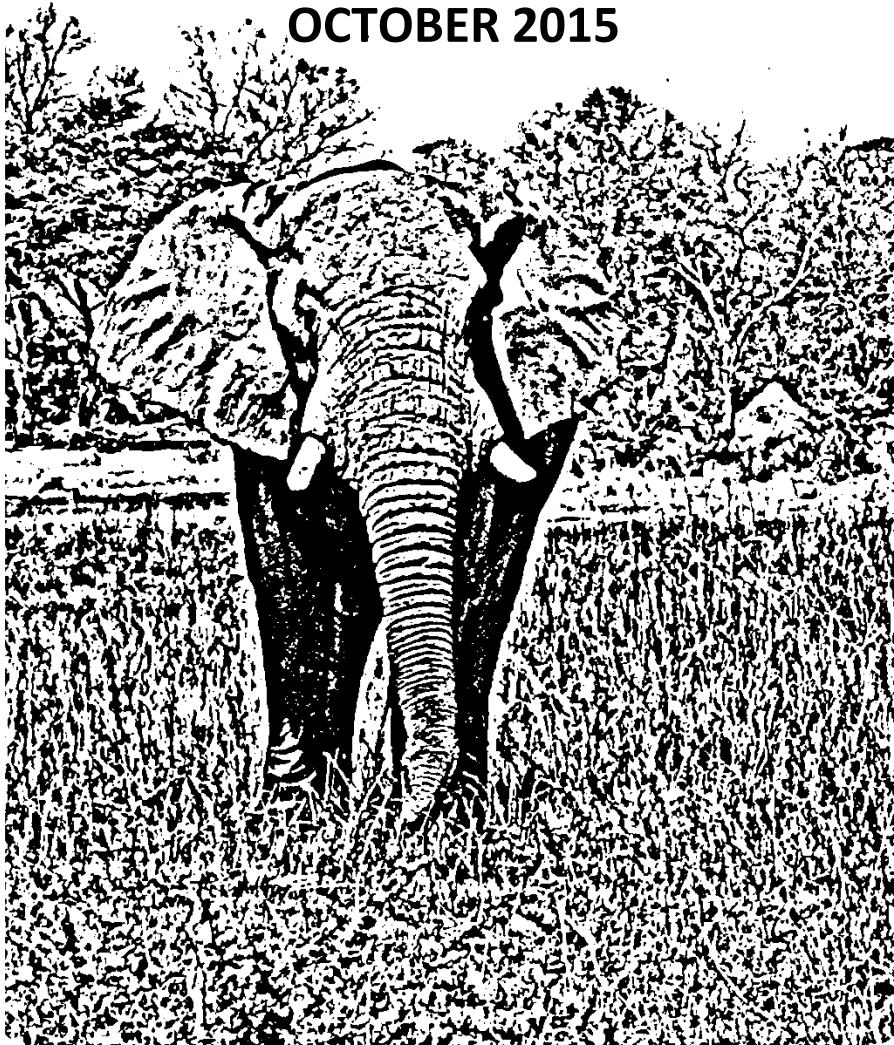




**AERIAL SURVEY OF ELEPHANTS
& OTHER WILDLIFE
IN KHAUDUM NATIONAL PARK &
NEIGHBOURING CONSERVANCIES
OCTOBER 2015**



D St C Gibson & G C Craig
DG Ecological Consulting
November 2015



The 2015 aerial survey of elephants and other wildlife in Khaudum National Park and neighbouring Conservancies, was commissioned by WWF on behalf of the Ministry of Environment and Tourism (MET), Government of Namibia

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AERIAL SURVEY OF ELEPHANTS & OTHER WILDLIFE IN KHAUDUM NATIONAL PARK & NEIGHBOURING CONSERVANCIES – OCTOBER 2015

SUMMARY

An aerial survey of wildlife and domestic livestock took place in the Khaudum National Park and its neighbouring conservancies from 6th to 14th October 2015. A total area of 12851km² was sampled at an average intensity of 9%. The focus of the survey was on obtaining good estimates of elephant numbers. Other species were recorded although it is likely that their numbers would be underestimated (Craig & Gibson, 2013a).

The estimates of numbers of each species are given in the table below. The estimate of elephants has not changed significantly since the 2014 survey. The estimated number of carcasses and the carcass ratio are relatively low.

SPECIES	Pop. est.	95% Range
Elephant Bull	1322	749 - 1895
Elephant Family	5091	2590 - 7592
<i>All Elephants</i>	6413	3847 - 8979
EleCarcass 3	13	2 - 32
EleCarcass 4	16	3 - 35
<i>All Elephant Carcasses</i>	29	5 - 56
Springbok	49	20 - 111
Buffalo	565	58 - 1389
Oryx	1475	930 - 2020
Duiker	319	194 - 444
Eland	1250	145 - 2355
Giraffe	1066	589 - 1544
Hartebeest	122	7 - 283
Kudu	531	289 - 772
Monkey	87	9 - 242
Roan	1253	560 - 1946
Steenbok	51	6 - 97
Warthog	142	21 - 263
Wildebeest	2638	1266 - 4010
Zebra	46	9 - 112
Donkey	151	10 - 317
Cattle	4702	1925 - 7480
Sheep/goats	984	216 - 1751
Horse	37	7 - 78
Ground Hornbill	39	4 - 109
Ostrich	450	211 - 689
OtherCarcass 4	34	4 - 73

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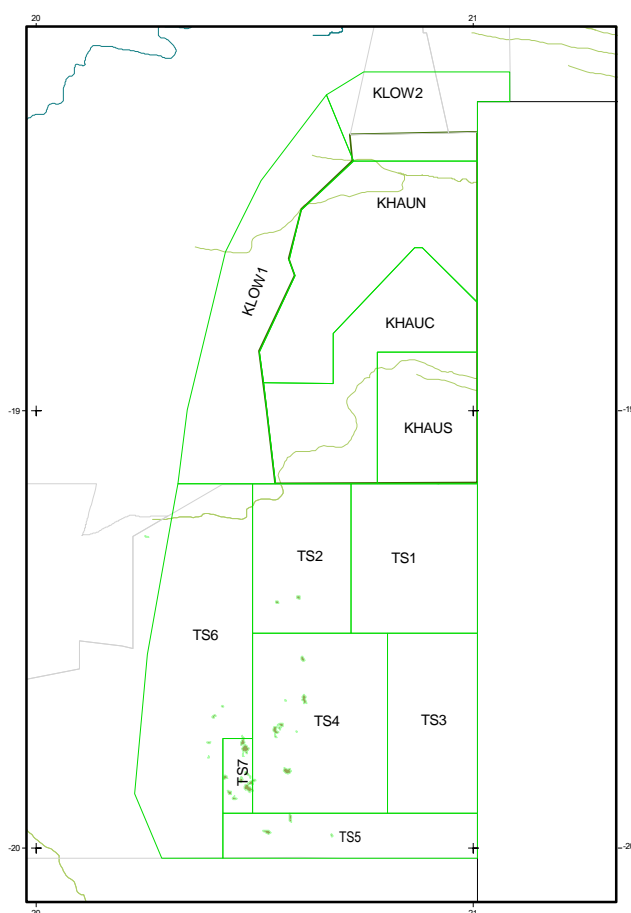
AERIAL SURVEY OF WILDLIFE IN KHAUDUM NATIONAL PARK & NEIGHBOURING CONSERVANCIES – OCTOBER 2015

1. INTRODUCTION

As part of an ongoing initiative to monitor elephant populations in the north-east of Namibia, the elephant range in and around Khaudum National Park was surveyed between 6th and 14th October 2015.

Other species including domestic livestock were included in the survey. Additionally records were made of human settlements and cultivation.

The survey was conducted according to standard practices in a light aircraft (a Cessna 182) flying at a nominal height of 300 feet above the ground. Detailed descriptions of methods are provided in Appendix I. Stratified systematic transect sampling was used (Norton Griffiths, 1978).



The stratification (Fig. 1) of the survey area was the same as for the 2013 survey (Craig & Gibson 2013b) which was based on the dry season distribution of elephants in 2011. The selection of sampling intensities was also the same except for an increase in the coverage of TS7 (pans in Nyae Nyae) where animals were concentrated on previous surveys.

While the main objective was estimating numbers and distributions of elephants and elephant carcasses, sightings of other species were recorded.

This report describes wildlife populations, human activities and other attributes in the section entitled Results.

Details of the design and methods are given in Appendix I while details of results

by stratum are given in Appendix II.

Figure 1 Strata used for the 2015 survey

2. RESULTS AND DISCUSSION

2.1. Reporting format

This report follows the format used for previous surveys of wildlife in Namibia. For each species, a table provides 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). This is shown as a percentage of the estimate in the column entitled PRP. 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.

Wildlife species in this section are arranged in alphabetical order of their common names with the exception of elephants and elephant carcasses, which are placed first and second respectively. Sightings of water points are then displayed and followed by sections on domestic livestock and human settlements.

For each species, estimates are presented as combinations of strata as follows:

STRATUM NAME	INDIVIDUAL COMPONENT STRATA
N&W Neighbours	KLOW1, KLOW2
Khaudum NP Overall	KHAU N, KHAU C, KHAUS
Khaudum NP & N & W	KHAU N, KHAU C, KHAUS, KLOW1, KLOW2
Tsumkwe Pans	TS7
Tsumkwe Overall	TS1, TS2, TS3, TS4, TS5, TS6, TS7
Khaudum & Tsumkwe Overall	Khaudum NP + N & W Neighbours + Tsumkwe Overall

Full results by individual and combined strata are given in Appendix II.

2.2. Observations of Wildlife

2.2.1. Elephants - numbers

Table 1. Estimates of All Elephants 2015

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./100km ²
N&W Neighbours	191	17	107	134.8	17 - 448	8.52
Khaudum NP Overall	3959	640	801	47.8	2066 - 5851	109.86
Khaudum NP + N&W	4150	657	908	45.7	2254 - 6045	70.99
Tsumkwe Pans	134	62	25	130.2	62 - 309	104.04
Tsumkwe Overall	2263	214	207	78	498 - 4029	32.31
Khaudum Tsumkwe Overall	6413	871	1115	40	3847 - 8979	49.9

Estimates of elephant numbers since 1998 are presented in Table 2.

Table 2. Results of aerial surveys of elephants in Khaudum/Tsumkwe area since 1998

Year	Estimate/ no counted	95% CL as % of Est.	95% range low high	Survey type	Source of Information
1998	2776	40.5	1652 - 3900	Sample	Craig
2004	4127	51.51	2001 - 6253	Sample	Kolberg
2011	4731	41.3	2777 - 6685	Sample	Craig
2013	3638	31.6	2490 - 4786	Sample	Craig
2015	6413	40.0	3847 - 8979	Sample	This report

The number of elephants appears to be increasing at about 3% per annum, although this trend is not statistically significant.

