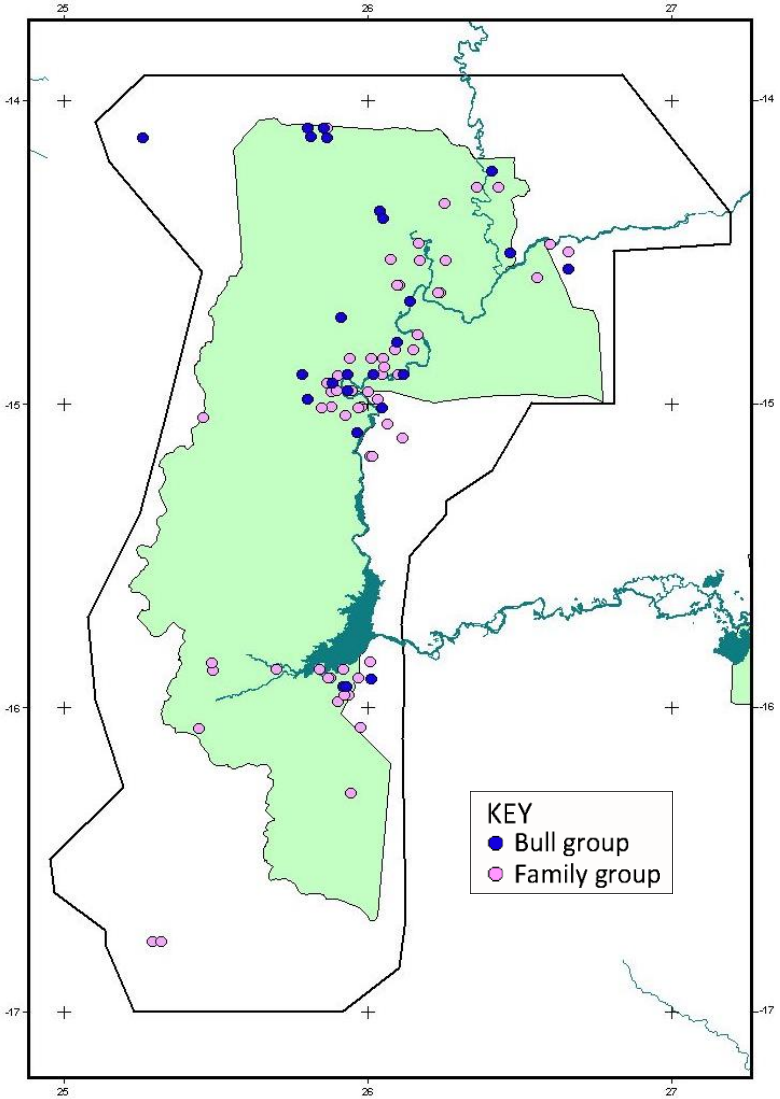


Figure 4 Elephant groups - Kafue System

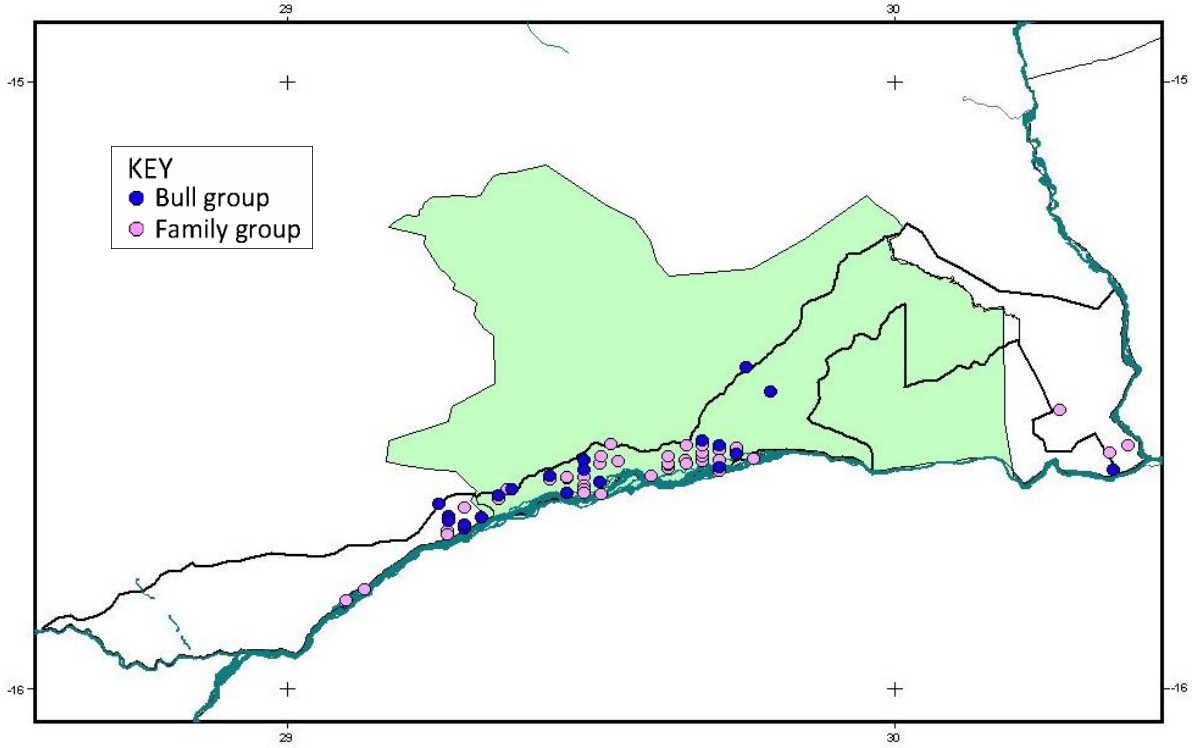


Figure 6 Elephant groups - Lower Zambezi Valley System

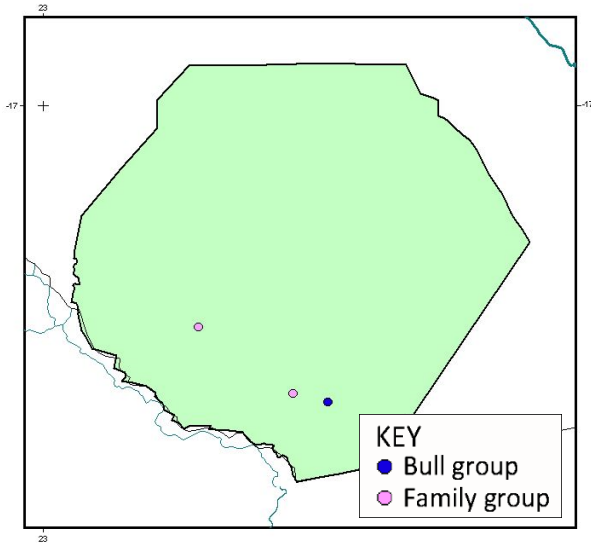


Figure 7 Elephant groups -Sioma Ngwezi

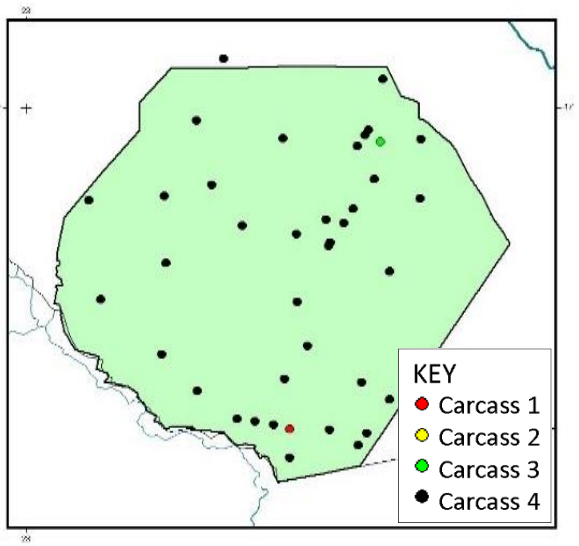


Figure 8 Elephant carcasses -Sioma Ngwezi

In Figs 7 and 8 the localised distribution of elephant sightings contrasts with the widespread distribution of carcasses in Sioma Ngwezi National Park.

2.2.2. Elephants – carcass numbers

Although carcasses are difficult to see and probably undercounted, they are of crucial importance to the evaluation of population status. Decay stages (1 to 4) of carcasses are defined in Appendix Ic below.

Table 4. Estimates of all Elephant Carcasses

AREA	Pop. est.	95%Range	No. In	No. Out	No./ 100km²
Kafue National Park	279	144 - 414	30	12	1.26
Kafue GMAs	226	95 - 357	14	2	0.99
Sub-total Kafue Ecosystem	*505*	*316 - 694*	*44*	*14*	*1.12*
South Luangwa National Park	73	15 - 131	7	1	0.84
North Luangwa National Park	8	1 - 24	1	0	0.17
Luambe National Park	0	-	0	0	0
Lukusuzi National Park	0	-	0	0	0
Sub-total Luangwa Parks	82	21 - 142	8	1	0.5
Luangwa GMAs	88	26 - 149	9	2	0.63
Sub-total Luangwa Ecosystem	*169*	*81 - 257*	*17*	*3*	*0.51*
Sioma Ngwezi National Park	*278*	*168 - 388*	*34*	*7*	*6.2*
Lower Zambezi National Park	29	3 - 69	3	1	2.53
Lower Zambezi GMAs	48	8 - 88	5	0	3.47
Sub-total Lower Zambezi Valley	*76*	*19 - 133*	*8*	*1*	*3.01*
Zambia Elephant Range Overall	**1029**	**788 - 1269**	**103**	**25**	**1.21**

Table 5. Estimates of Elephant Carcass 1

AREA	Pop. est.	95%Range	No. In	No. Out	No./ 100km²
Kafue National Park	0	-	0	0	0
Kafue GMAs	0	-	0	0	0
Sub-total Kafue Ecosystem	0	-	0	0	0
South Luangwa National Park	0	-	0	0	0
North Luangwa National Park	0	-	0	0	0
Luambe National Park	0	-	0	0	0
Lukusuzi National Park	0	-	0	0	0
Sub-total Luangwa Parks	0	-	0	0	0
Luangwa GMAs	0	-	0	0	0
Sub-total Luangwa Ecosystem	0	-	0	0	0
Sioma Ngwezi National Park	*8*	*1 - 23*	*1*	*0*	*0.18*
Lower Zambezi National Park	0	-	0	0	0
Lower Zambezi GMAs	0	-	0	0	0
Sub-total Lower Zambezi Valley	0	-	0	0	0
Zambia Elephant Range Overall	**8**	**1 - 23**	**1**	**0**	**0.01**

Note that only one Carcass stage 1 was seen during the survey. This is a reflection of the short time before the carcass decays to stage 2 and also the greater difficulty of picking them out from the air, as the hide is still on the carcass and makes it cryptic.

Table 6. Estimates of Elephant Carcass 2

AREA	Pop. est.	95%Range	No. In	No. Out	No./ 100km^2
Kafue National Park	9	1 - 27	1	1	0.04
Kafue GMAs	0	-	0	0	0
Sub-total Kafue Ecosystem	*9*	*1 - 27*	*1*	*1*	*0.02*
South Luangwa National Park	0	-	0	0	0
North Luangwa National Park	0	-	0	0	0
Luambe National Park	0	-	0	0	0
Lukusuzi National Park	0	-	0	0	0
Sub-total Luangwa Parks	0	-	0	0	0
Luangwa GMAs	0	-	0	0	0
Sub-total Luangwa Ecosystem	0	-	0	0	0
Sioma Ngwezi National Park	0	-	0	0	0
Lower Zambezi National Park	0	-	0	0	0
Lower Zambezi GMAs	10	1 - 28	1	0	0.72
Sub-total Lower Zambezi Valley	*10*	*1 - 28*	*1*	*0*	*0.38*
Zambia Elephant Range Overall	**19**	**2 - 44**	**2**	**1**	**0.02**

Table 7. Estimates of Elephant Carcass 3

AREA	Pop. est.	95%Range	No. In	No. Out	No./ 100km^2
Kafue National Park	28	2 - 67	2	0	0.13
Kafue GMAs	52	3 - 109	3	0	0.23
Sub-total Kafue Ecosystem	*79*	*10 - 149*	*5*	*0*	*0.18*
South Luangwa National Park	0	-	0	0	0
North Luangwa National Park	0	-	0	0	0
Luambe National Park	0	-	0	0	0
Lukusuzi National Park	0	-	0	0	0
Sub-total Luangwa Parks	0	-	0	0	0
Luangwa GMAs	8	1 - 24	1	0	0.06
Sub-total Luangwa Ecosystem	*8*	*1 - 24*	*1*	*0*	*0.03*
Sioma Ngwezi National Park	*8*	*1 - 24*	*1*	*0*	*0.19*
Lower Zambezi National Park	0	-	0	0	0
Lower Zambezi GMAs	0	-	0	0	0
Sub-total Lower Zambezi Valley	0	-	0	0	0
Zambia Elephant Range Overall	**95**	**23 - 169**	**7**	**0**	**0.11**