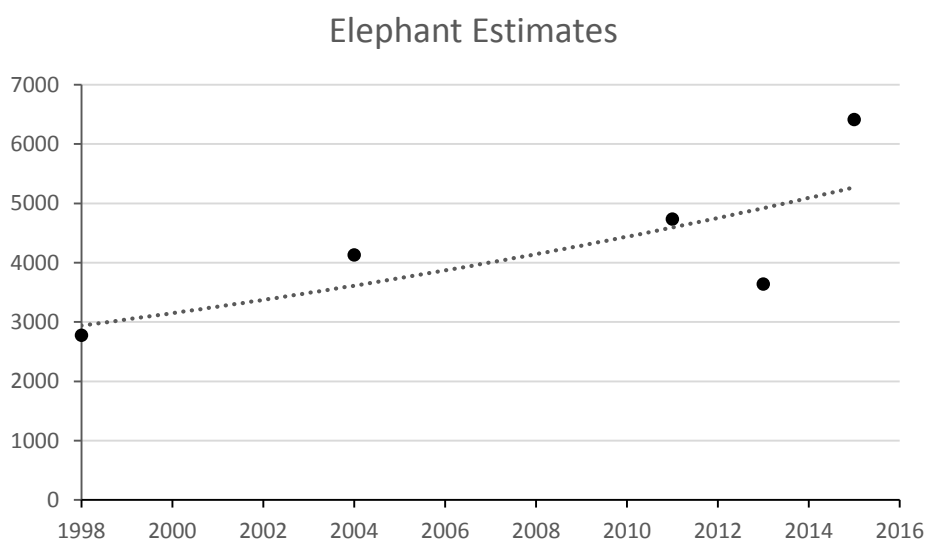


Figure 2 Population trend of elephants in Khaudum/Tsumkwe

The number of family groups seen (15) in the Tsumkwe strata in 2015 was almost double the number seen (8) in 2013, while the sightings in the national park were the same (80 in 2013 and 83 in 2015). This could be interpreted as a result, in 2013, of disturbance due to a capture operation that was taking place in the area during the survey. It is noticeable that there were several groups seen in Botswana in 2013 but not in 2015.

However, the difference between surveys could also be statistical variation resulting from the small number of groups present, and the low sampling intensity.

The overall density distribution is presented in Fig. 3 while the locations of actual sightings of elephant bulls and family groups are presented in the subsequent two maps (Figs 4 & 5)

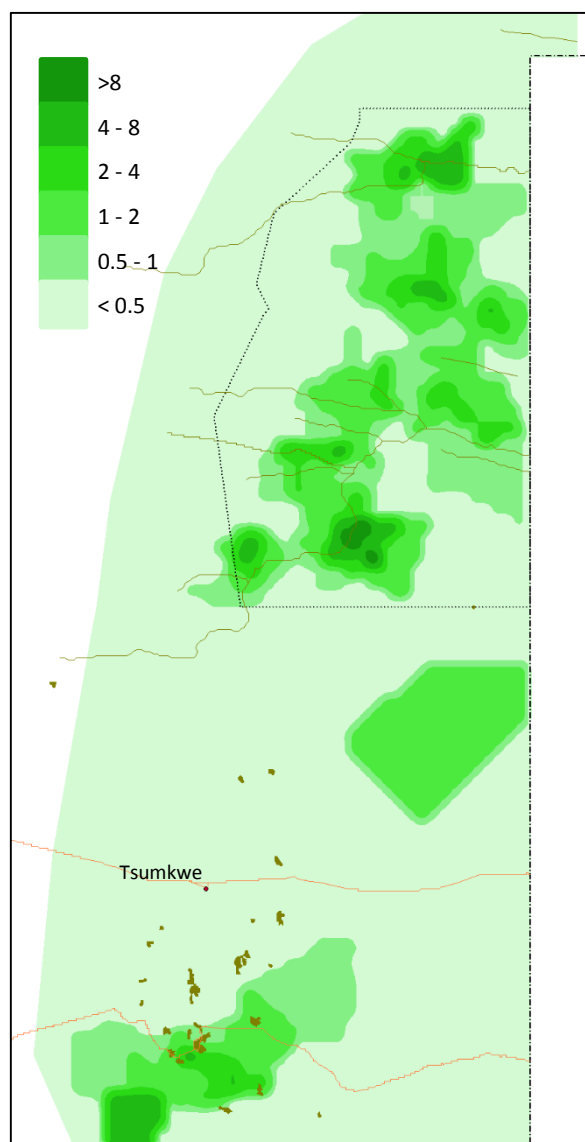


Figure 3 Density distribution of elephants in 2015

Table 3. Estimates of Elephants in Family Groups

STRATUM	Estimate	No. in	No. out	PRP%	Range	No/100Km ²
N&W Neighbours	127	12	64	194.3	12 - 373	5.66
Khaudum NP Overall	3458	566	628	54.3	1582 - 5335	95.97
Khaudum NP + N&W	3585	578	692	52.4	1707 - 5464	61.33
Tsumkwe Pans	108	50	18	158.9	50 - 280	83.91
Tsumkwe Overall	1505	145	164	112.1	145 - 3192	21.49
Khaudum Tsumkwe	5091	723	856	49.1	2590 - 7592	39.61

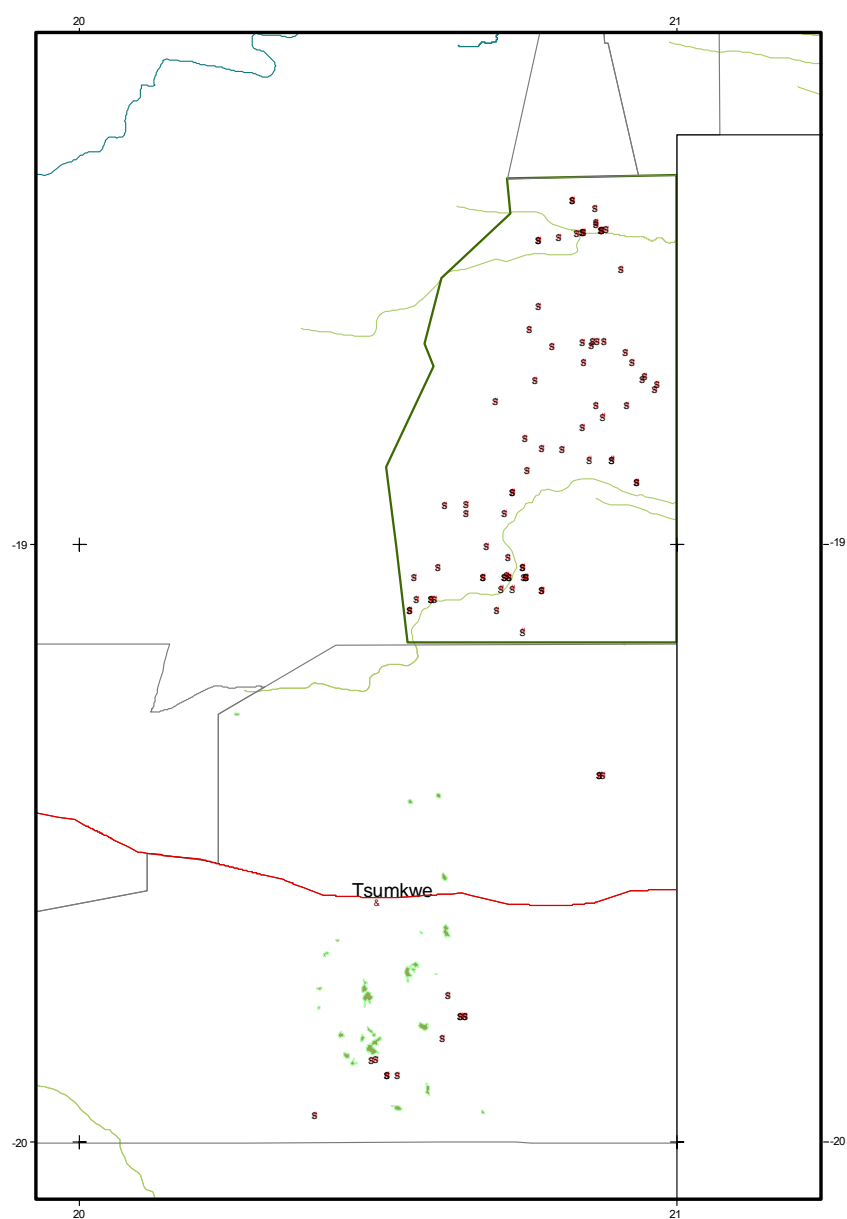


Figure 4 Sightings of elephant family groups

Table 4. Estimates of Elephant Bulls

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
N&W Neighbours	64	5	43	116	5 - 138	2.86
Khaudum NP Overall	500	74	173	48.9	256 - 745	13.88
Khaudum NP + N&W	564	79	216	44.8	311 - 817	9.65
Tsumkwe Pans	26	12	7	127.7	12 - 60	20.45
Tsumkwe Overall	758	69	43	68.8	237 - 1279	10.82
Khaudum Tsumkwe Overall	1322	148	259	43.3	749 - 1895	10.29

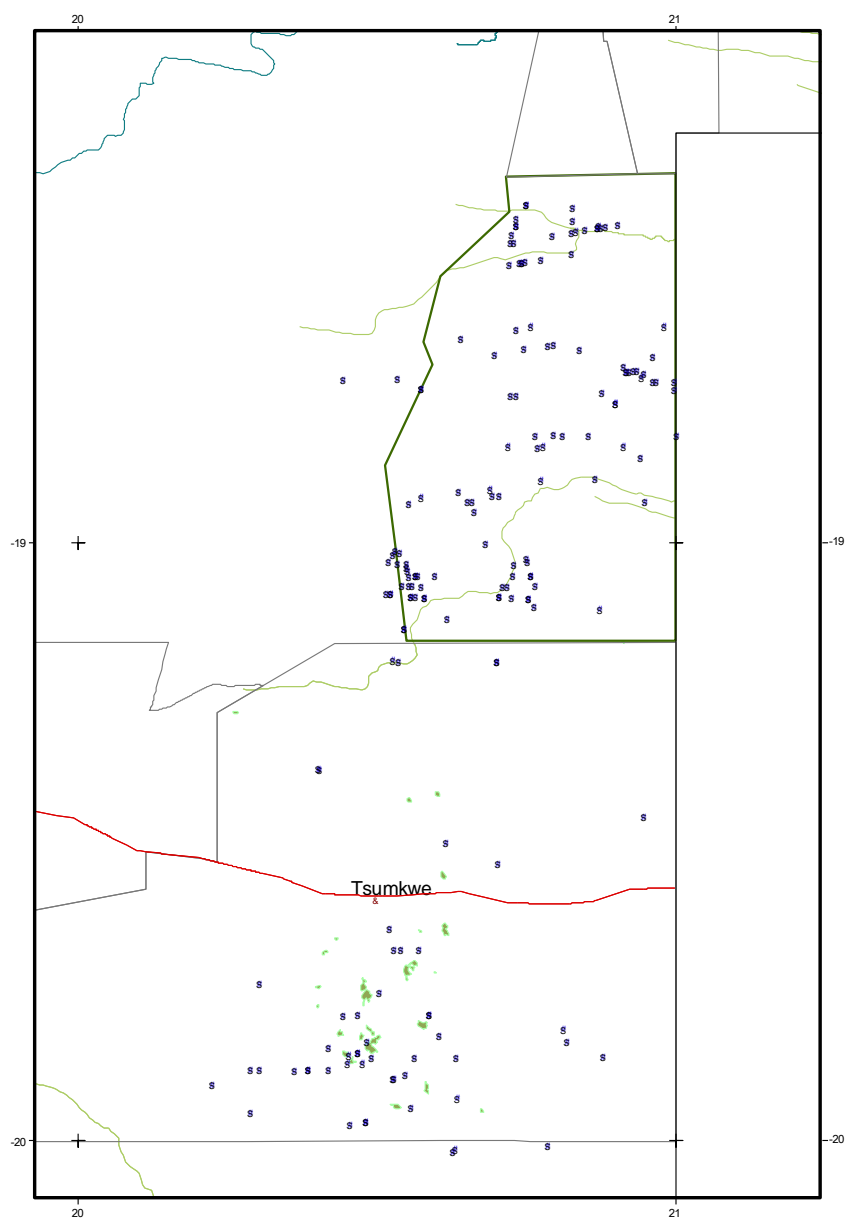


Figure 5 Sightings of elephant bull groups

2.2.2. Elephants – carcass numbers

Decay stages (1 to 4) of carcasses are described in Appendix Ig below. The numbers of sightings of elephant carcasses was not high. Only one was seen (south of Tsumkwe town) with its tusks missing. It is not known whether this was killed legally or not. The carcass ratio suggests that mortality is not unnaturally high.

Table 7. Estimates of Elephant Carcass 3

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
Khaudum NP Overall	5	1	0	192.1	1 - 15	0.14
Khaudum NP + N&W	5	1	0	190.7	1 - 15	0.09
Tsumkwe Overall	8	1	0	187.4	1 - 24	0.12
Khaudum Tsumkwe Overall	13	2	0	135.8	2 - 32	0.1

Table 8. Estimates of Elephant Carcass 4

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
Khaudum NP Overall	5	1	0	173.2	1 - 14	0.14
Khaudum NP + N&W	5	1	0	172	1 - 14	0.09
Tsumkwe Pans	2	1	0	155.6	1 - 5	1.64
Tsumkwe Overall	11	2	1	154	2 - 28	0.16
Khaudum Tsumkwe Overall	16	3	1	117.4	3 - 35	0.12

Table 9. Estimates of all classes of elephant carcasses

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
Khaudum NP Overall	10	2	0	129.3	2 - 23	0.28
Khaudum NP + N&W	10	2	0	128.4	2 - 23	0.17
Tsumkwe Pans	2	1	0	155.6	1 - 5	1.55
Tsumkwe Overall	19	3	1	119.2	3 - 42	0.27
Khaudum Tsumkwe Overall	29	5	1	88.9	5 - 56	0.23

Table 11. Carcass ratios

STRATUM	% CARCASS RATIO
N&W Neighbours	0
Khaudum NP	0.25
Khaudum NP + N&W	0.24
Tsumkwe Pans	1.47
Tsumkwe Overall	0.83
Khaudum Tsumkwe Overall	0.45

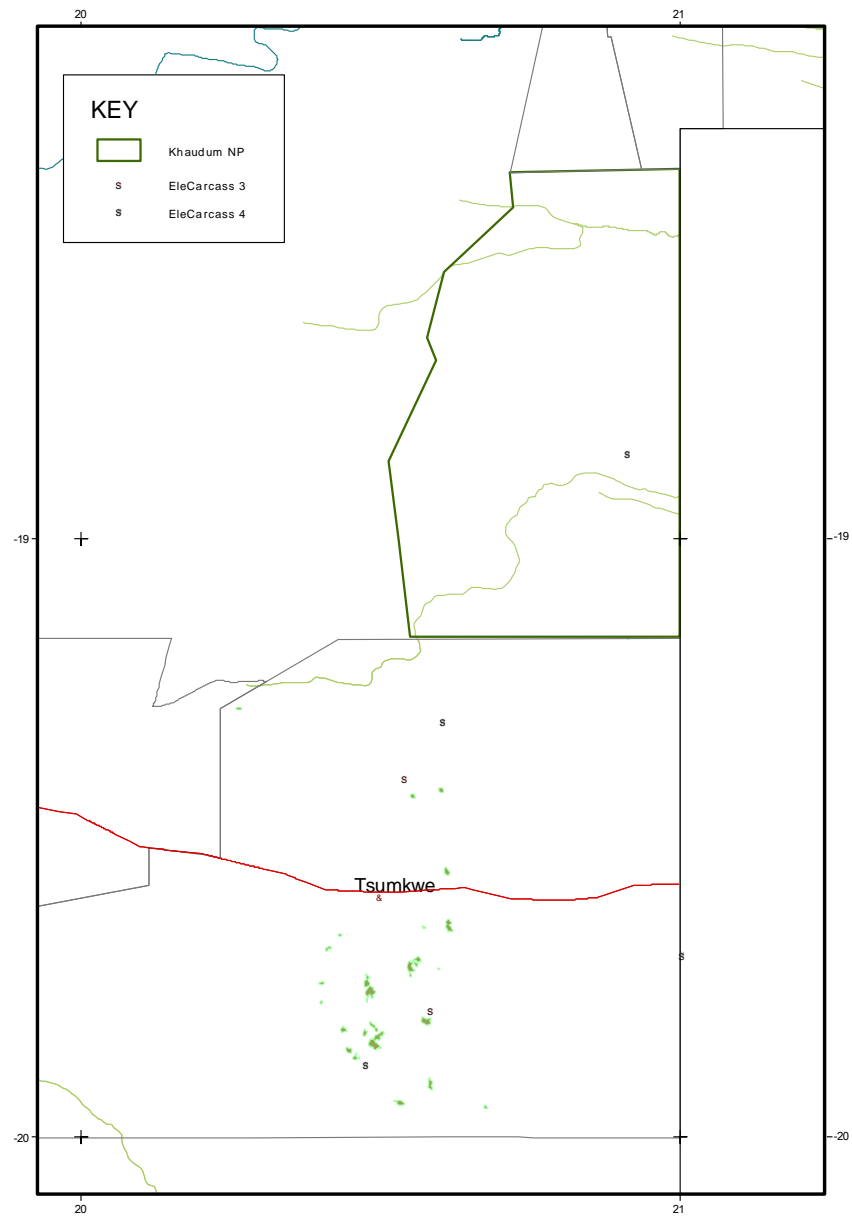


Figure 6 Sightings of elephant carcasses

2.2.3. Buffalo

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
Tsumkwe Overall	565	58	26	147.5	58 - 1399	8.07
Khaudum Tsumkwe Overall	565	58	26	145.8	58 - 1389	4.4

The estimate of buffalo is, as usual, extremely imprecise. It is based on three sightings of the animals within the buffalo camp. A total count of animals in the camp would provide a better estimate of the population. There were no buffalo seen outside the buffalo camp.

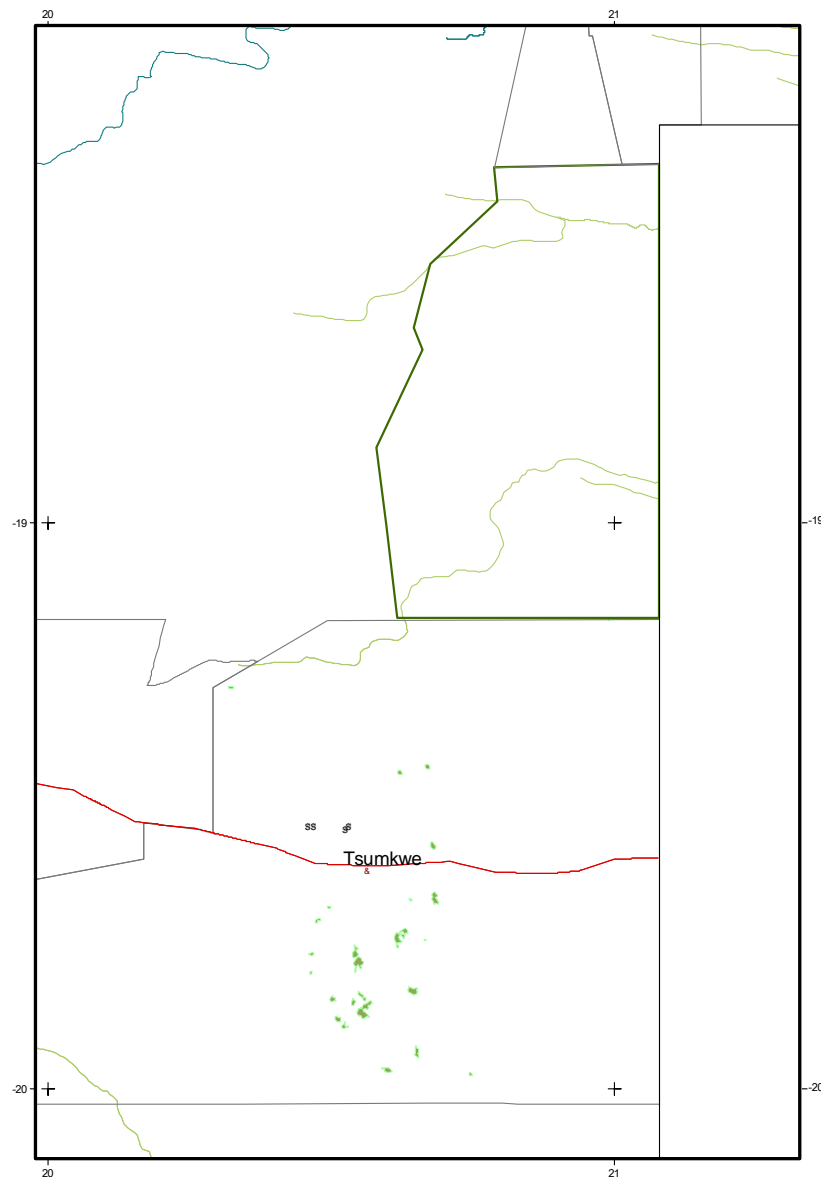


Figure 7 Sightings of buffalo

2.2.4. Duiker

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./100km ²
N&W Neighbours	91	7	0	91.6	8 - 174	4.05
Khaudum NP Overall	101	13	1	59.9	41 - 162	2.81
Khaudum NP + N&W	192	20	1	52	92 - 292	3.28
Tsumkwe Overall	127	10	1	60.5	50 - 205	1.82
Khaudum Tsumkwe Overall	319	30	2	39.2	194 - 444	2.49

Being small and rather cryptic, duiker numbers are likely to be underestimated from aerial surveys and there are probably considerably more than 319. They are quite widely spread throughout the sample area.