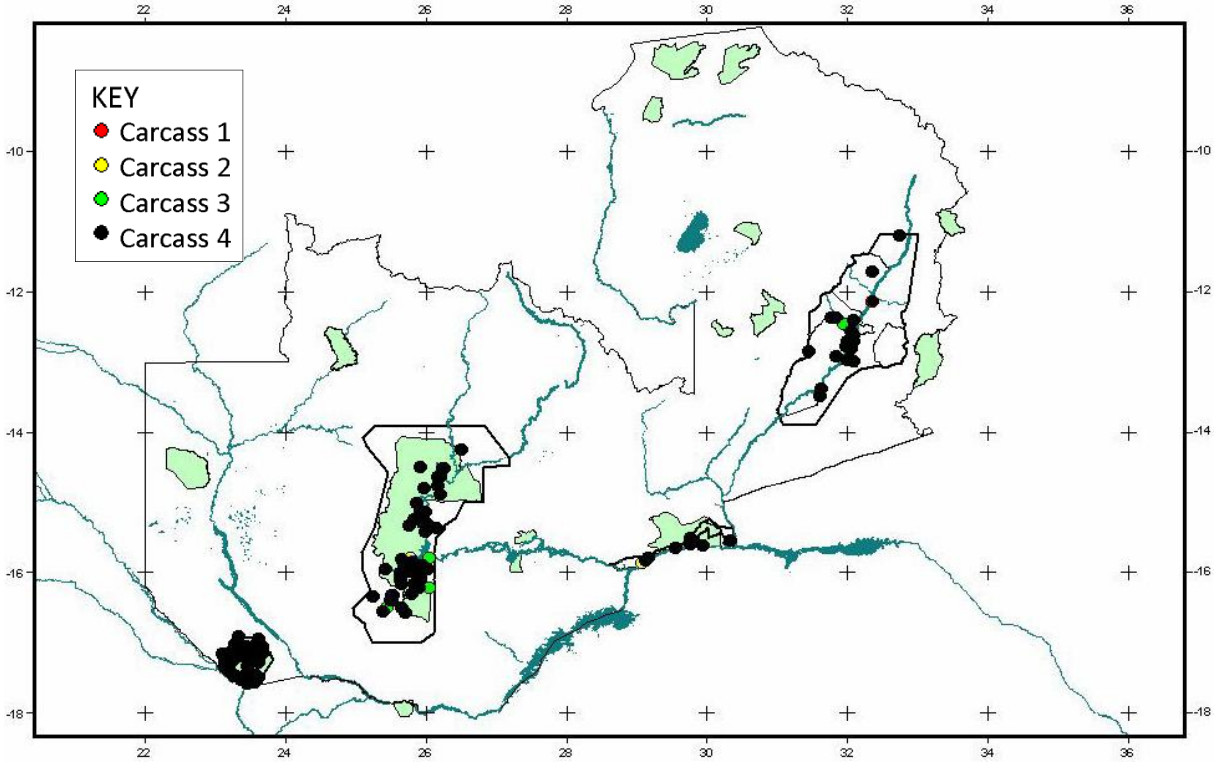
Table 8. Estimates of Elephant Carcass 4

AREA	Pop. est.	95%Range	No. In	No. Out	No./ 100km²
Kafue National Park	242	114 - 370	27	11	1.09
Kafue GMAs	174	56 - 292	11	2	0.76
Sub-total Kafue Ecosystem	*416*	*241 - 591*	*38*	*13*	*0.92*
South Luangwa National Park	73	15 - 131	7	1	0.84
North Luangwa National Park	8	1 - 24	1	0	0.17
Luambe National Park	0	-	0	0	0
Lukusuzi National Park	0	-	0	0	0
Sub-total Luangwa Parks	82	21 - 142	8	1	0.5
Luangwa GMAs	79	20 - 138	8	2	0.57
Sub-total Luangwa Ecosystem	*161*	*74 - 247*	*16*	*3*	*0.49*
Sioma Ngwezi National Park	*262*	*154 - 370*	*32*	*7*	*5.84*
Lower Zambezi National Park	29	3 - 69	3	1	2.53
Lower Zambezi GMAs	38	4 - 74	4	0	2.75
Sub-total Lower Zambezi Valley	*67*	*13 - 121*	*7*	*1*	*2.64*
Zambia Elephant Range Overall	**905**	**678 - 1133**	**93**	**24**	**1.07**

The largest number of carcasses is in Kafue (505). The largest density is in Sioma Ngwezi, followed by the Zambezi Valley. Proportion of carcasses is also important: this is discussed in section 2.2.4.

The following section maps the distribution of carcass sightings in the systems covered by the survey. Carcass distribution for Sioma Ngwezi, however, is illustrated in Fig. 8, above, to show the contrast with the elephant distribution (Fig. 7) for that area.

In Kafue carcasses are more widespread than elephants. This may reflect deaths occurring during the wet season when elephants are more widespread.



2.2.3. Elephants – carcass distribution

Figure 10 Elephant carcasses - Zambia 2015

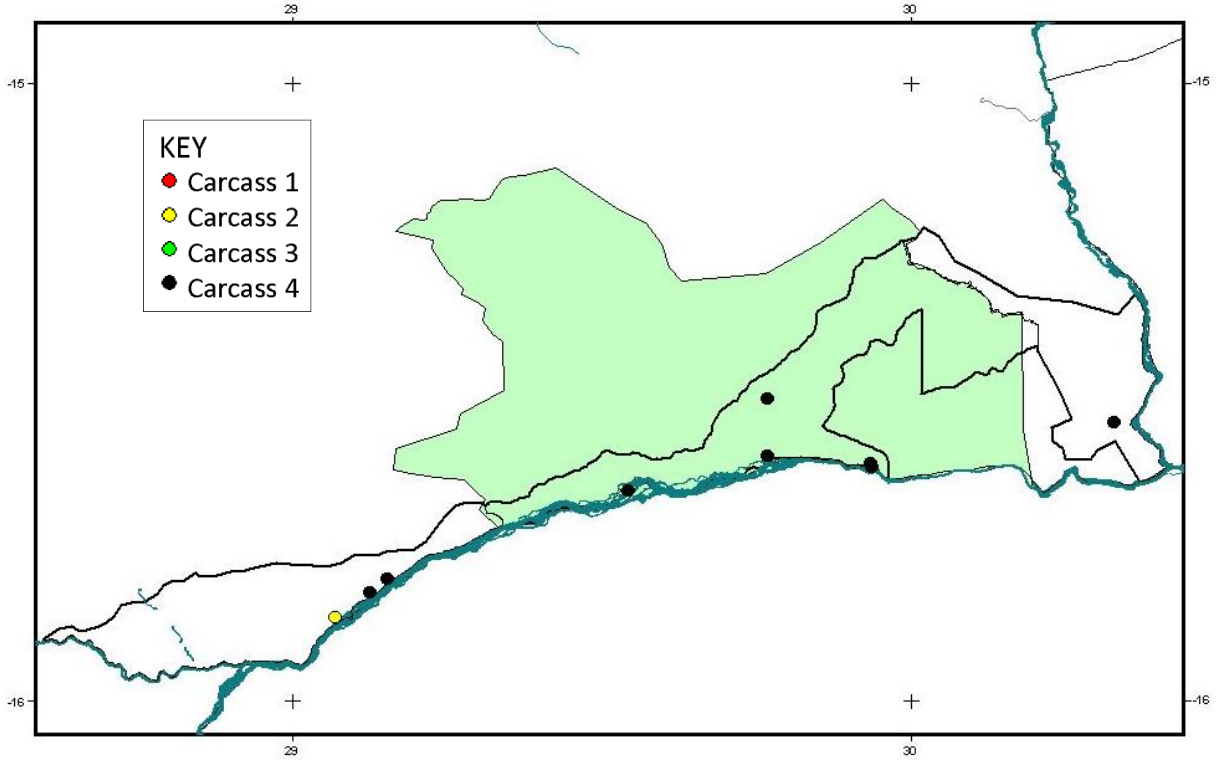


Figure 9 Elephant carcasses – Lower Zambezi Valley System

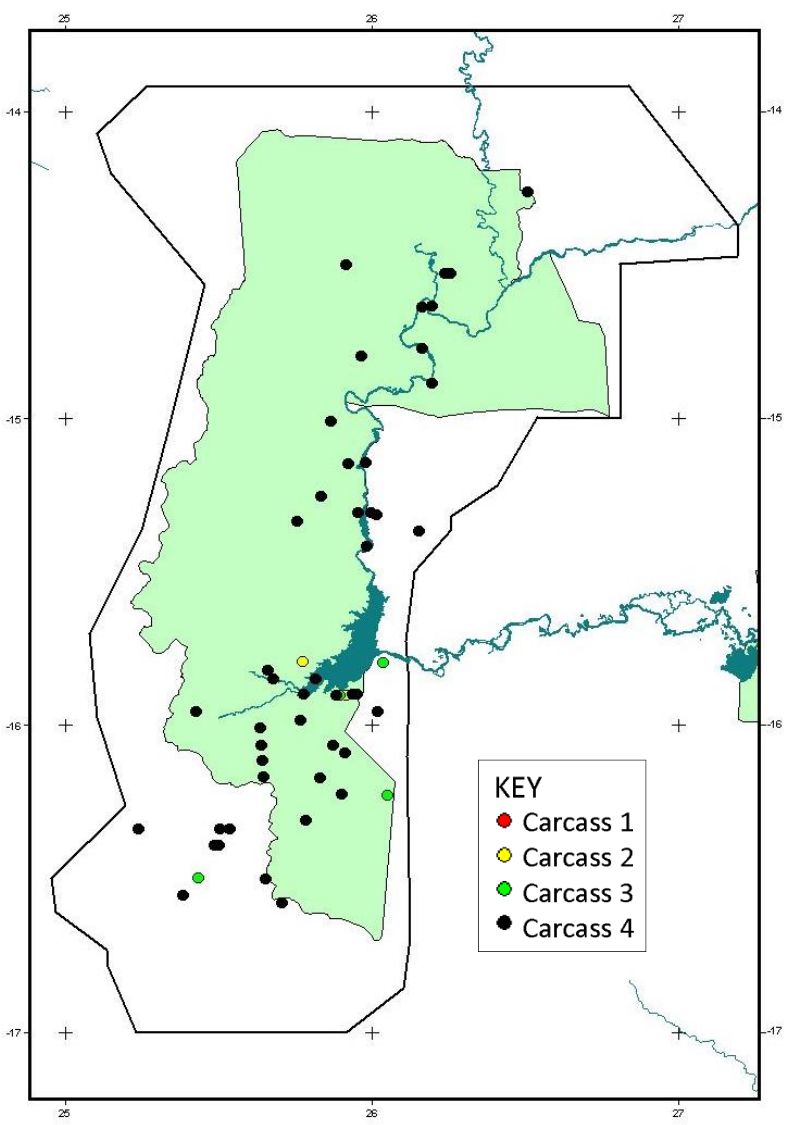


Figure 12 Elephant Carcasses - Kafue System

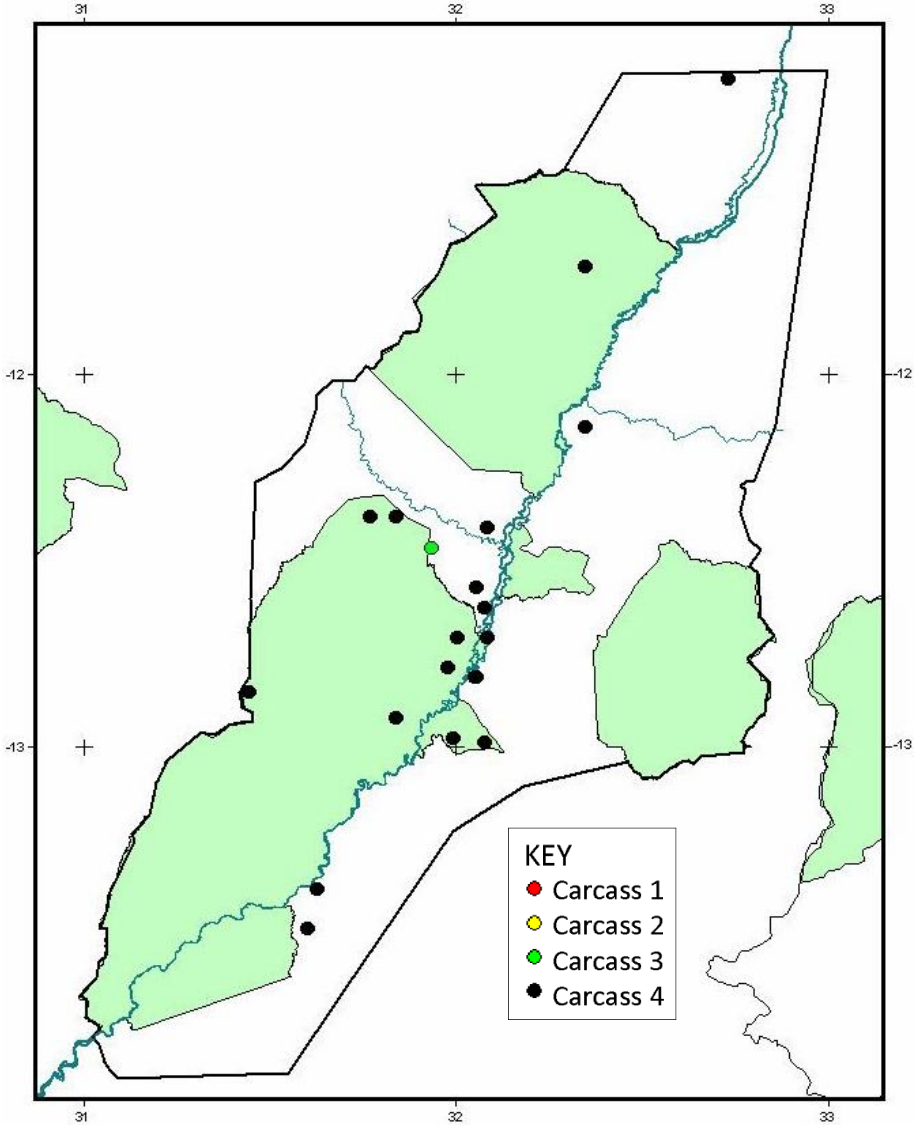


Figure 11 Elephant carcasses – Luangwa System

2.2.4. Elephants – carcass ratios

The carcass ratios are presented in Table 9.

Table 9. Carcass ratios

STRATUM	Elephant Estimate	Carcass Estimate	CARCASS RATIO %
Luangwa Ecosystem Overall	13898	169	1.20
Lower Zambezi valley	1125	76	6.33
Kafue Ecosystem Overall	6688	505	7.02
Sioma Ngwezi Overall	48	278	85.28
Zambia Elephant Range Overall	21760	1029	4.52

The calculation of carcass ratio as a percentage is explained in Appendix Ie. When the ratio is under 5%, most of the carcasses are produced by natural mortality. Over 8%, the losses may be unsustainable (Douglas-Hamilton *et al.* 1981). Old carcasses persist for 5-10 years, so one is looking at a number of carcasses accumulated over time. However, believing that a carcass ratio of 7% is approximately equivalent to an annual mortality of around 1% (7% over 7 years) would be misleading. Firstly, the number of carcasses may have accumulated over a shorter period if the mortalities are relatively recent. And secondly, carcasses are probably always undercounted (see Appendix IIc). The results of Douglas-Hamilton *et al.* (1981) are empirical, i.e. based on actual carcass ratios from surveys subject to undercounting and may be taken as useful guidelines That is, although there is evidence of undercounting, such undercounting is expected and other surveys are comparable in this regard. On that basis the Sioma Ngwezi result indicates a declining population. The Luangwa population should be increasing, while in Lower Zambezi and Kafue the mortality is in the region of the tipping point between increase and population decline. As some populations seem close to that tipping point, imprecision of the estimates gives cause for caution about conclusions drawn.

2.2.5. Other Observations – human activity and settlement

Sightings of human settlement and activities are shown here as an index of disturbance. There is settlement within Sioma Ngwezi (Fig. 12) which dates from before the gazetting of the Park. Lukusuzi also has human impacts within the park. Elephant distributions (Figs 5-7) are affected by human activities to some extent. Note Poacher's camps in Kafue (Fig.15).

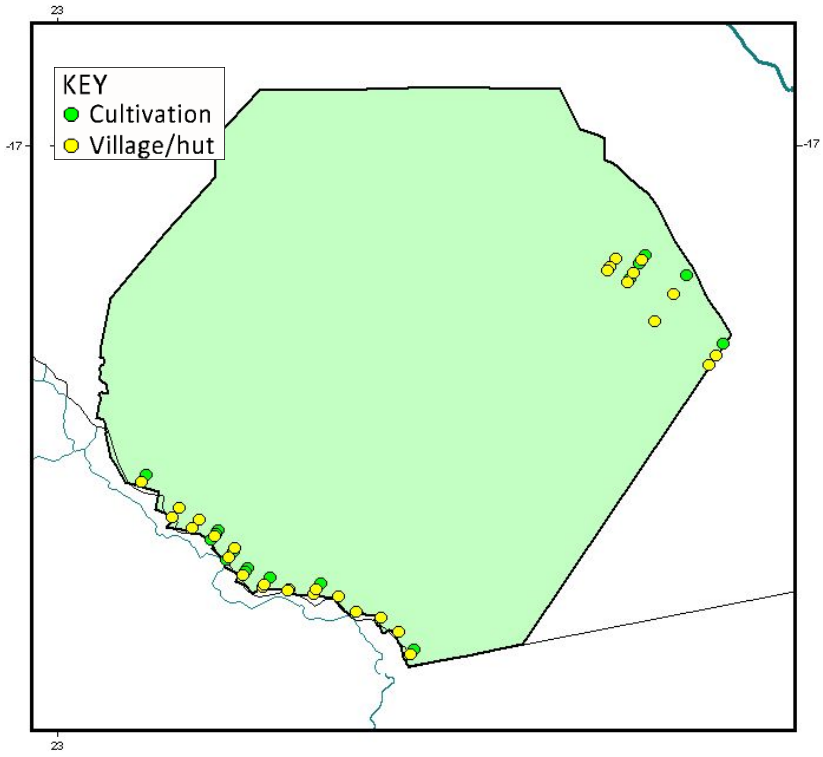


Figure 13 Human habitation/activity - Sioma Ngwezi

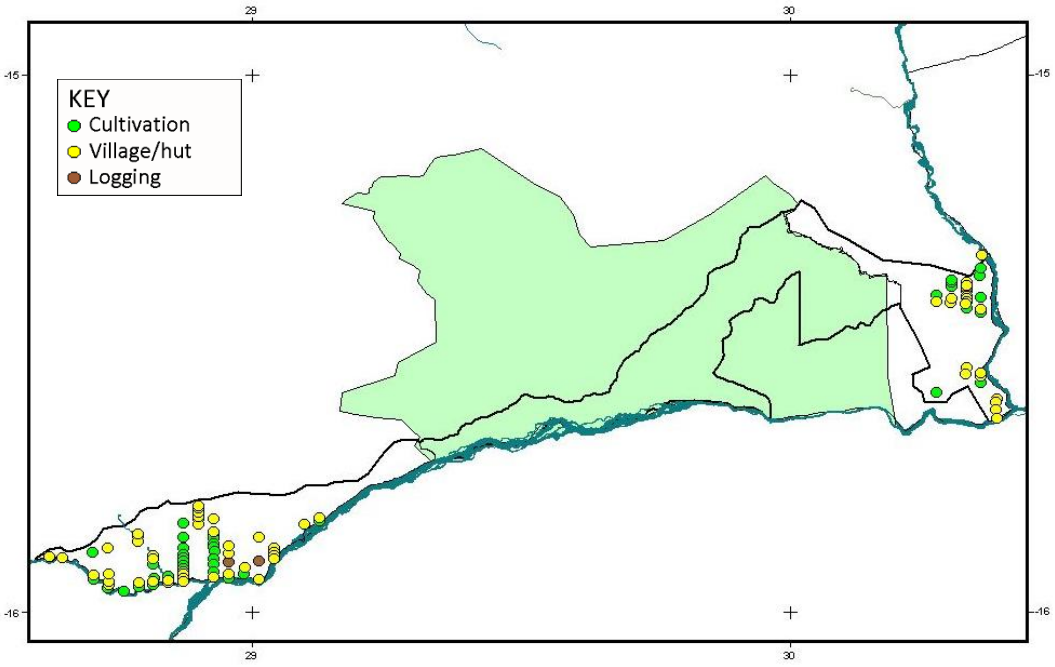


Figure 14 Human habitation/activity - Lower Zambezi Valley

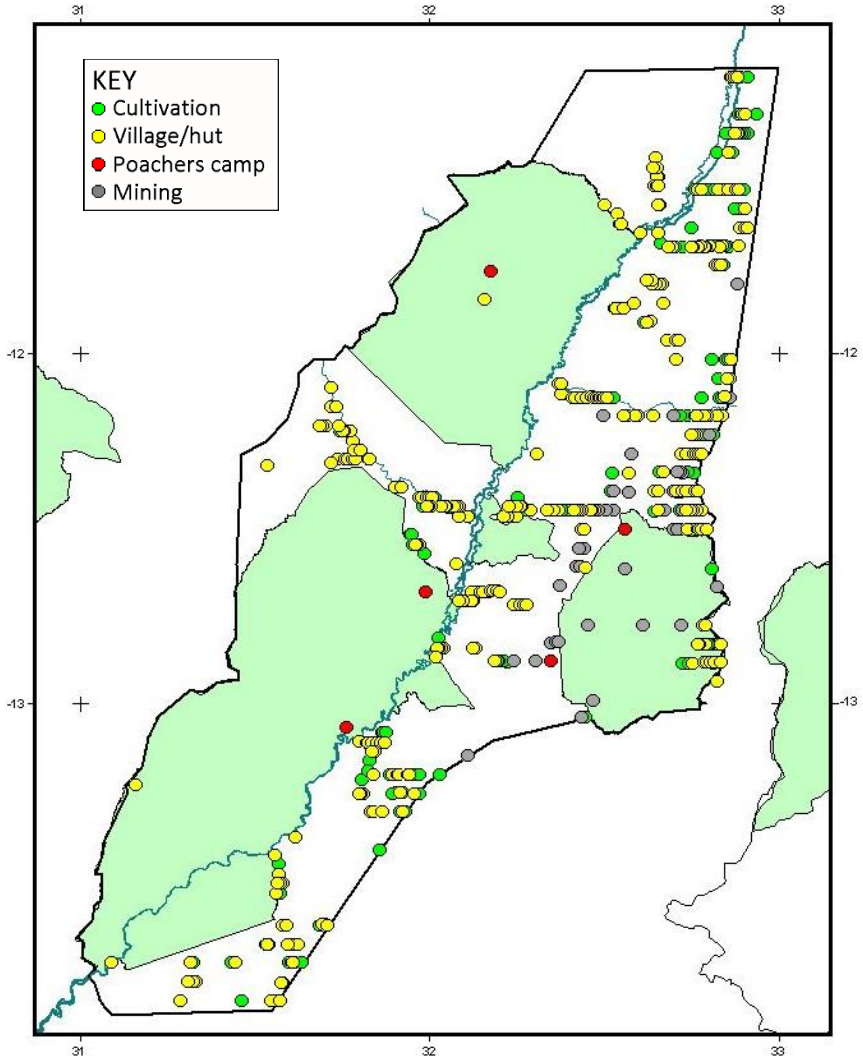


Figure 16 Human habitation/activity – Luangwa System

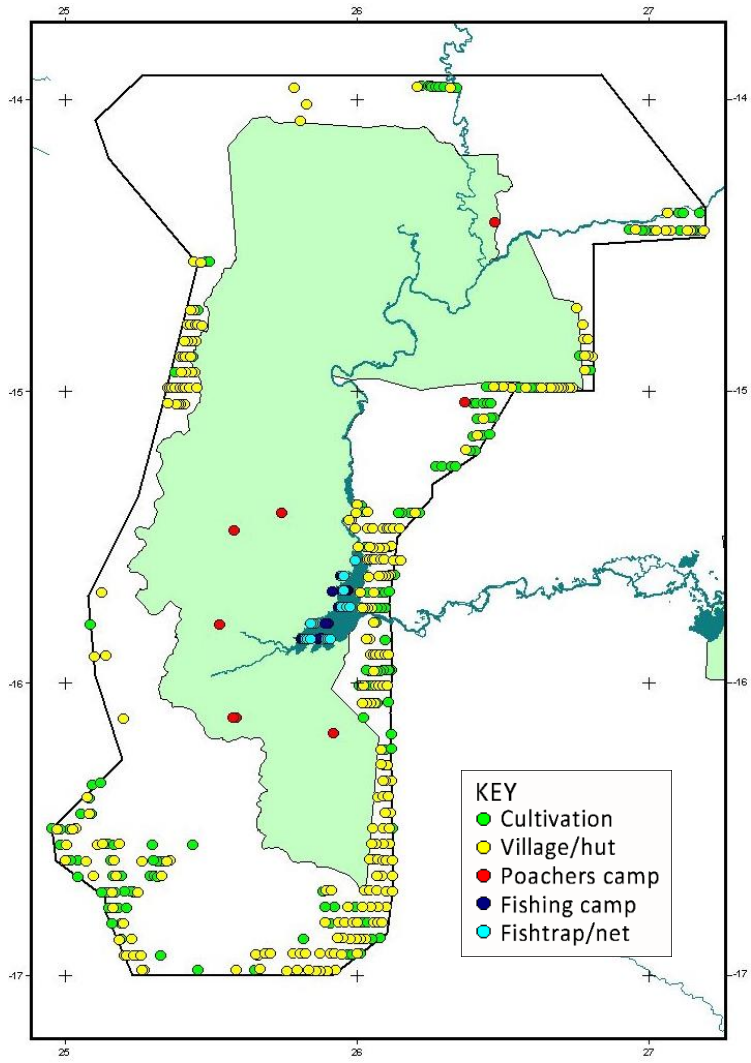


Figure 15 Human habitation/activity - Kafue

3 DISCUSSION AND CONCLUSIONS

3.1 Trends

It is difficult to obtain strictly comparable data over the years. Not all reports indicate details of survey areas so there may be differences in coverage, surveys were conducted in different seasons and methods may vary. However, Table 10 shows the estimates for elephant numbers from 1991. The data that were considered to be comparable from 2004 and used in the trend analysis are indicated with a #.

Table 10. Estimates since 1991

Year	North Luangwa NP	South Luangwa NP	Luangwa System	Lower Zambezi NP	Kafue NP	Kafue System	Sioma Ngwezi
1991							[1]1187
1994					[2]3862		
1995					[3]3847		
1995					[2]3840		
1996					[4]4956		
1997					[3]4482		
1997					[2]5250		
1998					[5]2177		
2000					[2]1453		
2000					[3]1486		
2001	[7]3750						
2001					[6]2141		
2002		[8]5434			[2]2197		
2002							
2003	[7]3235			# [9]1347			
2003				[10]1522			
2004							[11]1099
2004							# [11]899
2005							# [11]385
2005				[12]2137			
2005				# [13]3417			
2006		[14]6112					
2006					[3]2506	# [3]4273	
2007	[7]3487						
2008		[3]4419	# [3]12352		[3]2521	# [3]3455	
2008	[14]3990	[14]7457	[14]18634	[14]1298	[14]2951		[14]2389
2009	[7]3749		# [7]18211				[18]400
2011	[15]3460	[15]3855	# [15]11095		[16]2280	# [16]3715	
2012	[17]2214	[17]2813					
2013				# [12]1795			# [18]133
2015	4673	3302	# 13898	# 973	4813	# 6688	# 48

KEY TO REFERENCES IN TABLE 10					
1	Tembo 1995	7	WCS 2009	13	Simwanza 2005
2	ZAWA 2006	8	Dunham & Simwanza 2002	14	Simukonda 2009
3	ZAWA 2008	9	Simwanza 2004	15	Simukonda 2011
4	Miyauchi *et al.* 1997	10	Dunham 2004	16	Frederick 2011
5	Simwanza 1999	11	Chase & Griffin 2009	17	Frederick 2012
6	Fairall & Kampamba 2001	12	Viljoen 2013	18	EWB & ZAWA 2013

Estimates in Kafue, both for the National Park(4813) and the system as a whole(6688) are greater than previous ones, although not significantly – the apparent upward trend of the graph may be due to chance. So, while it can be said that there is no evidence of a population decline, a decline cannot be ruled out.

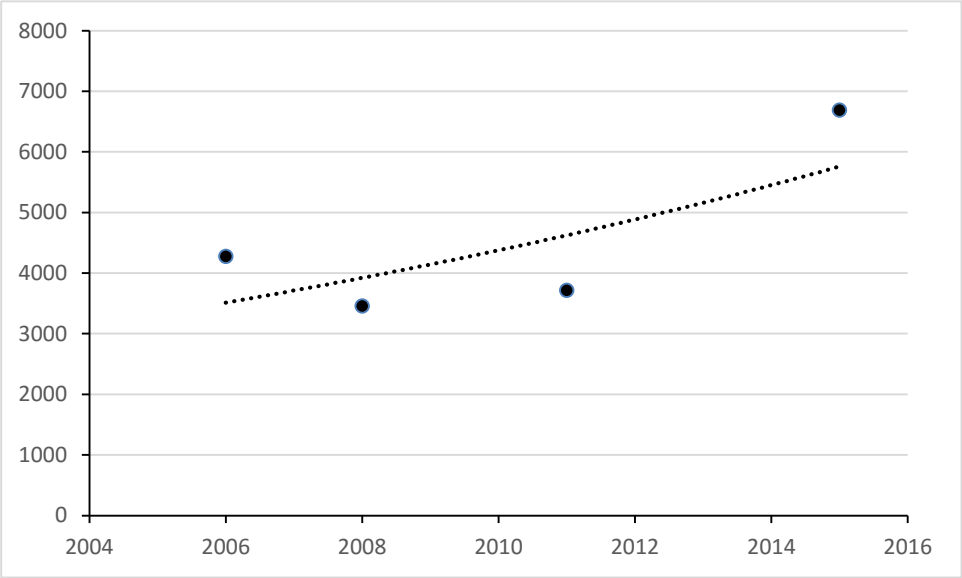


Figure 17 Elephant population trend – Kafue
(r = 0.055 p = 0.27 ns. r is the constant of the exponential equation)

The number of carcasses estimated in Kafue is greater than would be expected from natural mortality alone, suggesting ongoing illegal hunting. Poaching camps, some in use, were detected in the park (Fig 15). More carcasses were detected than on previous surveys, but it is not known whether previous carcass estimates were comparable. The current carcass ratio, 7.02%, is just within the limits considered sustainable (Douglas-Hamilton *et al.* 1981). The population may be close to stable, but also close to the tipping point between increase and decline.