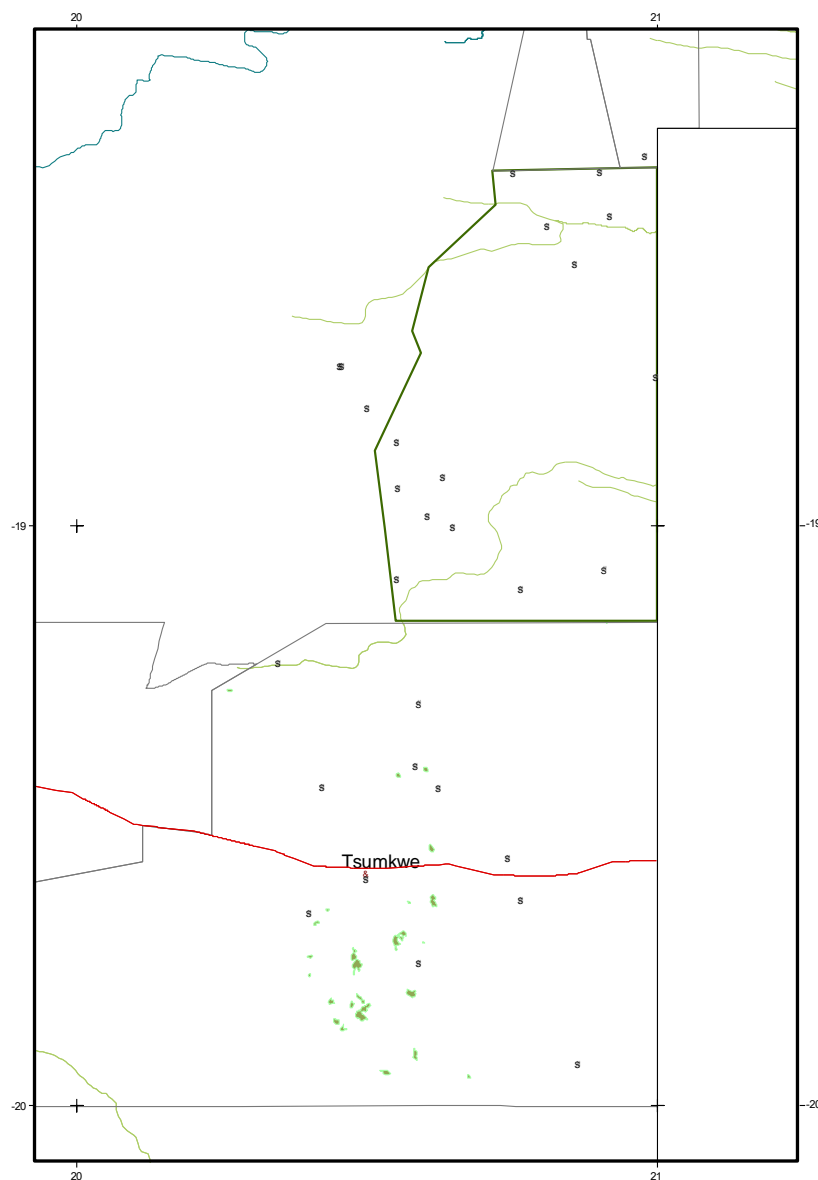


Figure 8 Sightings of duiker

2.2.5. Eland

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./100km ²
N&W Neighbours	227	14	2	142.5	14 - 550	10.11
Khaudum NP	276	29	27	111.8	29 - 585	7.67
Khaudum NP + N&W	503	43	29	86.6	67 - 939	8.6
Tsumkwe Overall	747	42	0	137.7	42 - 1776	10.67
Khaudum Tsumkwe Overall	1250	85	29	88.4	145 - 2355	9.73

Eland are numerous within the national park but are seldom found in areas of human settlement.

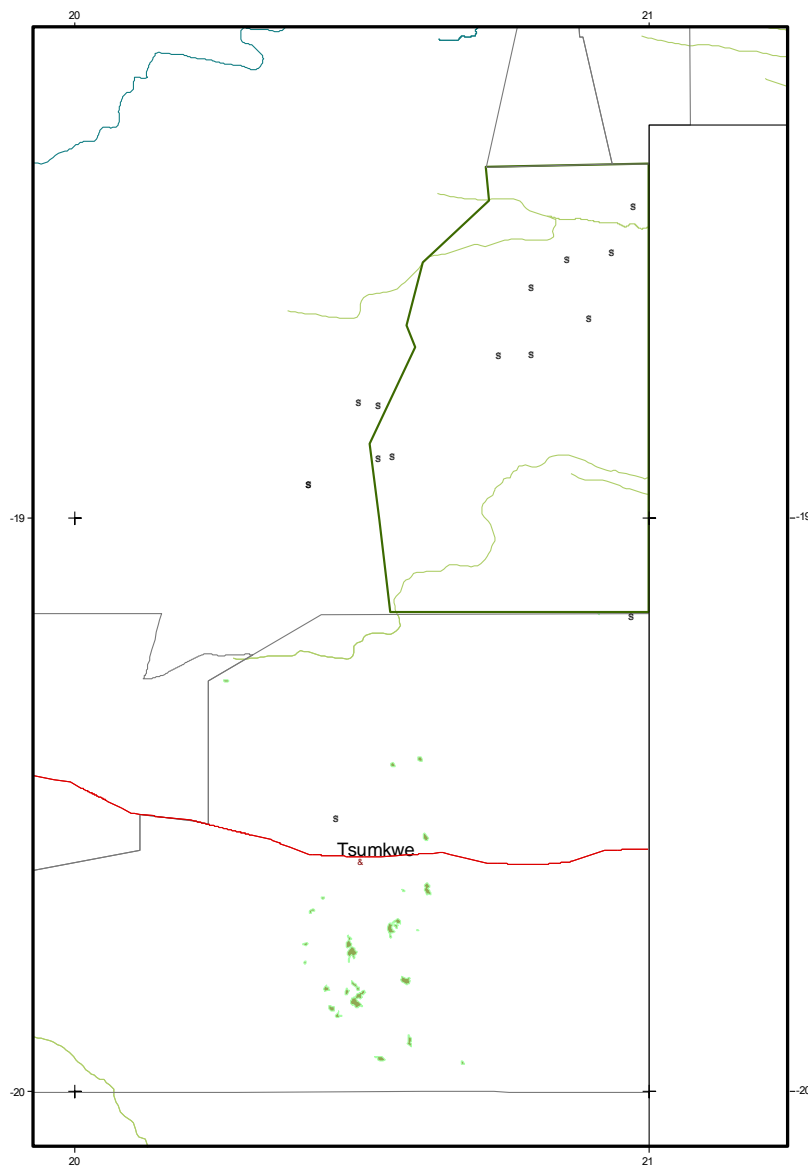


Figure 9 Sightings of eland

2.2.6. Giraffe

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
N&W Neighbours	340	21	6	103.6	21 - 692	15.16
Khaudum NP	613	74	42	52.9	289 - 937	17
Khaudum NP + N&W	953	95	48	48.9	486 - 1419	16.3
Tsumkwe Overall	114	8	3	103.9	8 - 232	1.63
Khaudum Tsumkwe Overall	1066	103	51	44.8	589 - 1544	8.3

As seen in previous surveys, giraffe are found throughout the national park but are less commonly seen elsewhere.

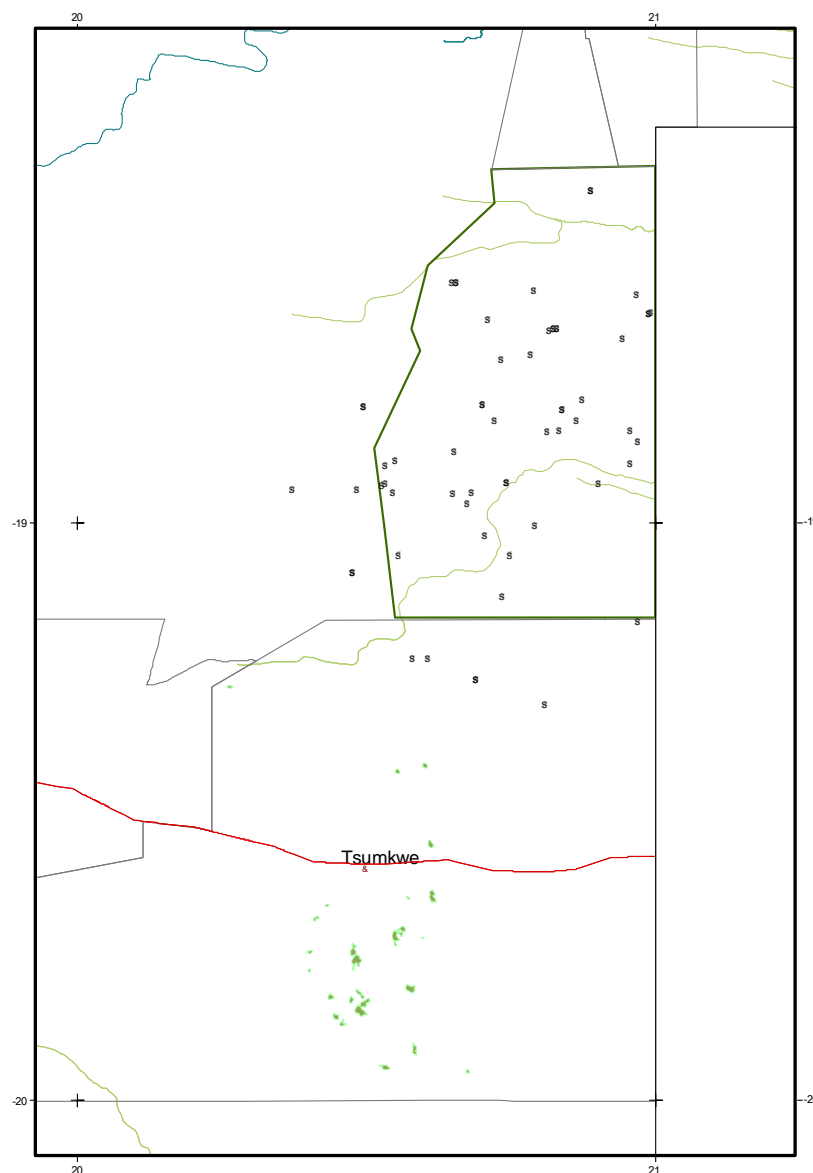


Figure 10 Sightings of giraffe

2.2.7. Hartebeest

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
Tsumkwe Overall	122	7	0	134	7 - 285	1.74
Khaudum Tsumkwe Overall	122	7	0	132.4	7 - 283	0.95

Hartebeest are not common and were seen only in the areas around Tsumkwe Pan.