In the Luangwa system, the population estimate for North Luangwa National Park is greater than previous estimates, while that for South Luangwa National Park is less. These differences are not significant. The estimate for the whole system (13898) is greater than previous but comparable to the 2008 (18211) and 2009 (12352) estimates, from which it does not differ significantly.

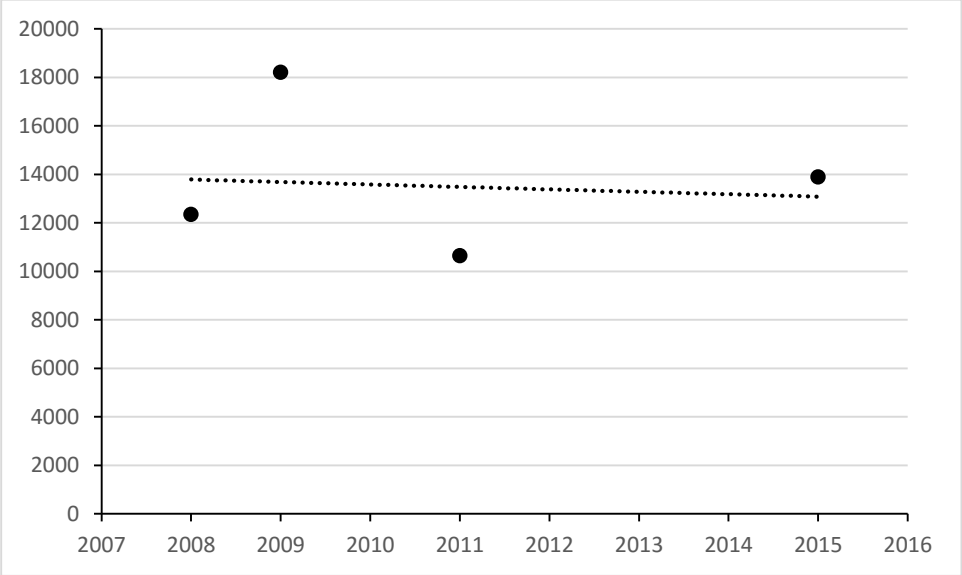


Figure 18 Elephant population trend – Luangwa
(r =-0.02 p = 0.71 ns)

The carcass ratio in the Luangwa system (1.2%) is in the range expected where only natural mortality is operating, although such a conclusion would depend on the number of carcasses not being underestimated more than is usual.

The population estimate for the Lower Zambezi Valley system (1125) is similar to the 2003 and 2013 estimates. The system is open to elephant movement across the river from Zimbabwe, so numbers could potentially change markedly from year to year.

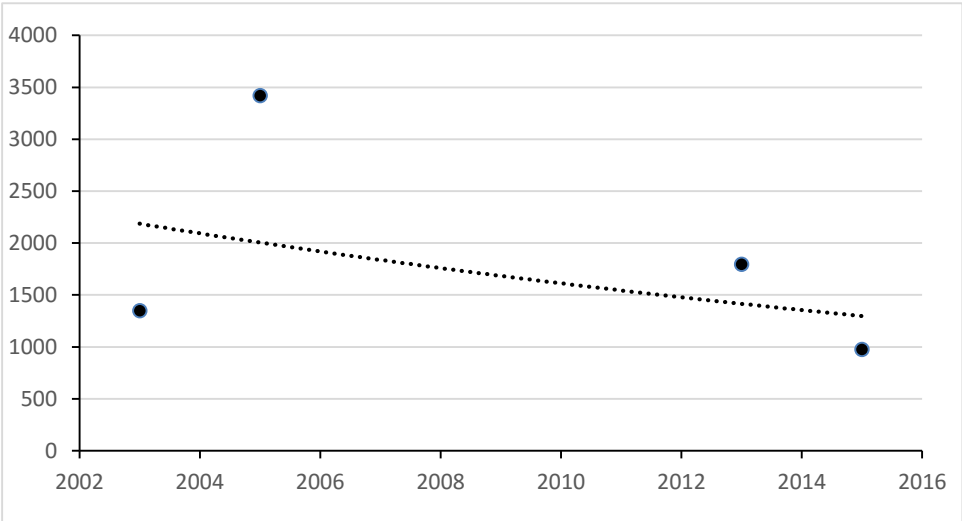


Figure 19 Elephant population trend - Lower Zambezi
(r = - 0.044 p = 0.52 ns)

The carcass ratio (6.3%) suggests losses which are still sustainable.

Surveys in Sioma Ngwezi National Park have produced comparable estimates since 2004. Prior to that, the surveys took place in the wet season and the higher numbers then might be due to seasonal migration. However, the trend since 2004 has been significantly (p=0.015) downwards with an exponential decline rate of -0.22. The present estimate is 48.

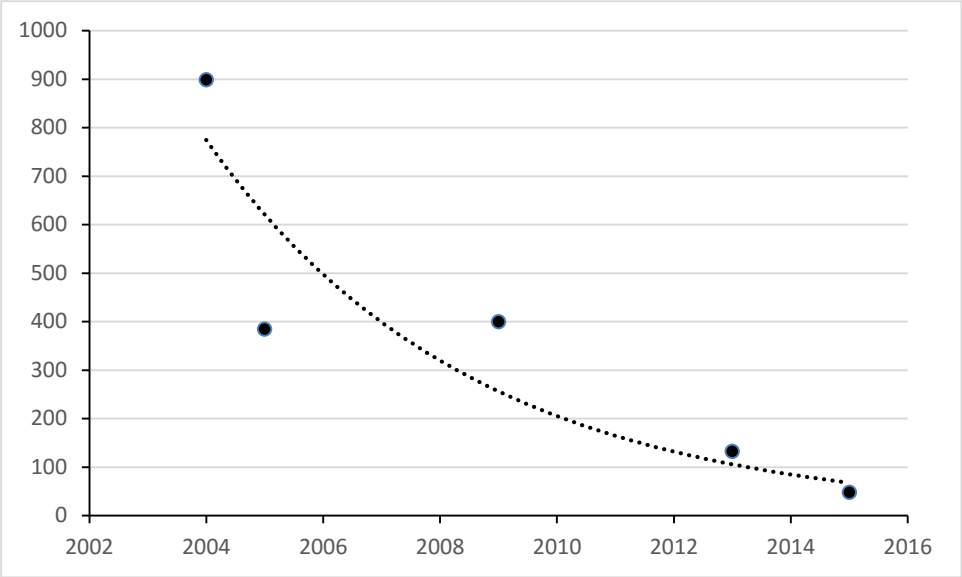


Figure 20 Elephant population trend - Sioma Ngwezi
(r = -0.221 p = 0.018*)

Two hundred and seventy eight carcasses were estimated to be on the ground, giving a carcass ratio of 85.5%. Most of these carcasses were old and the number is similar to that estimated in 2013 (281). Nevertheless, the results suggest a recent or ongoing problem of illegal hunting which has led to a loss of most of the original population. The estimate of 400 for the 2009 population comes from Chase and Griffin (2009). If one accepts the ZAWA (2009) figure of 2389, then the decline must have been much steeper than illustrated in Fig. 19.

Although illegal hunting has resulted in losses, the national estimate of elephant numbers in areas covered by this survey (21760 ± 4523) is only a few thousand lower than the 2008 estimate (26382 ± 4405) and not significantly different from it (t, =1.5, p=o.13). This appears to be the only previous national survey, but 2011 can be compared if only Luangwa and Kafue, which hold most of the elephants, are included. This comparison is 14472 $\pm$ 2060 in 2011 with 20586 $\pm$ 4460 in 2015. The difference is significant (t=2.4, p = 0.015). The apparent increase and its significance, is due to the increase in Kafue, however (see Fig 17).

Overall, this is an optimistic result, but the undoubted continuation of illegal hunting strikes a cautionary note.

3.2 Other

Deviations from best, intended or ideal practice on the survey were: carcasses were missed; some elephant observations were not classified; 1 transect was missed; speeds were too high; heights were too variable; some marker rods were insufficiently rigid; no permanent voice recordings were made; no usable photographs (of elephants) were taken. It is not thought that any of the above materially affects the conclusions of the survey, however.

4 ACKNOWLEDGEMENTS

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Zambia Air Force

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APPENDIX I: METHODS

Methods followed CITES MIKE aerial survey standards using stratified systematic transect sampling (Norton Griffiths, 1978) with analysis by Jolly's method for unequal size sampling units (Jolly, 1969).

a. Survey design

The survey area was stratified on the basis of previously reported elephant densities. The Lower Zambezi Valley was not stratified.

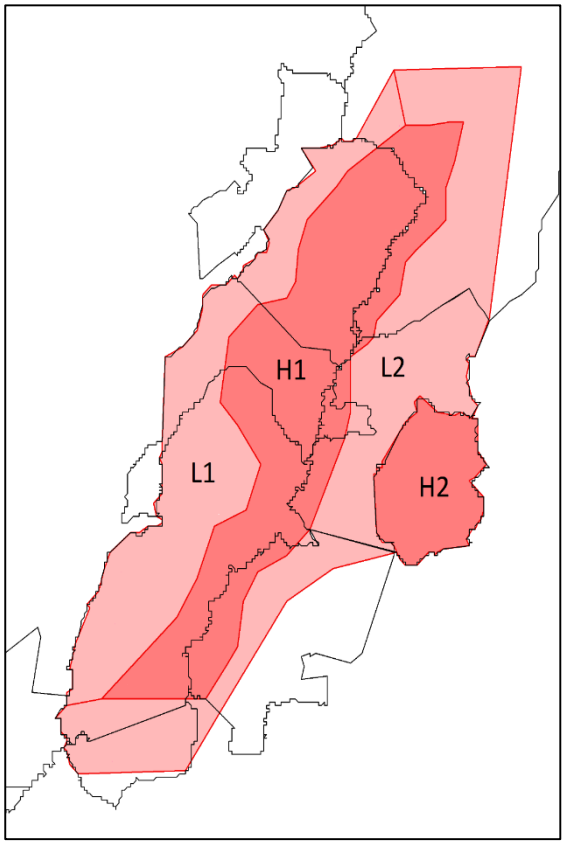

Figure 22 Luangwa Survey Zones.
Light shading: 7.5% sampling; Dark shading: 15% sampling; Unshaded: excluded from survey. Final stratum names in Fig 23.

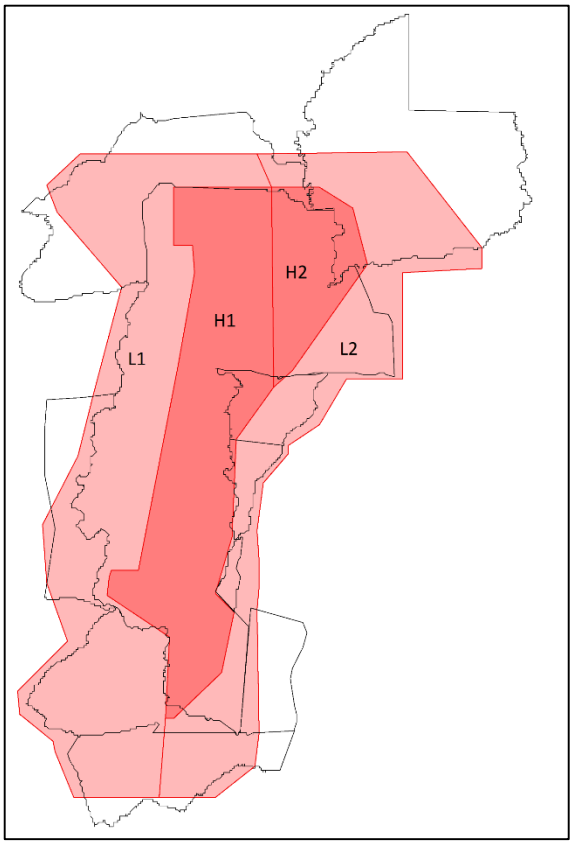

Figure 21 Kafue Survey Zones.
Light shading: 7.5% sampling; Dark shading: 15% sampling; Unshaded: excluded from survey

b. Selection of transects

Transects were evenly spaced according to the required sampling intensity (3 km for 10% coverage, etc.) from a randomly chosen start point and oriented at right angles to major features (e.g. rivers) in each stratum, as far as possible (Fig. 18).

Sampling intensities were designed to maximise the precision of elephant estimates so were selected for each stratum on the basis of previously reported elephant densities and modified to fit budgetary constraints.

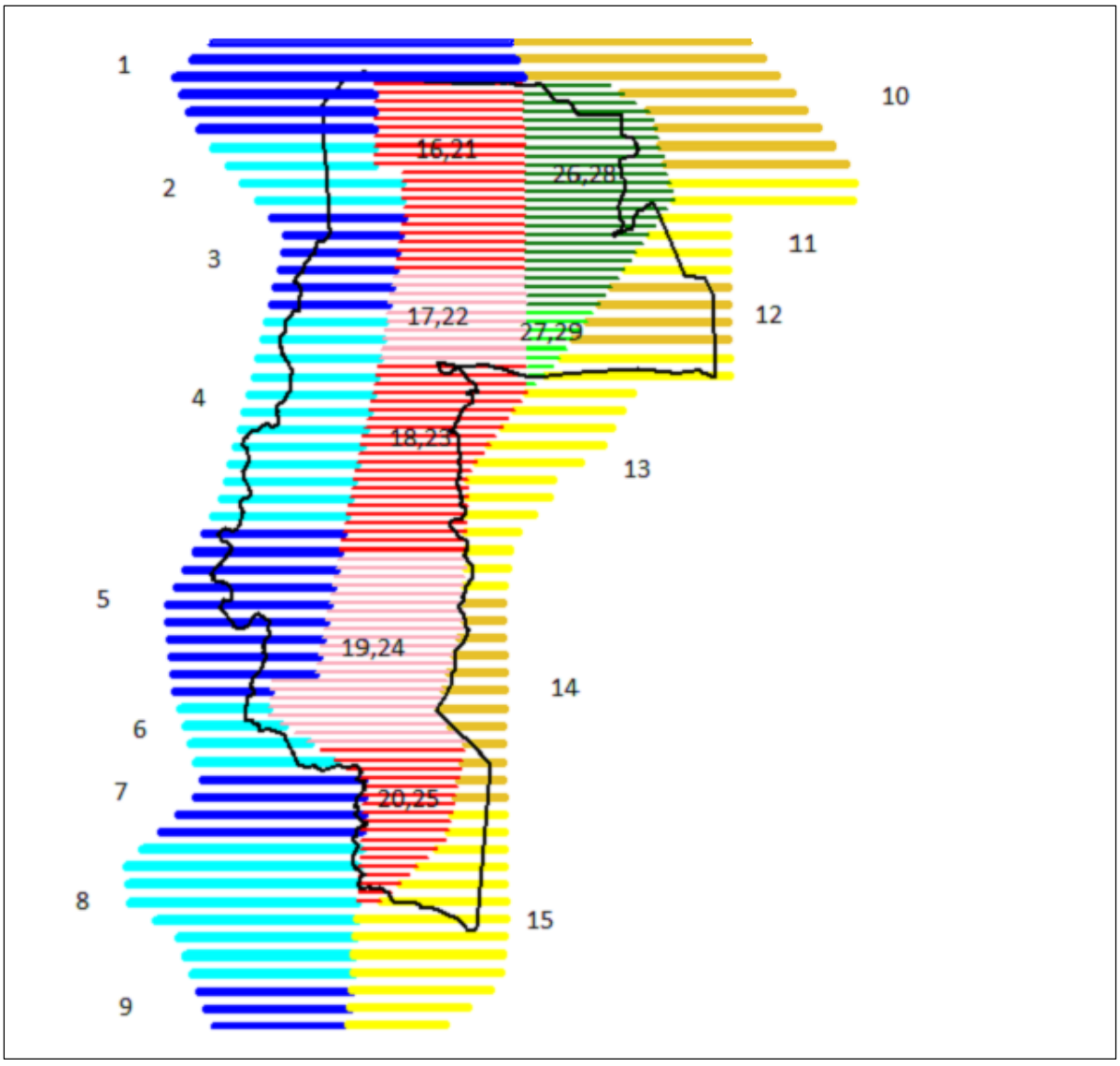

Figure 23 Strata and substrata in Kafue ecosystem

Eastern Stratum is KA, Western is KB and the two central strata are named KC (red) and KD (green), respectively. As each central stratum consists of two interleaved sets of transects, these sets are named KCA, KCB, KDA and KDB. Flight substrata are distinguished by colour here, and numbered 1-25.

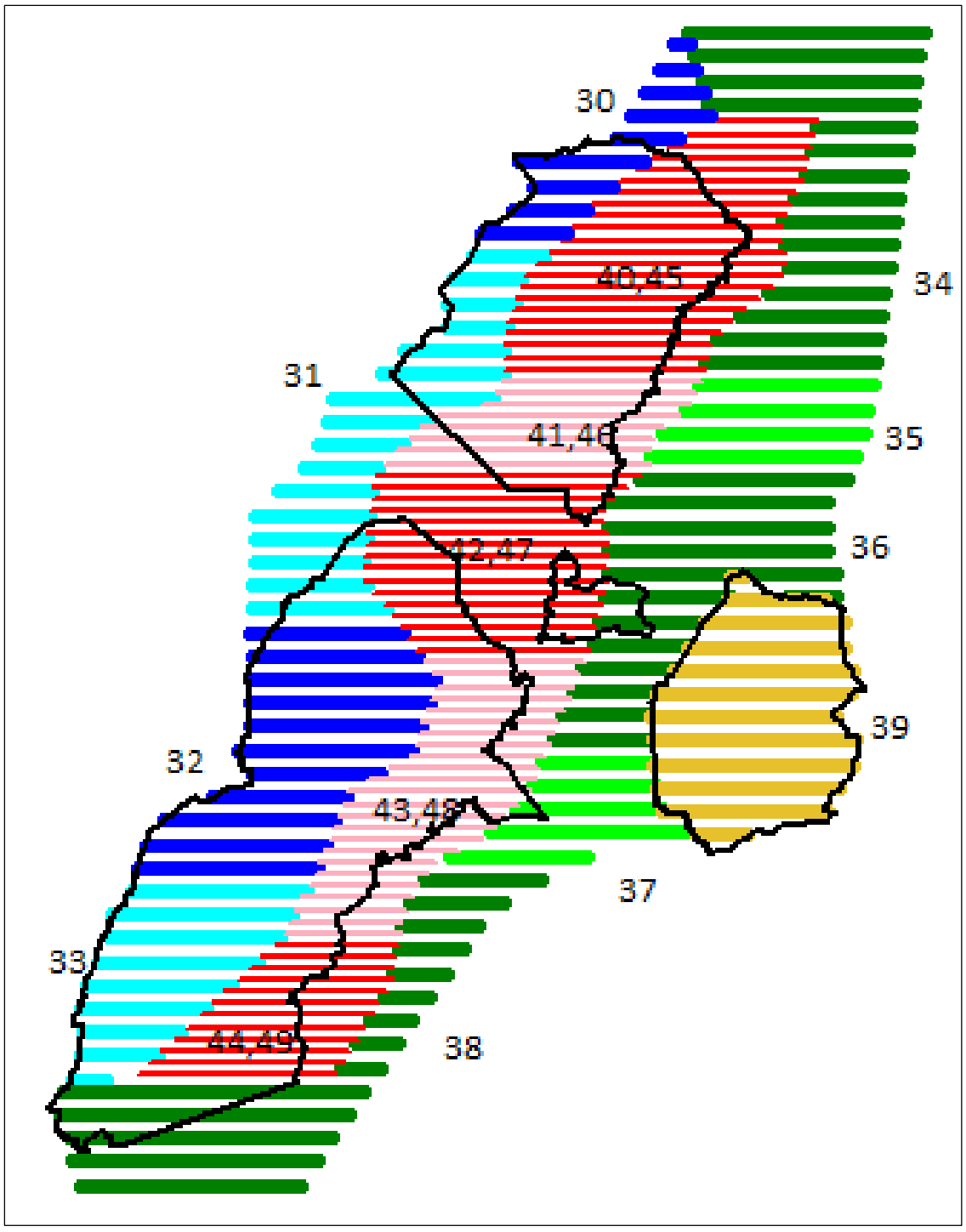

Figure 24 Strata and substrata in the Luangwa Ecosystem

5% sampling blocks are named LA(blue), LB(green) and LD(yellow). Central block (red) consists of two interleaved 5% coverages: LCA and LCB. Flight substrata are numbered. LD is Lukusuzi National Park - other parks do not coincide with strata.

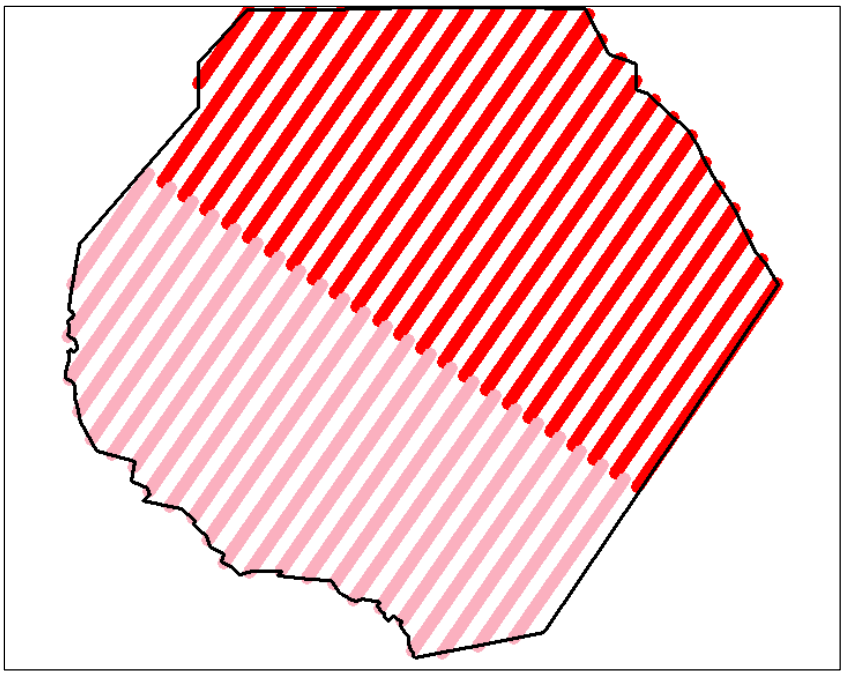

Figure 25 Transects in Sioma Ngwezi.
Northernmost stratum is SiA, the other is SiB

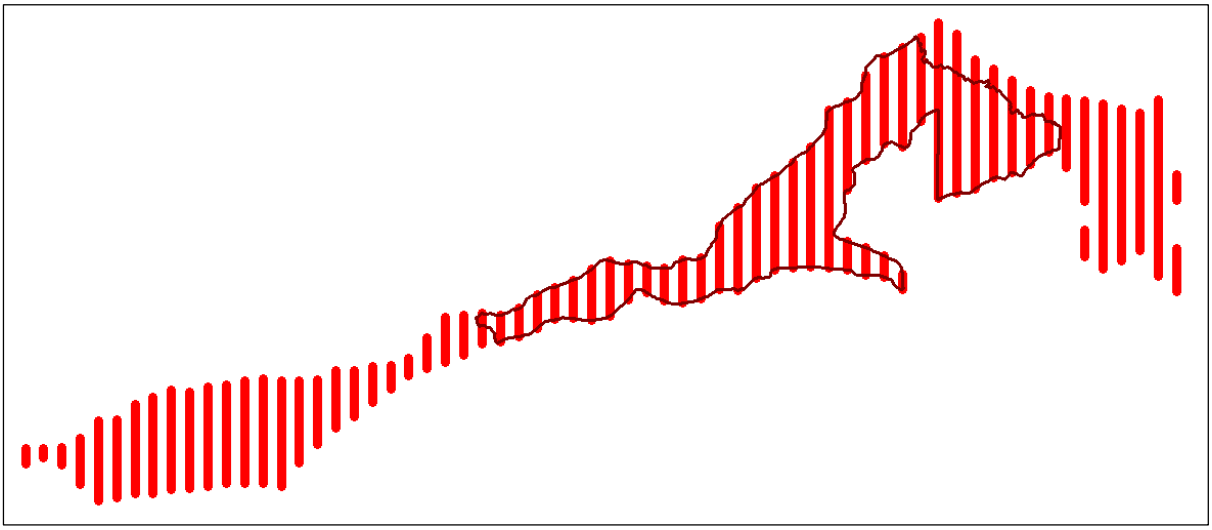

Figure 26 Transects in Lower Zambezi Valley.
Outline is of park. Note that only the Valley floor is covered: the escarpment is excluded from the survey.

c. Data collection

The aircraft were flown at a nominal height of 300 feet above ground level along the transects. Height above ground level was maintained by the pilots using the radar altimeters fitted in each aircraft. The height was recorded every 30 seconds along the transect and the mean height was used to correct the strip width for the transect from the calibrated width at 300ft to the actual width.

Calibration was carried out prior to the survey by flying over numbers painted on the airstrip at 10m intervals. The further and nearer numbers just within the strip markers were called out by each observer on each of about 20 passes over the airstrip. Height readings on both pressure and radar altimeters were taken on each pass. Results and calculations to give calibrated height are reported in Appendix II. Strip markers were fishing rods clamped to the aircraft struts.

Accurate navigation along each transect was achieved using Garmin GPS sets uploaded with transect coordinates. The position of each sighting was recorded on the GPS, which was also Used to record tracklogs of all flights. This data was downloaded as GPX files after each flight. Digital data of uploads and downloads are provided separately with this report.

Species and number seen for each sighting were recorded on data sheets. Data was captured to digital form during and after the survey.

d. Data analysis

Jolly's (1969) method for blocks of unequal size was used to calculated estimates of density and variance for each species in each stratum as follows:

$$R = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} z_i}$$

$$\hat{Y} = Z.R$$

$$V_{\hat{Y}} = \frac{N(N-n)}{n}.(s_y^2 - 2.R.s_{zy} + R^2.s_z^2)$$

where:

R = density of animals
Y = total number estimated
Z = total area of stratum
y_i = number of animals counted in transect i
z_i = area of transect i
n = number of transects
N = number of transects possible in stratum where $N = n.Z/\Sigma z$
s_y^2 = variance of number seen per transect
s_z^2 = variance of transect areas
s_{zy} = covariance between number seen per transect and transect area
V_y = variance of estimated number in stratum (i.e. variance of Y)

Overall estimates and variances were obtained from the sums of the stratum estimates and their variances.

Where strata were flown twice by different aircraft (strata KC A&B,KD A&B and LC A&B) the mean estimate of the two results was taken as the overall estimate. The variance of the mean result was the sum of the variances divided by four.

The standard error (*SE*) of the estimate is the square root of the variance and the 95% confidence limits of the estimate is $Y \pm t\,.\,SE$, where t is Student's t for a two-tailed probability of 0.05 and n-1 degrees of freedom.

Estimates for areas other than original strata (e.g. Parks) were obtained by classifying sightings according to area and reanalysing the strata with the reduced sets of sightings.

e. Elephant sightings, carcass classification and ratios

Elephants were recorded as being in family groups or bull groups, defined as follows:

Family groups - herds in which females and young are present. Any bulls in the group are counted as part of the group.

Bull groups - single bulls or herds which contain no females or juveniles.

Carcasses were classified into four categories according to their estimated time since death ((Douglas-Hamilton & Hillman 1981; Douglas-Hamilton & Burril 1991)). These have been divided further (to allow the objective recording of very recent deaths. The four classes are:

Carcass 1 - Fresh (<1 month): skin covered, with flesh present giving the body a rounded appearance; vultures often present; ground still moist from body fluids.

Carcass 2 - Recent (<1 year): rot patch still visible; hide still attached to carcass; bones not scattered

Carcass 3 - Old (>1 year): skin absent; bones not scattered; vegetation re-grown in rot patch.

Carcass 4 - Very old (up to 10 years): bones bleached and scattered.

The estimated time since death of carcasses may vary between regions as the rate of decomposition depends on a number of factors such as moisture and temperature.

A "carcass ratio" defined as the ratio of dead elephants to all elephants (dead plus live animals). Here it is converted to a percentage by multiplying by 100.