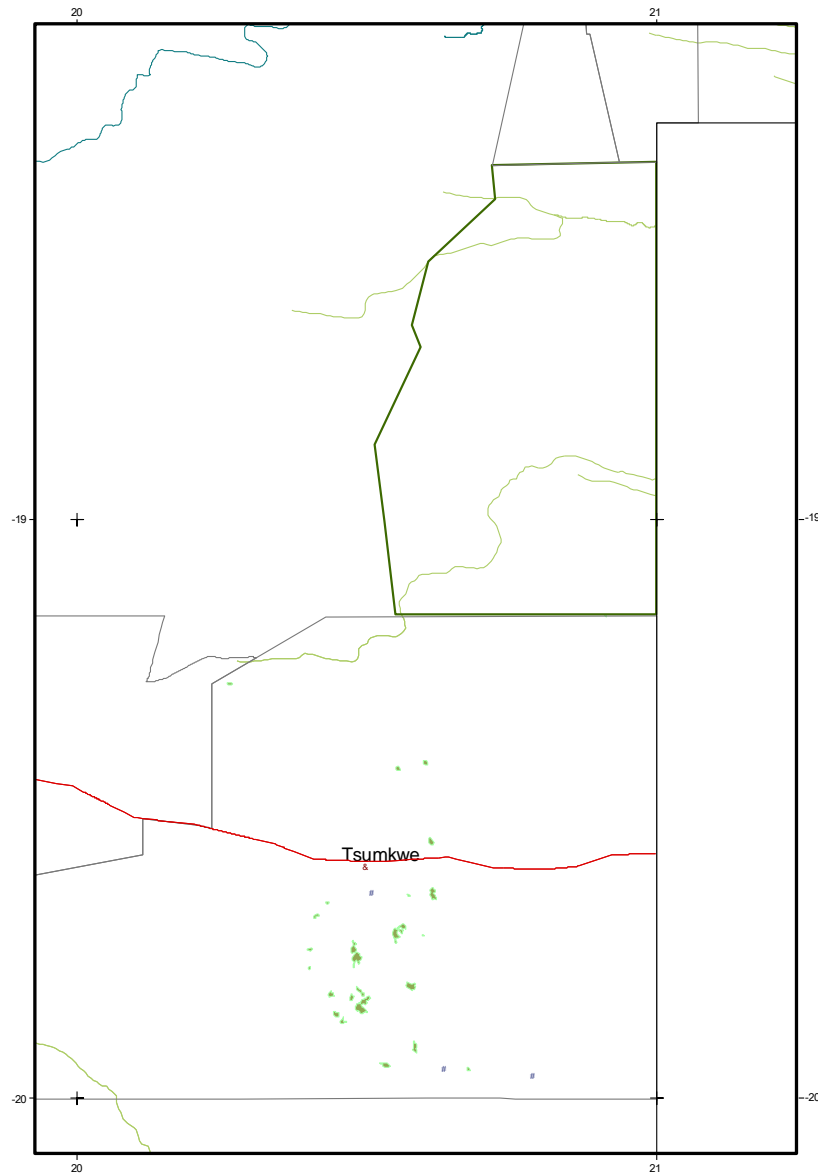


Figure 11 Sightings of hartebeest

2.2.8. Kudu

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./100km ²
Khaudum NP	213	32	8	83.2	36 - 391	5.92
Khaudum NP + N&W	213	32	8	82.6	37 - 389	3.65
Tsumkwe Pans	35	15	0	89.1	15 - 66	27.06
Tsumkwe Overall	317	44	15	53	149 - 486	4.53
Khaudum Tsumkwe Overall	531	76	23	45.5	289 - 772	4.13

Kudu are difficult to see from the air due to their cryptic colouration. The low estimate in 2015 is unlikely to be a result of a decline in the population.

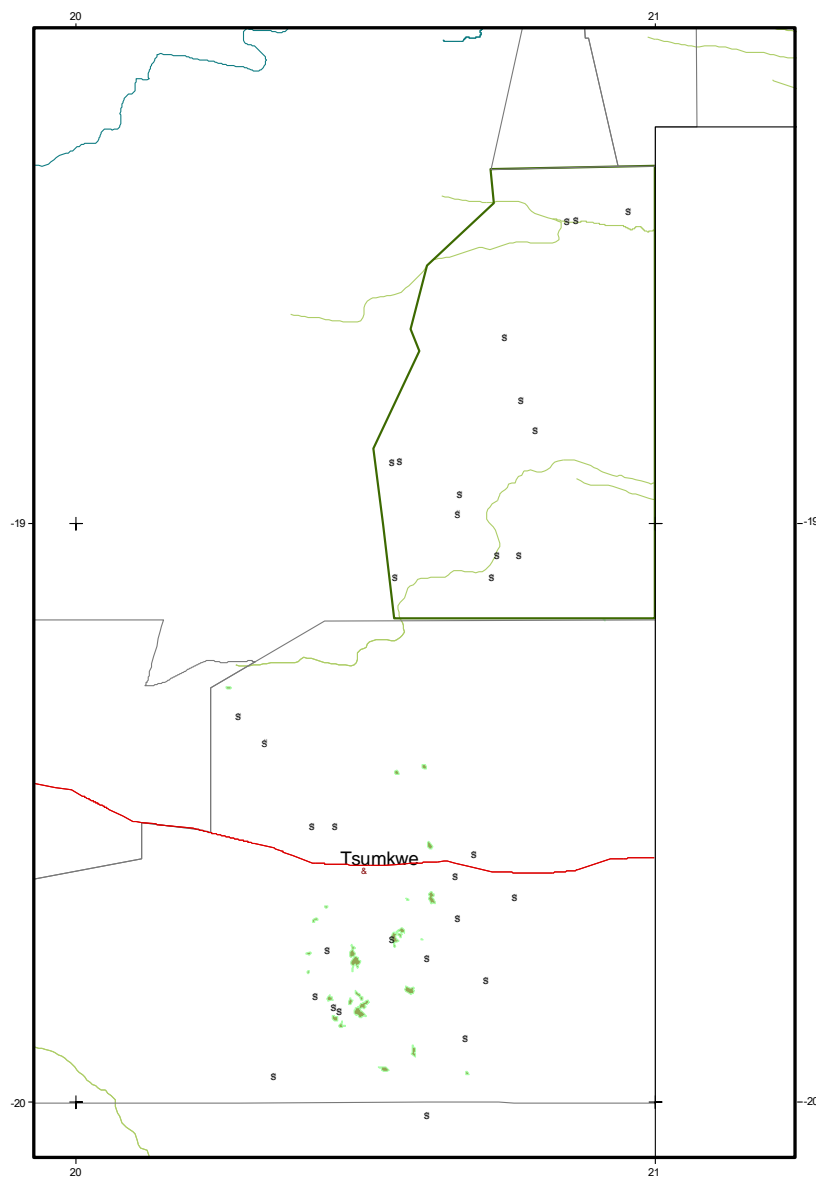


Figure 12 Sightings of kudu

2.2.9. Oryx

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
N&W Neighbours	146	9	5	132.7	9 - 339	6.5
Khaudum NP	1001	128	41	45.4	546 - 1455	27.76
Khaudum NP + N&W	1146	137	46	42.6	658 - 1634	19.61
Tsumkwe Overall	329	33	22	76.9	76 - 582	4.69
Khaudum Tsumkwe Overall	1475	170	68	36.9	930 - 2020	11.48

Oryx are widespread and numerous, particularly within the national park.