Douglas-Hamilton *et al.* (Douglas-Hamilton & Hillman 1981; Douglas-Hamilton & Burril 1991) suggest a carcass ratio of 2 - 8% as being normal for a stable or increasing population, while a ratio of over 9% indicates a declining population.

f. Searching rate and height

The searching rate (km^2/hr) was calculated for each transect and the mean for each stratum provided as an indication the survey quality. Overall mean and standard deviation of height was calculated for each pilot as another indication of quality.

g. Mapping wildlife distribution

The positions of the sightings were simply plotted on a map of the area without accounting for the relative numbers of animals per sighting or the sampling intensity at which the sighting was made. All sightings (in the sample strips and out) were plotted.

APPENDIX II: RESULTS

Supporting data indicating survey quality are given below. Track logs of the transects flown are shown in Figs 22 to 25. Most tracks display acceptable levels of variation about the intended lines. One transect was missed on the last flight in Sioma Ngwezi and could not be repeated, as the aircraft had been fully refuelled for return to Lusaka, so could not take off with a full survey crew.

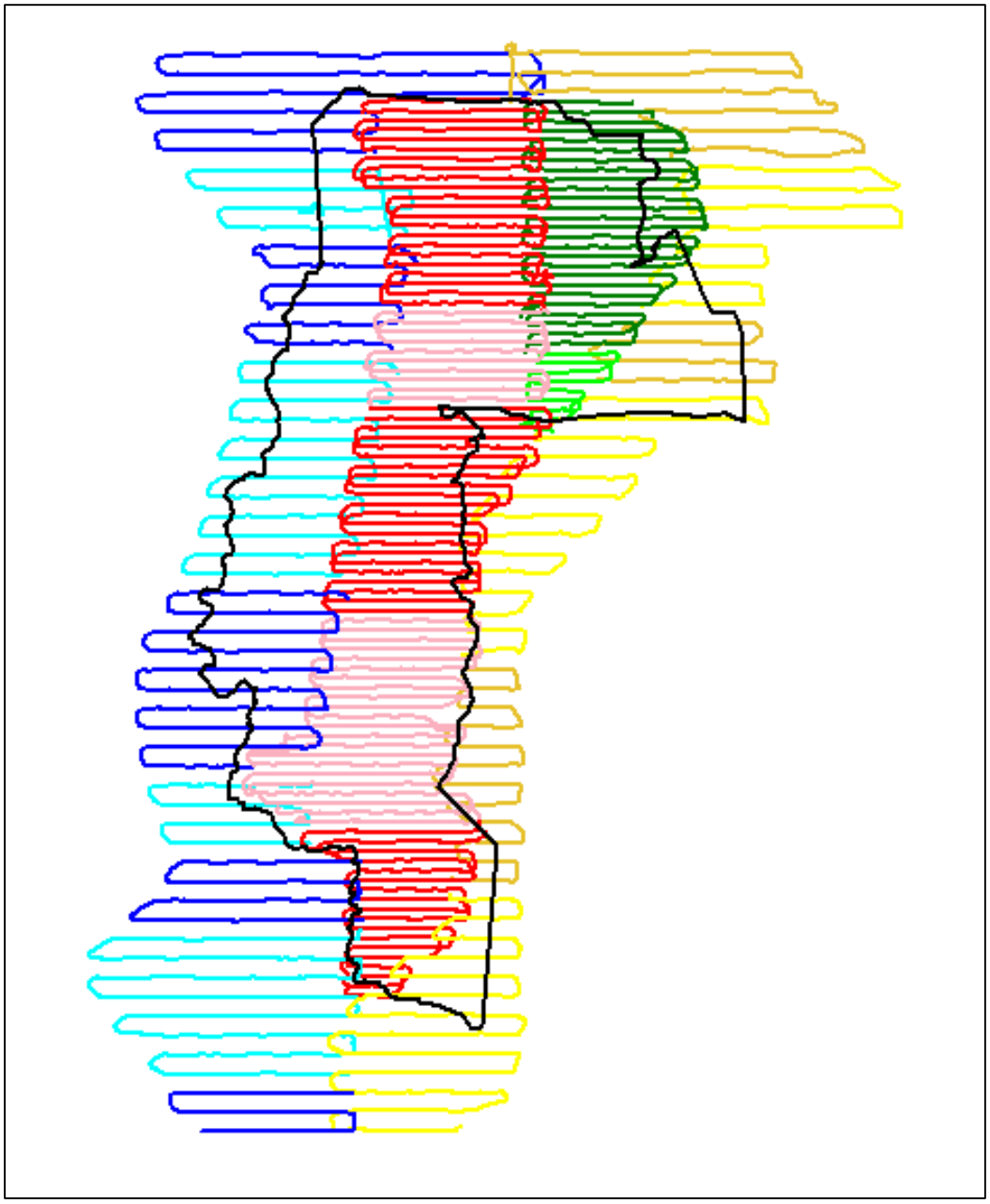

Figure 27 Tracks actually flown in Kafue

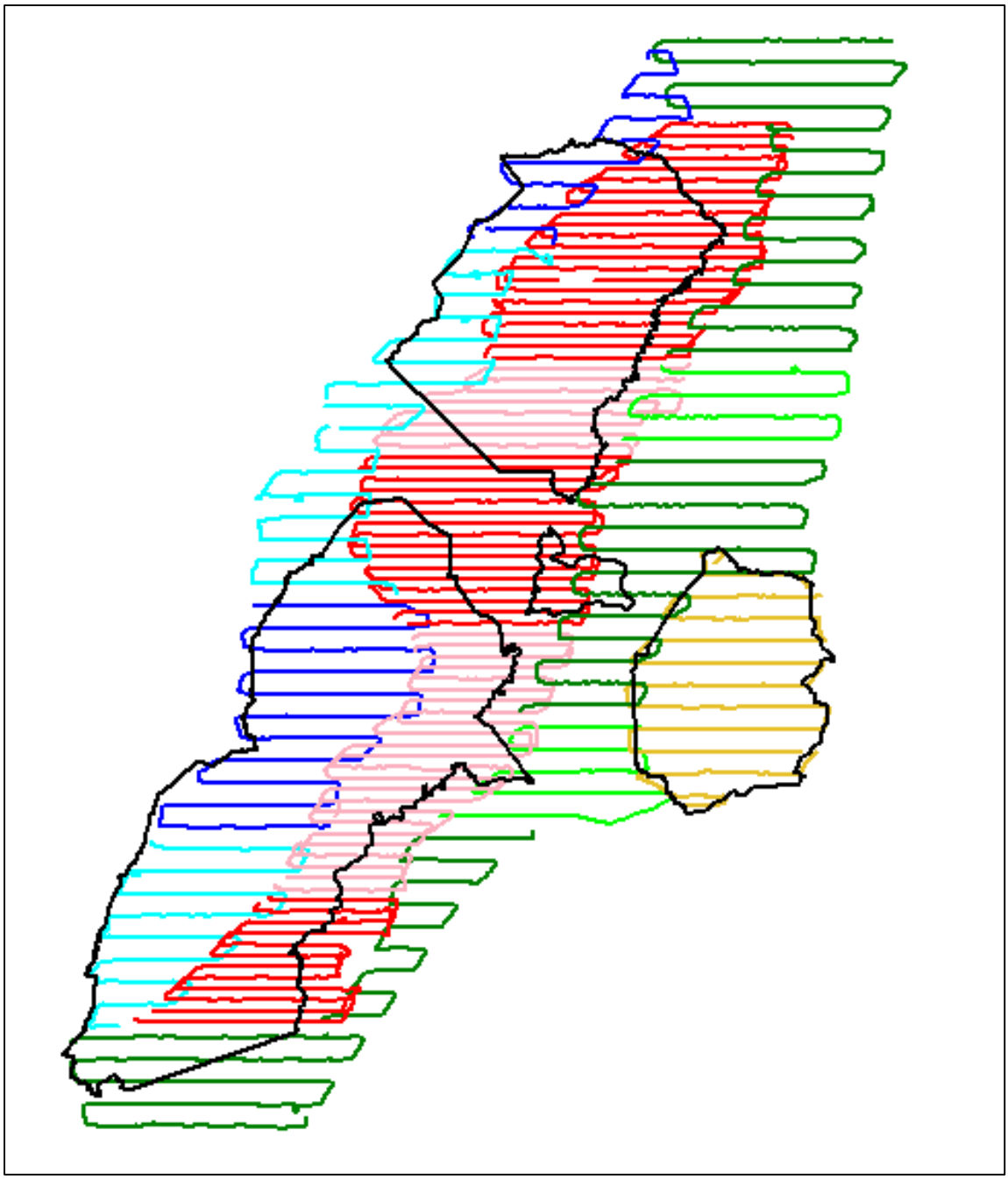

Figure 28 Tracks actually flown in Luangwa

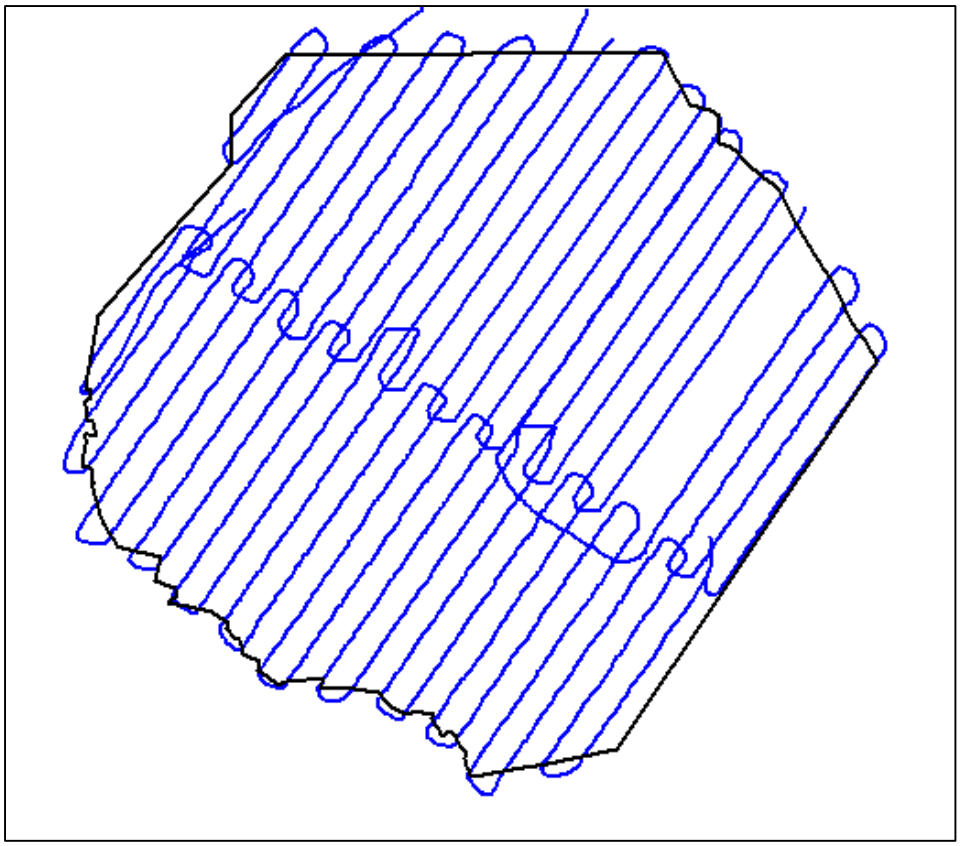

Figure 29 Tracks actually flown in Sioma Ngwezi
(Note missing transect)

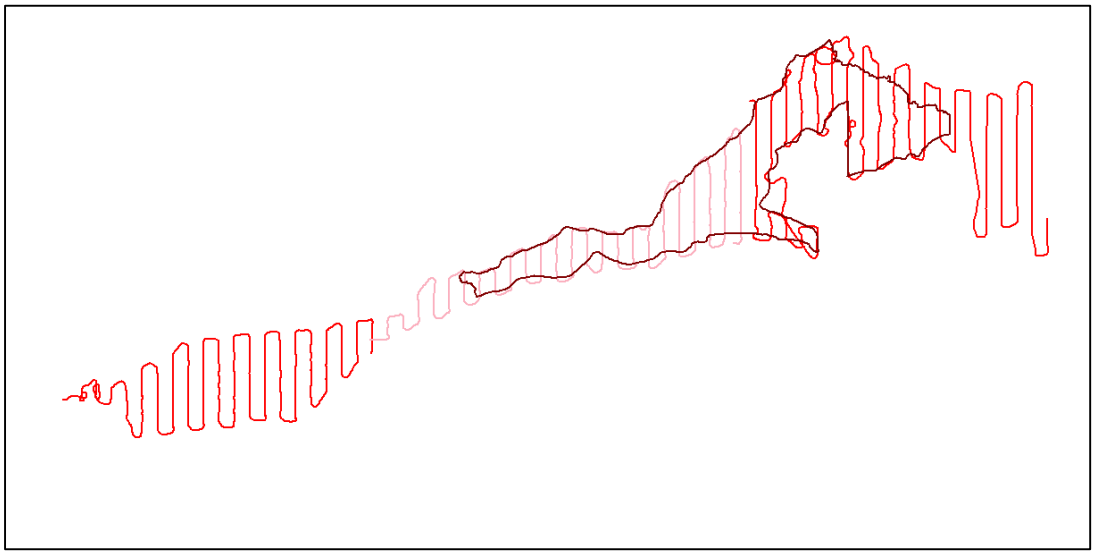

Figure 30 Tracks actually flown in Lower Zambezi Valley

a. **Survey statistics:**

Table 11. **Stratum statistics**

Area = km^2 ; No. trans = number of transects in stratum; SI% = SI; trans time = total flight time on transects; total length = total length of transects in km; ground speed : knots; search rate (SR) = km^2/min

System	Stratum	Area	no Trans	SI%	Trans time	Sample area	Length	GSkph	SR
Kafue	KA	17638	57	5.965	15.917	1052.046	2967.747	186.455	1.102
Kafue	KB	12141	57	5.452	11.217	661.981	2029.001	180.892	0.984
Kafue	KCA	11821	47	6.155	11.100	727.642	1990.283	179.305	1.093
Kafue	KCB	11821	47	5.394	11.000	637.608	1964.709	178.610	0.966
Kafue	KDA	3430	18	5.442	3.317	186.658	577.032	173.980	0.938
Kafue	KDB	3430	17	6.262	3.117	214.787	564.326	181.067	1.149
Luangwa	LA	7767	45	5.607	7.200	435.464	1298.774	180.385	1.008
Luangwa	LB	11108	51	5.785	11.083	642.636	1855.578	167.421	0.966
Luangwa	LD	2610	12	5.385	2.850	140.555	441.584	154.942	0.822
Luangwa	LCA	11334	41	5.337	11.200	604.849	1898.446	169.504	0.900
Luangwa	LCB	11334	41	5.911	10.750	669.930	1914.094	178.055	1.039
Sioma	SIA	2472	24	11.937	4.317	295.073	837.261	193.960	1.139
Sioma	SIB	2010	2	12.444	3.617	250.130	666.848	184.382	1.153
L. Zambezi	Lzam	2528	70	10.488	4.833	265.128	849.442	175.747	0.914

Target groundspeed was 90 knots (167 km/hr). Speed per transect varied considerably, but this was unavoidable because of the strong winds during the survey. Target search rate was 1 km^2 / minute.