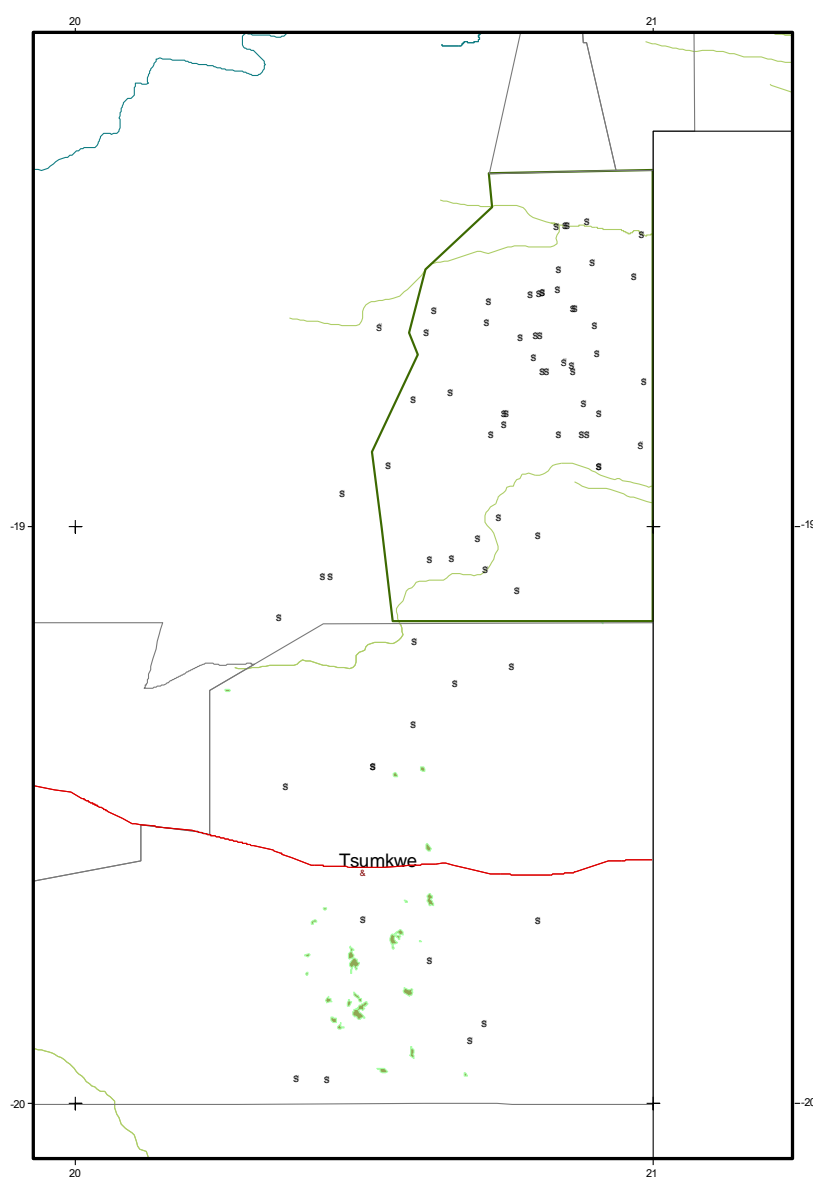


Figure 13 Sightings of oryx

2.2.10. Roan

Estimates of Roan

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./100km ²
N&W Neighbours	254	24	3	106.9	24 - 525	11.32
Khaudum NP	756	110	11	70.1	226 - 1285	20.97
Khaudum NP + N&W	1010	134	14	58.1	423 - 1596	17.27
Tsumkwe Overall	243	29	14	156.4	29 - 624	3.47
Khaudum Tsumkwe Overall	1253	163	28	55.3	560 - 1946	9.75

Slightly fewer roan were estimated in 2015 than in 2013 but the difference is not significant. Most occur in the national park, but they are also found in northern and southern conservancies.

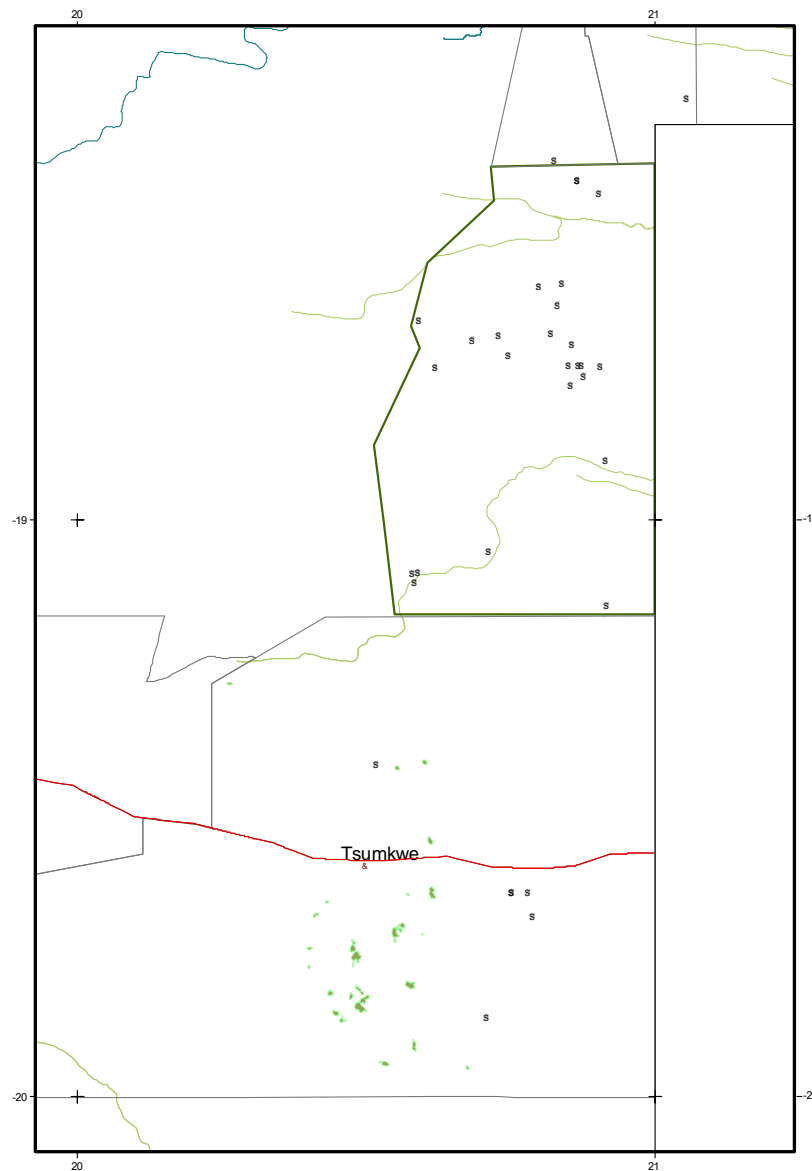


Figure 14 Sightings of roan

2.2.11. Springbok

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
Tsumkwe Pans	41	19	0	156.6	19 - 105	31.88
Tsumkwe Overall	49	20	0	126.2	20 - 112	0.71
Khaudum Tsumkwe Overall	49	20	0	124.7	20 - 111	0.38

Springbok are not numerous in the area and only found in and around Tsumkwe Pan. The estimated number in 2015 was similar to that of 2013.

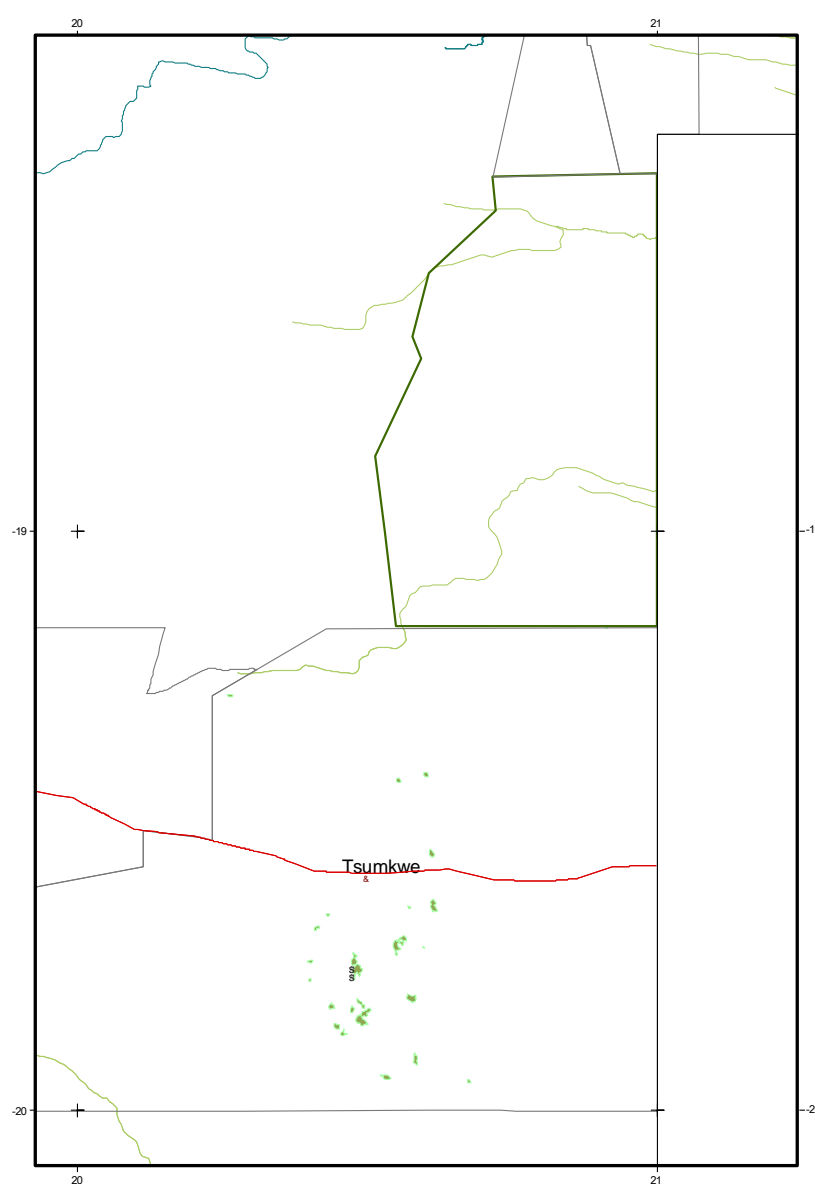


Figure 15 Sightings of springbok

2.2.12. Steenbok

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
N&W Neighbours	11	1	0	193.9	1 - 31	0.47
Khaudum NP	14	3	0	126.8	3 - 31	0.38
Khaudum NP + N&W	24	4	0	107.9	4 - 50	0.41
Tsumkwe Overall	27	2	0	147.3	2 - 66	0.38
Khaudum Tsumkwe Overall	51	6	0	91.8	6 - 97	0.39

The low estimate of steenbok may be a result of the difficulty in seeing these small animals from the air.