Table 12. Maintenance of height

System	Pilot	Aircraft	Mean Height	95% Range
Kafue	Vergara	DA	300.47	± 44.03
Kafue/Sioma	RamaKrishna	MP	299.32	± 45.20
Luangwa	Kradolfer	MA	302.60	± 41.04
Luangwa	Weaver	FZ	305.14	± 43.28
Luangwa/L Zambezi	Kehr	FZ,MA	303.7	± 58.06

Heights in feet recorded by the coordinator were used to evaluate performance. 95% range is the range within which 95% of height observations lie. An ideal standard is would be ± 20 feet. The least constant performance was probably partly caused by flying in difficult terrain.

b. Calibration of strip widths

The results of the strip width calibrations are given below. L and R are left and right observers. P and H are the heights on the pressure altimeter and the radar altimeter respectively. In and out are the inner and outer numbers in the strip. Width is 10*(out-in+1). Corrected refers to the width corrected to 300 feet (width.H/300). Tot W is the total corrected width. Var is the variance of the total width. Varmn and SEmn are the variance and standard error of the *mean* total width. t is student's t for n-1 degrees of freedom. PRP% is the percent relative precision, i.e. 100%.2t.SE/Mean. Target PRP is <5%.

Table 13: Calibration C206, DA, 4/9/15

			Annette		Netta						
			L		**R**		**Width**		**Corrected**		
	P	**H**	**in**	**out**	**in**	**out**	**L**	**R**	**L**	**R**	**Tot W**
1	260	270	6	18	7	27	130	210	144.44	233.33	377.78
2	260	270	8	21	5	18	140	140	155.56	155.56	311.11
3	280	290	3	17	13	29	150	170	155.17	175.86	331.03
4	300	320	7	22	16	31	160	160	150.00	150.00	300.00
5	240	280	4	18	9	23	150	150	160.71	160.71	321.43
6	260	290	9	24	6	17	160	120	165.52	124.14	289.66
7	230	250	6	17	9	21	120	130	144.00	156.00	300.00
8	260	260	8	21	7	19	140	130	161.54	150.00	311.54
9	240	260	8	20	8	24	130	170	150.00	196.15	346.15
10	320	340	12	28	7	21	170	150	150.00	132.35	282.35
11	260	250	7	19	7	21	130	150	156.00	180.00	336.00
12	350	350	8	24	10	31	170	220	145.71	188.57	334.29
13	280	280	12	23	4	18	120	150	128.57	160.71	289.29
14	310	300	9	25	7	24	170	180	170.00	180.00	350.00
15	270	280	10	21	3	21	120	190	128.57	203.57	332.14
16	340	330	9	24	8	26	160	190	145.45	172.73	318.18
17	270	270	8	21	5	21	140	170	155.56	188.89	344.44
18	290	290	10	23	6	23	140	180	144.83	186.21	331.03
19	280	290	10	24	4	19	150	160	155.17	165.52	320.69
20	300	300	11	25	6	21	150	160	150.00	160.00	310.00
21	270	270	7	20	8	24	140	170	155.56	188.89	344.44
								Mean	151.07	171.87	322.93
										Var	556.29
										Varmn	26.49
										SEmn	5.15
										t	1.72
										PRP%	2.75

Table 14: Calibration C182, MP, 4/9/15

			Diilwe		Howard						
			L		R		Width		Corrected		
	P	H	in	out	in	out	L	R	L	R	Tot W
1	300	300	14	30	11	29	170	190	170.00	190.00	360.00
2	300	250	11	29	11	28	190	180	228.00	216.00	444.00
3	300	280	9	27	15	32	190	180	203.57	192.86	396.43
4	300	300	22	34	17	32	130	160	130.00	160.00	290.00
5	280	280	15	26	14	28	120	150	128.57	160.71	289.29
6	280	250	14	28	15	27	150	130	180.00	156.00	336.00
7	320	300	14	29	14	30	160	170	160.00	170.00	330.00
8	250	250	10	21	14	31	120	180	144.00	216.00	360.00
9	310	295	14	28	15	33	150	190	152.54	193.22	345.76
10	300	280	17	33	11	34	170	240	182.14	257.14	439.29
11	300	300	11	24	11	27	140	170	140.00	170.00	310.00
12	280	280	14	29	11	28	160	180	171.43	192.86	364.29
13	300	280	11	25	15	29	150	150	160.71	160.71	321.43
14	280	270	13	29	10	28	170	190	188.89	211.11	400.00
15	260	250	12	26	9	25	150	170	180.00	204.00	384.00
16	310	290	14	29	16	33	160	180	165.52	186.21	351.72
17	280	280	14	30	10	28	170	190	182.14	203.57	385.71
18	250	250	12	28	11	28	170	180	204.00	216.00	420.00
19	250	250	11	29	9	26	190	180	228.00	216.00	444.00
20	260	260	15	30	11	28	160	180	184.62	207.69	392.31
21	280	290	11	28	12	28	180	170	186.21	175.86	362.07
								Mean	174.78	193.14	367.92
										Var	2177.38
										Varmn	103.68
										SEmn	10.18
										T	2.09
										PRP%	5.78

Table 15. Calibration C206 FZ 18/9/2015. Columns P2 and H2 are Pressure and Radar Heights taken independently of the calibration in this case.

		Wilfred		Margaret								
		L		R		Width		Corrected				
	H	in	out	in	out	L	R	L	R	Tot W	P2	H2
1	280	7	22	9	27	160	190	171.428	203.571	375	290	315
2	305	11	28	6	23	180	180	177.048	177.049	354.098	300	330
3	300	6	22	7	28	170	220	170	220	390	290	320
4	305	9	25	6	23	170	180	167.213	177.049	344.262	330	350
5	300	7	23	10	28	170	190	170	190	360	320	325
6	230	7	18	6	21	120	160	156.521	208.695	365.217	310	315
7	300	6	19	12	29	140	180	140	180	320	300	300
8	295	7	23	9	27	170	190	172.881	193.220	366.101	300	315
9	295	8	24	8	23	170	160	172.881	162.711	335.593	310	330
10	235	6	18	8	23	130	160	165.957	204.255	370.212	280	290
11	235	6	16	9	24	110	160	140.425	204.255	344.680	280	290
12	250	8	25	6	20	180	150	216	180	396	260	265
13	300	9	25	12	30	170	190	170	190	360	300	335
14	300	8	24	10	26	170	170	170	170	340	210	215
15	270	4	18	11	28	150	180	166.667	200	366.667	300	320
16	280	5	21	9	27	170	190	182.142	203.571	385.714	290	310
17	225	5	16	8	22	120	150	160	200	360	320	345
18	320	8	24	10	29	170	200	159.375	187.5	346.875	190	200
19	300	8	24	7	26	170	200	170	200	370	290	290
20	310	8	24	9	27	170	190	164.516	183.870	348.387	250	265
21	290	7	25	9	25	190	170	196.551	175.862	372.413	310	330
							Mean	169.505	191.029	360.534	290	320
									Var	348.176	300	320
									Varmn	16.5798	280	290
									SEmn	4.07181	270	290
									t	2.08596		
									PRP%	2.35587		

Table 16. Calibration C206 MA 17/9/2015

			Mwansa		Jarton						
			L		R		Width		Corrected		
	P	H	in	out	in	out	L	R	L	R	Tot W
1	300	305	6	23	9	20	180	120	177.049	118.032	295.081
2	310	315	11	30	6	17	200	120	190.476	114.285	304.761
3	300	320	6	23	9	22	180	140	168.75	131.25	300
4	280	280	9	24	7	18	160	120	171.428	128.571	300
5	270	270	6	21	8	18	160	110	177.777	122.222	300
6	290	300	8	27	9	23	200	150	200	150	350
7	200	205	5	18	6	16	140	110	204.878	160.975	365.853
8	305	315	10	29	8	20	200	130	190.476	123.809	314.285
9	290	295	5	21	11	24	170	140	172.881	142.372	315.254
10	255	255	7	23	7	17	170	110	200	129.411	329.411
11	320	320	7	27	11	22	210	120	196.875	112.5	309.375
12	290	285	9	27	7	19	190	130	200	136.842	336.842
13	190	178	4	13	5	12	100	80	168.539	134.831	303.370
14	260	265	9	25	7	18	170	120	192.452	135.849	328.301
15	310	310	4	20	12	26	170	150	164.516	145.161	309.677
16	290	290	10	25	7	16	160	100	165.517	103.448	268.965
17	305	305	8	25	9	20	180	120	177.049	118.032	295.081
18	200	188	6	17	4	11	120	80	191.489	127.659	319.146
19	310	305	7	23	7	19	170	130	167.213	127.868	295.081
20	350	375	7	29	9	28	230	200	184	160	344
21	310	305	8	25	8	18	180	110	177.049	108.196	285.242
22	355	375	9	32	11	28	240	180	192	144	336
23		270	6	18	10	21	130	120	144.444	133.333	277.777
24		350	8	27	11	23	200	130	171.428	111.428	282.857
25		305	6	22	10	21	170	120	167.213	118.032	285.245
26		310	7	23	9	22	170	140	164.516	135.483	300
								Mean	182.781	130.062	309.672
										Var	557.390
										Varmn	21.438
										SEmn	4.630
										t	2.059
										PRP%	3.079

c. Comparison of observers and aircraft, by number of sightings

Table 17. Comparison of observers

Aircraft	Attrib.	Observed No		Chi²	P	
		L	R			
DA	Carcass	23	11	4.2352	0.0395	*
DA	Ele Bull	2	2	0	1	
DA	Ele Family	12	16	0.5714	0.4496	
MP	Carcass	1	4	1.8	0.1797	
MP	Ele Bull	4	5	0.1111	0.7388	
MP	Ele Family	14	13	0.0370	0.8473	
FZ	Carcass	5	3	0.5	0.4795	
FZ	Ele Bull	20	33	3.1886	0.0741	
FZ	Ele Family	41	46	0.2873	0.5919	
MA	Carcass	2	7	2.7777	0.0955	
MA	Ele Bull	21	12	2.4545	0.1171	
MA	Ele Family	49	50	0.0101	0.9199	

Table 18. Comparison of aircraft/crews

		Observed No.		Chi²	P	
	Aircraft	**DA**	**MP**			
Kafue	Carcass	20	5	9	0.0027	*
Kafue	Ele Bull	4	8	1.3333	0.2482	
Kafue	Ele Family	18	25	1.1395	0.2857	
	Aircraft	**MA**	**FZ**			
Luangwa	Carcass	9	6	0.6	0.4385	
Luangwa	Ele Bull	26	47	6.0410	0.0139	*
Luangwa	Ele Family	84	82	0.0240	0.8766	

Aircraft crews were compared only where both aircraft covered the same stratum.

When there is a discrepancy between observers it can not necessarily be assumed that the observer with the lesser count is missing animals. The other observer could be over-counting by counting animals that are outside the strip as being in the sample. With carcasses, however, few are seen outside the strip and it is a reasonable assumption that the observer with the highest count is missing fewer carcasses. Significant differences in carcass number seen in this survey therefore suggest carcasses are being missed. However, this may not mean that results are not meaningful or not comparable with other surveys, undercounting being universal (section 2.2.4).

Differences in bulls seen are partly due to inadequate classification, i.e. one crew often failed to record the type of group seen.

APPENDIX III: RESULTS BY LAND CATEGORY AND STRATUM

a. Estimates of numbers, densities and confidence limits

The following tables give the results for each stratum based on the numbers seen in the sample. Results for all species and attributes counted are given. These are the individual stratum results which have been combined to give higher level results reported above.

SI refers to the sampling intensity for the stratum. Column 6, labelled PRP (Percent Relative Precision), is the 95% confidence interval expressed as a percentage of the estimate. "No. in" is the number of animals seen between the sampling strips. "No. out" is the number seen outside of them. Where the calculated lower limit of the confidence range is less than the number actually seen in the stratum (including all sightings, both in and out), the number seen is given as the lower limit of the range.

Where the overall result for a stratum is the result of separate coverages, the overall result is given separately. Component coverages have italicised titles.