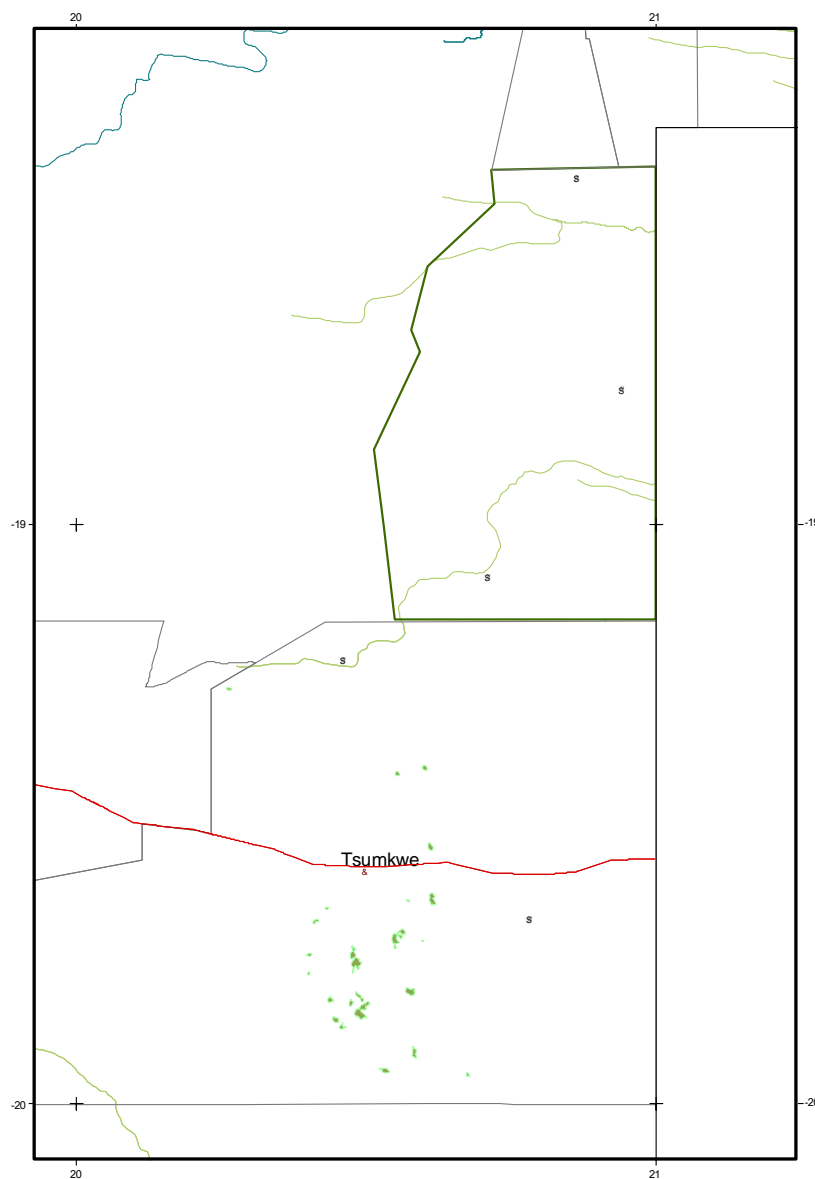


Figure 16 Sightings of steenbok

2.2.13. Warthog

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
N&W Neighbours	42	4	0	194.3	4 - 124	1.89
Khaudum NP	63	8	0	128.9	8 - 143	1.73
Khaudum NP + N&W	105	12	0	107.1	12 - 217	1.79
Tsumkwe Pans	2	1	0	154.8	1 - 6	1.68
Tsumkwe Overall	37	4	0	129.4	4 - 85	0.53
Khaudum Tsumkwe Overall	142	16	0	85.3	21 - 263	1.1

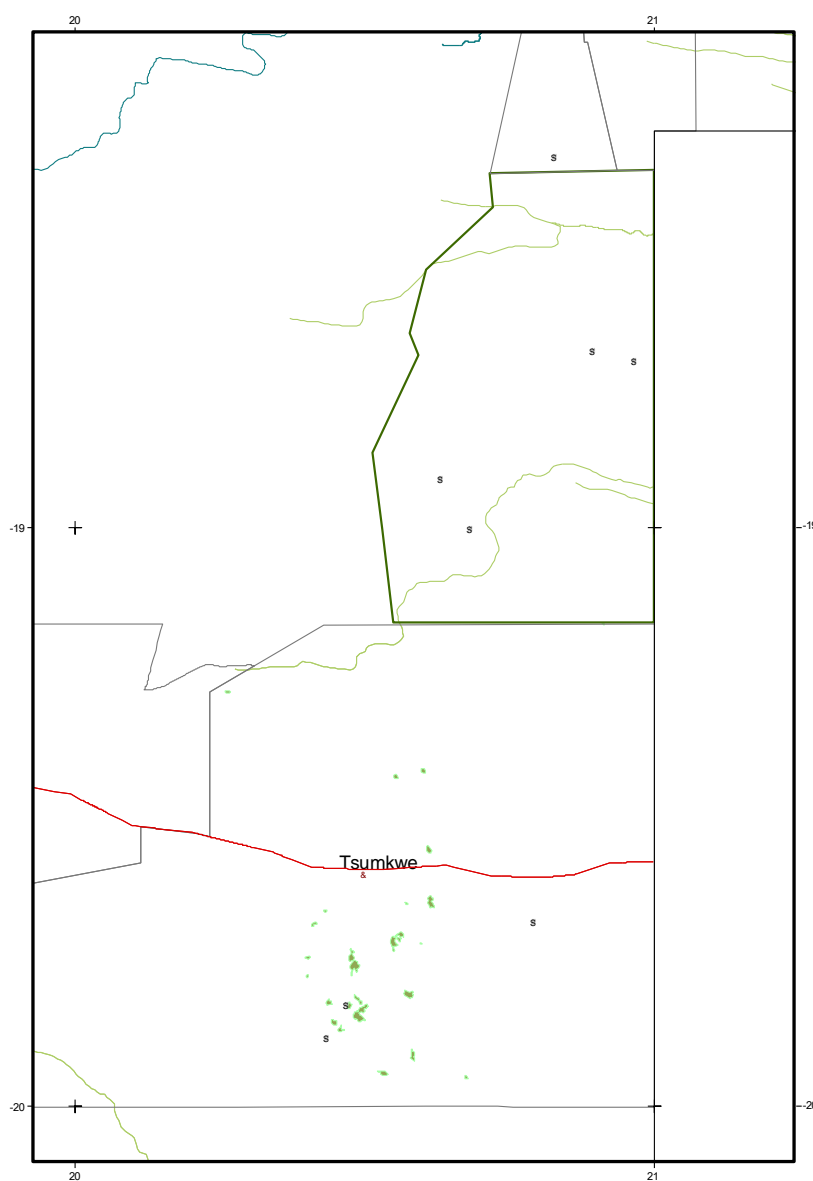


Figure 17 Sightings of warthog

2.2.14. Wildebeest

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./100km ²
Khaudum NP	639	90	0	67	211 - 1067	17.73
Khaudum NP + N&W	639	90	0	66.6	214 - 1064	10.93
Tsumkwe Pans	346	154	184	71.9	154 - 595	268.64
Tsumkwe Overall	1999	270	267	66.1	678 - 3320	28.54
Khaudum Tsumkwe Overall	2638	360	267	52	1266 - 4010	20.53

The estimated number of wildebeest in Khaudum NP is almost double that estimated in 2013 (349) but the difference is not significant. The number in Tsumkwe was the same as previously estimated.

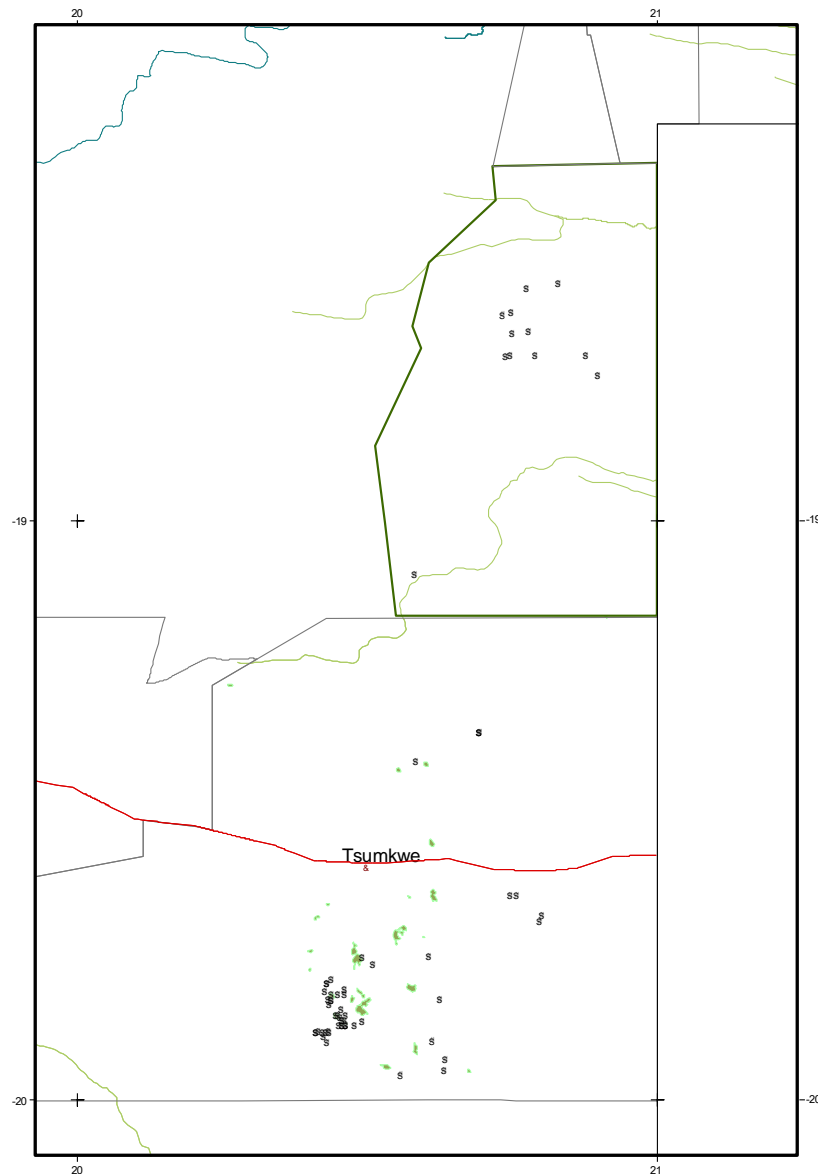


Figure 18 Sightings of wildebeest

2.2.15. Zebra

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
Khaudum NP	46	9	0	145.8	9 - 112	1.27
Khaudum NP + N&W	46	9	0	144.8	9 - 112	0.78
Khaudum Tsumkwe Overall	46	9	0	143.7	9 - 112	0.36