OVERALL ESTIMATES

Zambia Elephant Range Overall Estimates

Area: 84859.3 km^2 SI: 7.99 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	1851	188	79	49912.4	23.7	1412 - 2291	2.18
ElephantFamily	19909	1942	1398	5232454	22.6	15407 - 24410	23.46
All Elephants	21760	2130	1477	5282366	20.8	17237 - 26283	25.64
EleCarcass 1	8	1	0	56.8	184.5	1 - 23	0.01
EleCarcass 2	19	2	1	158.6	131.8	2 - 44	0.02
EleCarcass 3	96	7	0	1371.7	75.7	23 - 169	0.11
EleCarcass 4	905	93	24	13399.9	25.2	678 - 1133	1.07
All Ele Carcasses	1029	103	25	14986.9	23.4	788 - 1269	1.21

ESTIMATES BY LAND CATEGORY

Kafue National Park 22230 km^2

SPECIES	Pop. Est.	No. In	No. Out	Variance	PRP%	95%Range			No./ km^2
ElephantBull	147	17	11	2628.5	68.6	46	-	248	0.66
ElephantFamily	4666	459	556	1319500	48.5	2403	-	6929	20.99
All Elephants	4813	476	567	1322128	47.1	2548	-	7078	21.65
EleCarcass 2	9	1	1	76.6	186	1	-	27	0.04
EleCarcass 3	28	2	0	402.9	143.2	2	-	67	0.13
EleCarcass 4	242	27	11	4236.7	53	114	-	370	1.09
All Ele Carcasses	279	30	12	4716.2	48.5	144	-	414	1.26

Kafue GMAs 22755 km^2

SPECIES	Pop. Est.	No. In	No. Out	Variance	PRP%	95%Range			No./ km^2
ElephantBull	25	2	2	320	141.6	2	-	60	0.11
ElephantFamily	1851	156	54	670956.7	87.2	237	-	3464	8.13
All Elephants	1876	158	56	671276.7	86.1	262	-	3490	8.24
EleCarcass 3	52	3	0	840.2	110.1	3	-	109	0.23
EleCarcass 4	174	11	2	3594.8	67.8	56	-	292	0.76
All Ele Carcasses	226	14	2	4435	58	95	-	357	0.99

Luangwa South National Park 8646 km^2

SPECIES	Pop. Est.	No. In	No. Out	Variance	PRP%	95%Range			No./ km^2
ElephantBull	403	40	22	11227.1	51.9	194	-	612	4.66
ElephantFamily	2900	318	179	354729.8	40.5	1724	-	4075	33.54
All Elephants	3302	358	201	365956.9	36.2	2108	-	4496	38.19
EleCarcass 4	73	7	1	873.7	79.8	15	-	131	0.84
All Ele Carcasses	73	7	1	873.7	79.8	15	-	131	0.84

Luangwa North National Park 4676 km^2

SPECIES	Pop. Est.	No. In	No. Out	Variance	PRP%	95%Range			No./ km^2
ElephantBull	437	44	20	14374.1	54.3	200	-	675	9.35
ElephantFamily	4236	430	225	801561.7	41.8	2464	-	6008	90.59
All Elephants	4673	474	245	815935.8	38.3	2885	-	6461	99.94
EleCarcass 4	8	1	0	62.3	184.7	1	-	24	0.17
All Ele Carcasses	8	1	0	62.3	184.7	1	-	24	0.17

Luambe National Park 344 km²

SPECIES	Pop. Est.	No. In	No. Out	Variance	PRP%	95%Range	No./ km²
ElephantBull	0	0	5	0	0	0 - 0	0
ElephantFamily	54	6	0	1495.3	140.6	6 - 131	15.7
All Elephants	54	6	5	1495.3	140.6	6 - 131	15.7

Luangwa Parks 16276 km²

SPECIES	Pop. Est.	No. In	No. Out	Variance	PRP%	95%Range	No./ km²
ElephantBull	840	84	47	25601.2	37.5	525 - 1155	5.16
ElephantFamily	7190	754	404	1157787	29.5	5072 - 9307	44.18
All Elephants	8030	838	451	1183388	26.7	5889 - 10170	49.34
EleCarcass 4	82	8	1	936	73.8	21 - 142	0.5
All Ele Carcasses	82	8	1	936	73.8	21 - 142	0.5

Luangwa GMAs 13933 km²

SPECIES	Pop. Est.	No. In	No. Out	Variance	PRP%	95%Range	No./ km²
ElephantBull	659	66	10	23155.2	45.5	359 - 960	4.73
ElephantFamily	5209	468	201	2455808	59.4	2116 - 8302	37.39
All Elephants	5869	534	211	2478963	53	2761 - 8976	42.12
EleCarcass 3	8	1	0	62.3	184.1	1 - 24	0.06
EleCarcass 4	79	8	2	899.5	74.7	20 - 138	0.57
All Ele Carcasses	88	9	2	961.8	69.8	26 - 149	0.63

Lower Zambezi Valley Park 1145 km²

SPECIES	Pop. Est.	No. In	No. Out	Variance	PRP%	95%Range	No./ km²
ElephantBull	86	9	3	1029.7	74.6	22 - 150	7.51
ElephantFamily	887	93	40	86165.7	66	301 - 1472	77.47
All Elephants	973	102	43	87195.4	60.6	384 - 1562	84.98
EleCarcass 4	29	3	1	413.2	141.8	3 - 69	2.53
All Ele Carcasses	29	3	1	413.2	141.8	3 - 69	2.53

Lower Zambezi ValleyGMAs 1383 km²

SPECIES	Pop. Est.	No. In	No. Out	Variance	PRP%	95%Range	No./ km²
ElephantBull	86	9	6	3409.7	135.7	9 - 202	6.22
ElephantFamily	67	7	128	4050.8	190.2	7 - 194	4.84
All Elephants	153	16	134	7460.4	112.9	16 - 325	11.06
EleCarcass 2	10	1	0	82	189.5	1 - 28	0.72
EleCarcass 4	38	4	0	322.9	94	4 - 74	2.75
All Ele Carcasses	48	5	0	405	84.2	8 - 88	3.47

ESTIMATES BY STRATUM

Stratum KA

Area: 17638 Km² SI: 5.96 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km²
ElephantBull	17	1	0	262.4	193.6	1 - 49	0.1
ElephantFamily	1425	85	12	780061.1	124.2	85 - 3194	8.08
All Elephants	1442	86	12	780323.6	122.7	86 - 3211	8.18
EleCarcass 3	34	2	0	513.8	135.4	2 - 79	0.19
EleCarcass 4	101	6	1	2480.5	99.2	6 - 200	0.57
All Ele Carcasses	134	8	1	2994.3	81.7	25 - 244	0.76

Stratum KB

Area: 12141 km² SI: 5.45 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km²
ElephantFamily	954	52	27	259144.6	106.9	52 - 1973	7.86
All Elephants	954	52	27	259144.6	106.9	52 - 1973	7.86
EleCarcass 3	37	2	0	658.1	140.1	2 - 88	0.3
EleCarcass 4	55	3	0	963.8	113	3 - 117	0.45
All Ele Carcasses	92	5	0	1622	88	11 - 172	0.76

Stratum KCA

Area: 11821 km² SI: 6.16 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km²
ElephantBull	146	9	8	4315.1	90.4	14 - 278	1.24
ElephantFamily	3038	187	462	798146.9	59.2	1240 - 4836	25.7
All Elephants	3184	196	470	802462	56.6	1381 - 4987	26.94
EleCarcass 4	114	7	3	1954	78.2	25 - 203	0.96
All Ele Carcasses	114	7	3	1954	78.2	25 - 203	0.96

Stratum KCB

Area: 11821 km^2 SI: 5.39 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	148	8	5	6789.6	111.8	8 - 314	1.25
ElephantFamily	3337	180	73	2486222	95.1	180 - 6511	28.23
All Elephants	3485	188	78	2493012	91.2	307 - 6664	29.48
EleCarcass 2	19	1	1	324.9	195.7	1 - 55	0.16
EleCarcass 3	19	1	0	324.9	195.7	1 - 55	0.16
EleCarcass 4	352	19	7	15366.6	70.8	103 - 602	2.98
All Ele Carcasses	389	21	8	16016.4	65.4	135 - 644	3.29

Stratum KC Mean Estimates

Area: 11821 km^2 SI: 11.55 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	147	17	13	2608.6	68.9	46 - 249	1.25
ElephantFamily	3188	367	535	772566.9	54.8	1442 - 4933	26.96
All Elephants	3335	384	548	775175.5	52.4	1586 - 5083	28.21
EleCarcass 2	9	1	1	76.6	187.5	1 - 27	0.08
EleCarcass 3	9	1	0	76.6	187.5	1 - 27	0.08
EleCarcass 4	233	26	10	4079.1	54.4	106 - 360	1.97
All Ele Carcasses	252	28	11	4232.3	51.4	122 - 381	2.13

Stratum KDA

Area: 3430 km^2 SI: 5.44 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantFamily	974	53	16	276050.6	113.8	53 - 2082	28.39
All Elephants	974	53	16	276050.6	113.8	53 - 2082	28.4
EleCarcass 4	55	3	1	1468.1	146.6	3 - 136	1.61
All Ele Carcasses	55	3	1	1468.1	146.6	3 - 136	1.6

Stratum KDB

Area: 3430 km^2 SI: 6.26 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	16	1	0	230.2	201.4	1 - 48	0.47
ElephantFamily	926	58	20	254924.5	115.6	58 - 1997	27
All Elephants	942	59	20	255154.7	113.7	59 - 2013	27.46
EleCarcass 4	0	0	1	0	0	0 - 0	0
All Ele Carcasses	0	0	1	0	0	59 - 2013	0

Stratum KD Mean Estimates

Area: 3430 km^2 SI: 11.70 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	8	1	0	53.7	186.7	1 - 23	0.23
ElephantFamily	950	111	36	124514.6	75.6	232 - 1668	27.7
All Elephants	958	112	36	124568.3	74.9	240 - 1676	27.93
EleCarcass 4	28	3	2	345.9	137.3	3 - 65	0.8
All Ele Carcasses	28	3	2	345.9	137.3	3 - 65	0.82

Kafue Ecosystem Overall Results

Area: 45030 km^2 SI: 7.73 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	172	19	13	2924.8	61.9	65 - 279	0.38
ElephantFamily	6516	615	610	1936287	42.1	3775 - 9258	14.47
All Elephants	6688	634	623	1939212	41	3945 - 9432	14.85
EleCarcass 2	9	1	1	76.6	186	1 - 27	0.02
EleCarcass 3	79	5	0	1248.5	87.6	10 - 149	0.18
EleCarcass 4	416	38	13	7869.3	42	241 - 591	0.92
All Ele Carcasses	505	44	14	9194.4	37.4	316 - 694	1.12

Stratum SIA

Area: 2472.1 km^2 SI: 11.94 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
EleCarcass 3	8	1	0	60.9	193.2	1 - 25	0.34
EleCarcass 4	109	13	7	1052.6	61.8	42 - 176	4.41
All Ele Carcasses	117	14	7	1113.6	59	48 - 186	4.73

Stratum SIB

Area: 2010.2 km^2 SI: 12.44 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	8	1	0	56.8	194.4	1 - 24	0.4
ElephantFamily	40	5	15	1414.8	194.1	5 - 118	2
All Elephants	48	6	15	1471.6	165	6 - 128	2.39
EleCarcass 1	8	1	0	56.8	194.4	1 - 24	0.4
EleCarcass 4	153	19	0	1819.2	57.9	64 - 241	7.6
All Ele Carcasses	161	20	0	1875.9	55.9	71 - 251	8.01

Sioma Ngwezi Overall Estimates

Area: 4482.3 km^2 SI: 12.16 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	8	1	0	56.8	188.9	1 - 23	0.18
ElephantFamily	40	5	15	1414.8	188.7	5 - 116	0.9
All Elephants	48	6	15	1471.6	160.3	6 - 126	1.07
EleCarcass 1	8	1	0	56.8	188.9	1 - 23	0.18
EleCarcass 3	8	1	0	60.9	187.7	1 - 24	0.19
EleCarcass 4	262	32	7	2871.8	41.3	154 - 370	5.84
All Ele Carcasses	278	34	7	2989.5	39.6	168 - 388	6.2

Stratum LA

Area: 7767 km^2 SI: 5.61 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	232	13	9	10209.8	87.8	28 - 436	2.99
ElephantFamily	1320	74	40	252824	76.8	307 - 2333	16.99
All Elephants	1552	87	49	263033.8	66.6	518 - 2585	19.98
EleCarcass 4	18	1	0	293.7	193.7	1 - 52	0.23
All Ele Carcasses	18	1	0	293.7	193.7	1 - 52	0.23

Stratum LB

Area: 11108 km^2 SI: 5.79 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	138	8	4	4626.3	98.8	8 - 275	1.24
ElephantFamily	1832	106	37	2106619	159.1	106 - 4748	16.49
All Elephants	1970	114	41	2111245	148.1	114 - 4889	17.73
EleCarcass 4	17	1	1	275.2	192.8	1 - 51	0.16
All Ele Carcasses	17	1	1	275.2	192.8	1 - 51	0.15

Stratum LCA

Area: 11334 km² SI: 5.34 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km²
ElephantBull	787	42	33	43720.9	53.7	364 - 1210	6.94
ElephantFamily	8901	475	332	1980239	32	6057 - 11745	78.53
All Elephants	9688	517	365	2023960	29.7	6813 - 12563	85.48
EleCarcass 4	150	8	0	4376.3	89.2	16 - 284	1.32
All Ele Carcasses	150	8	0	4376.3	89.2	16 - 284	1.32

Stratum LCB

Area: 11334 km² SI: 5.91 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km²
ElephantBull	1472	87	11	74095.9	37.4	922 - 2022	12.99
ElephantFamily	9593	567	196	1613315	26.8	7025 - 12160	84.64
All Elephants	11064	654	207	1687411	23.7	8439 - 13690	97.62
EleCarcass 3	17	1	0	265.7	194.7	1 - 50	0.15
EleCarcass 4	102	6	2	1392.1	74.3	26 - 177	0.9
All Ele Carcasses	118	7	2	1657.8	69.5	36 - 201	1.04

Stratum LC Mean Estimates

Area: 11334 km² SI: 11.25 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km²
ElephantBull	1129	129	44	27674.3	29.3	798 - 1461	9.97
ElephantFamily	9247	1042	528	845142.2	19.8	7417 - 11076	81.58
All Elephants	10376	1171	572	872816.5	17.9	8517 - 12235	91.55
EleCarcass 3	8	1	0	62.3	185.6	1 - 24	0.07
EleCarcass 4	126	14	2	1358.5	58.4	52 - 199	1.11
All Ele Carcasses	134	15	2	1420.8	55.9	59 - 209	1.18

Stratum LD = Lukusuzi National Park

Area: 2610 Km2 S I: 5.385 %

SPECIES	Pop. Est.	No. In	No. Out	Variance	PRP%	95%Range	No./ km²
All Elephants	0	0	0	N/A	N/A	N/A	0
All Ele Carcasses	0	0	0	N/A	N/A	N/A	0

Luangwa Ecosystem Overall Estimates

Area: 32819 km^2 SI: 7.60 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	1500	150	57	42510.4	27.1	1093 - 1906	4.57
ElephantFamily	12399	1222	605	3204585	28.5	8867 - 15931	37.78
All Elephants	13898	1372	662	3247096	25.6	10343 - 17454	42.35
EleCarcass 3	8	1	0	62.3	184	1 - 24	0.03
EleCarcass 4	161	16	3	1927.5	53.9	74 - 247	0.49
All Ele Carcasses	169	17	3	1989.8	52	81 - 257	0.51

Lower Zambezi Valley Ecosystem

Area: 2528 km2 SI: 10.49 %

SPECIES	Pop. est.	No. in	No. out	Variance	PRP%	95%Range	No./ 100km^2
ElephantBull	172	18	9	4420.5	77.3	39 - 304	6.79
ElephantFamily	954	100	168	90166.6	62.8	354 - 1553	37.72
All Elephants	1125	118	177	94587	54.5	512 - 1739	44.5
EleCarcass 2	10	1	0	82	189.5	1 - 28	0.38
EleCarcass 4	67	7	1	731.3	80.8	13 - 121	2.64
All Ele Carcasses	76	8	1	813.3	74.6	19 - 133	3.01