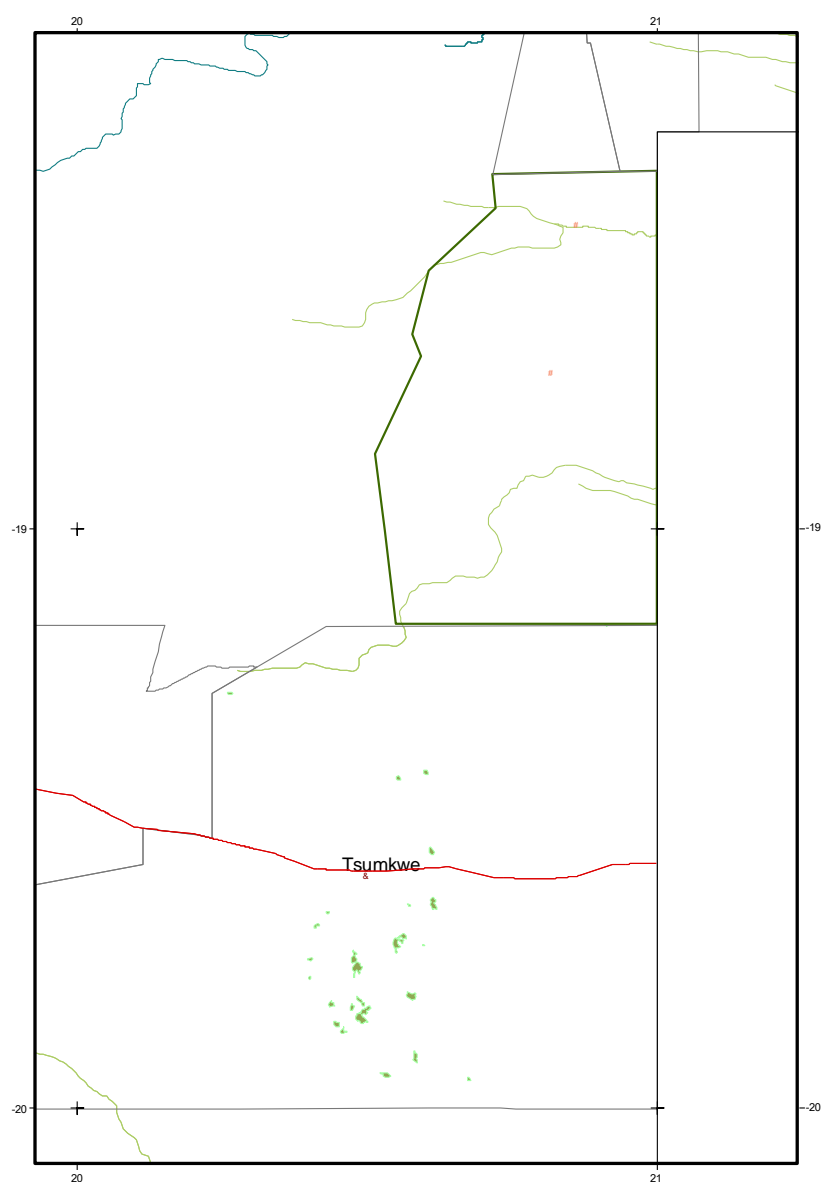


Figure 19 Sightings of zebra

2.2.16. Ostrich

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
N&W Neighbours	81	5	7	162.6	5 - 213	3.61
Khaudum NP	56	10	6	89.6	10 - 106	1.56
Khaudum NP + N&W	137	15	13	99	15 - 273	2.34
Tsumkwe Pans	15	7	8	91.4	7 - 29	11.65
Tsumkwe Overall	313	30	22	63.7	114 - 513	4.47
Khaudum Tsumkwe Overall	450	45	35	53	211 - 689	3.5

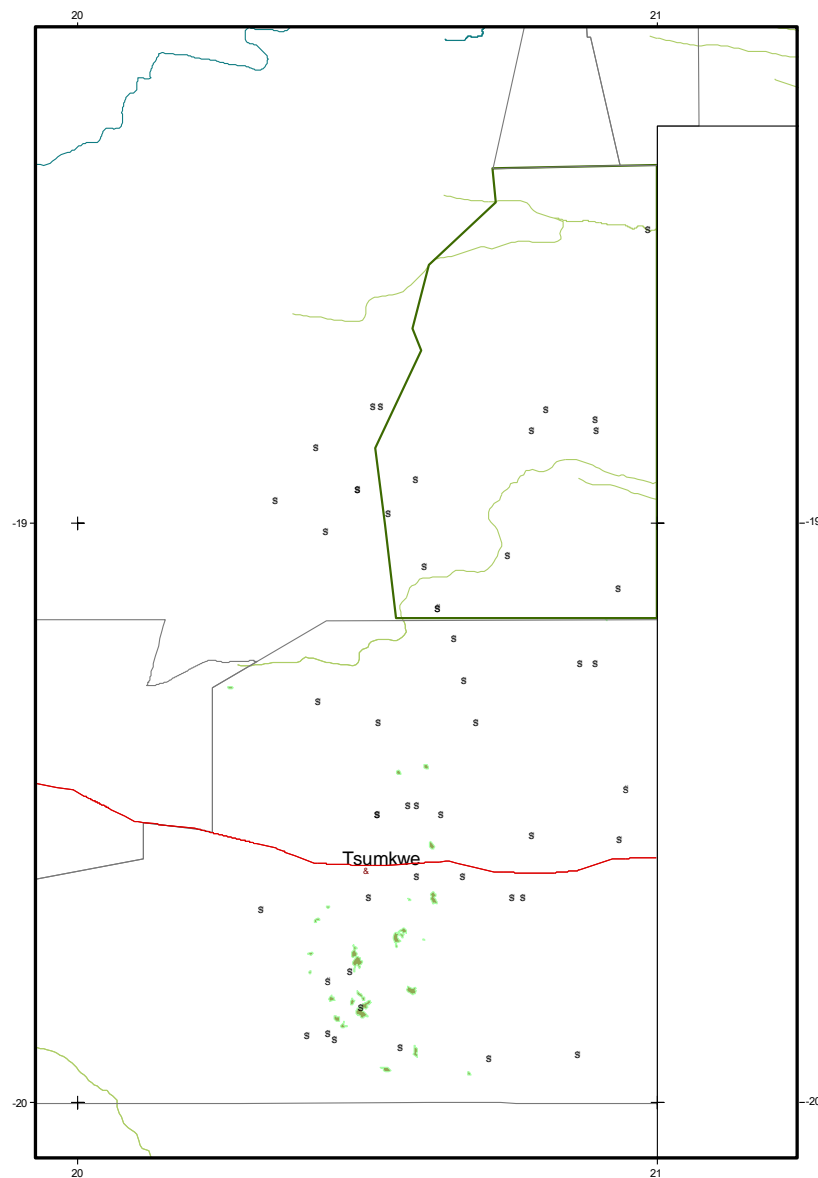


Figure 20 Sightings of ostrich

2.2.17. Water points

Water was available throughout the national park and around the Tsumkwe Pan. A small number (6) of water points were dry.

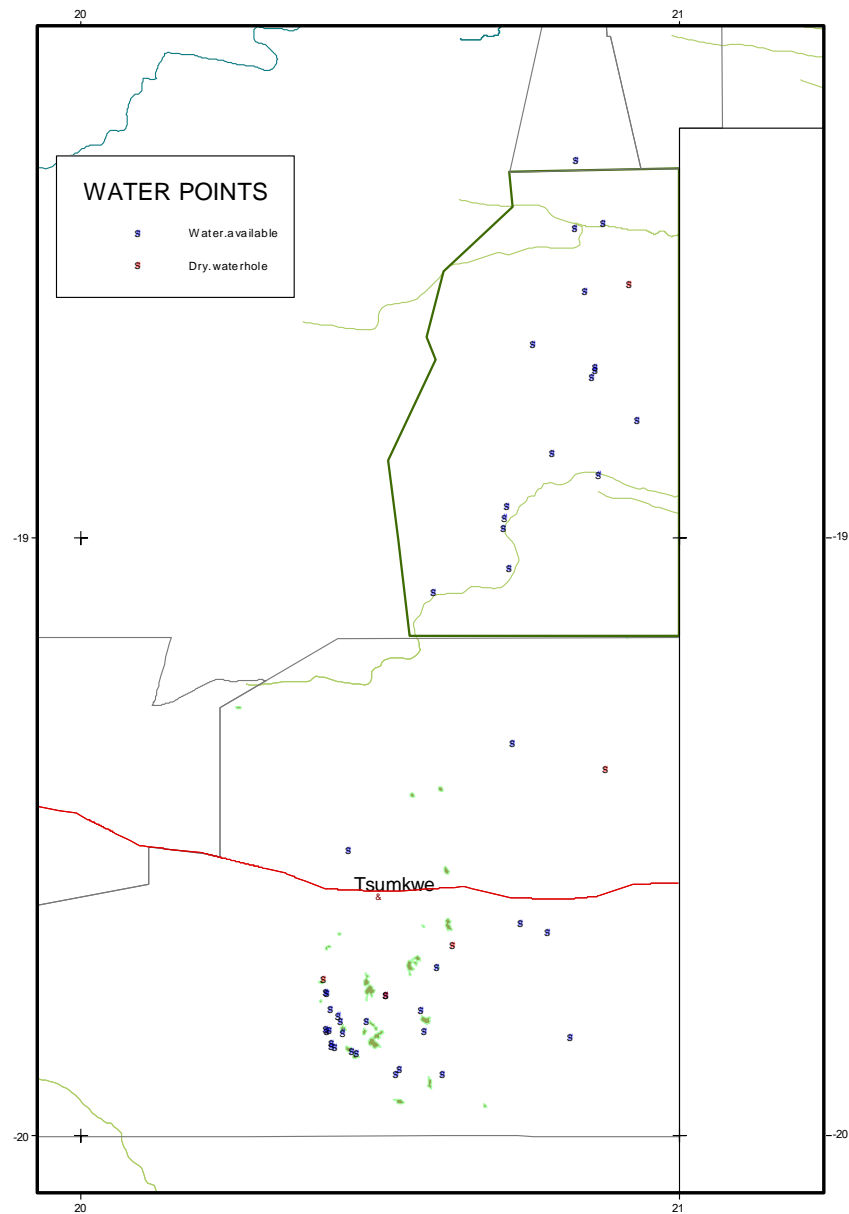


Figure 21 Sightings of waterpoints

2.2.18. Domestic livestock

Estimates of cattle

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
N&W Neighbours	2749	191	218	87.6	340 - 5158	122.62
Khaudum NP + N&W	2749	191	218	84	440 - 5058	47.03
Tsumkwe Overall	1953	159	168	81.3	365 - 3541	27.88
Khaudum Tsumkwe Overall	4702	350	386	59.1	1925 - 7480	36.59

Estimates of donkeys

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
N&W Neighbours	151	10	0	115.8	10 - 325	6.72
Khaudum NP + N&W	151	10	0	111	10 - 318	2.58
Khaudum Tsumkwe Overall	151	10	0	110.1	10 - 317	1.17

Estimates of sheep/goats

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
N&W Neighbours	717	46	20	98.6	46 - 1423	31.96
Khaudum NP + N&W	717	46	20	94.5	46 - 1394	12.26
Tsumkwe Overall	267	26	0	140.2	26 - 642	3.82
Khaudum Tsumkwe Overall	984	72	20	78	216 - 1751	7.66

STRATUM	Estimate	No. in	No. out	PRP%	95%Range	No./ 100km ²
Tsumkwe Overall	37	7	10	111.1	7 - 78	0.29
Khaudum Tsumkwe Overall	37	7	10	109.9	7 - 123	3.27

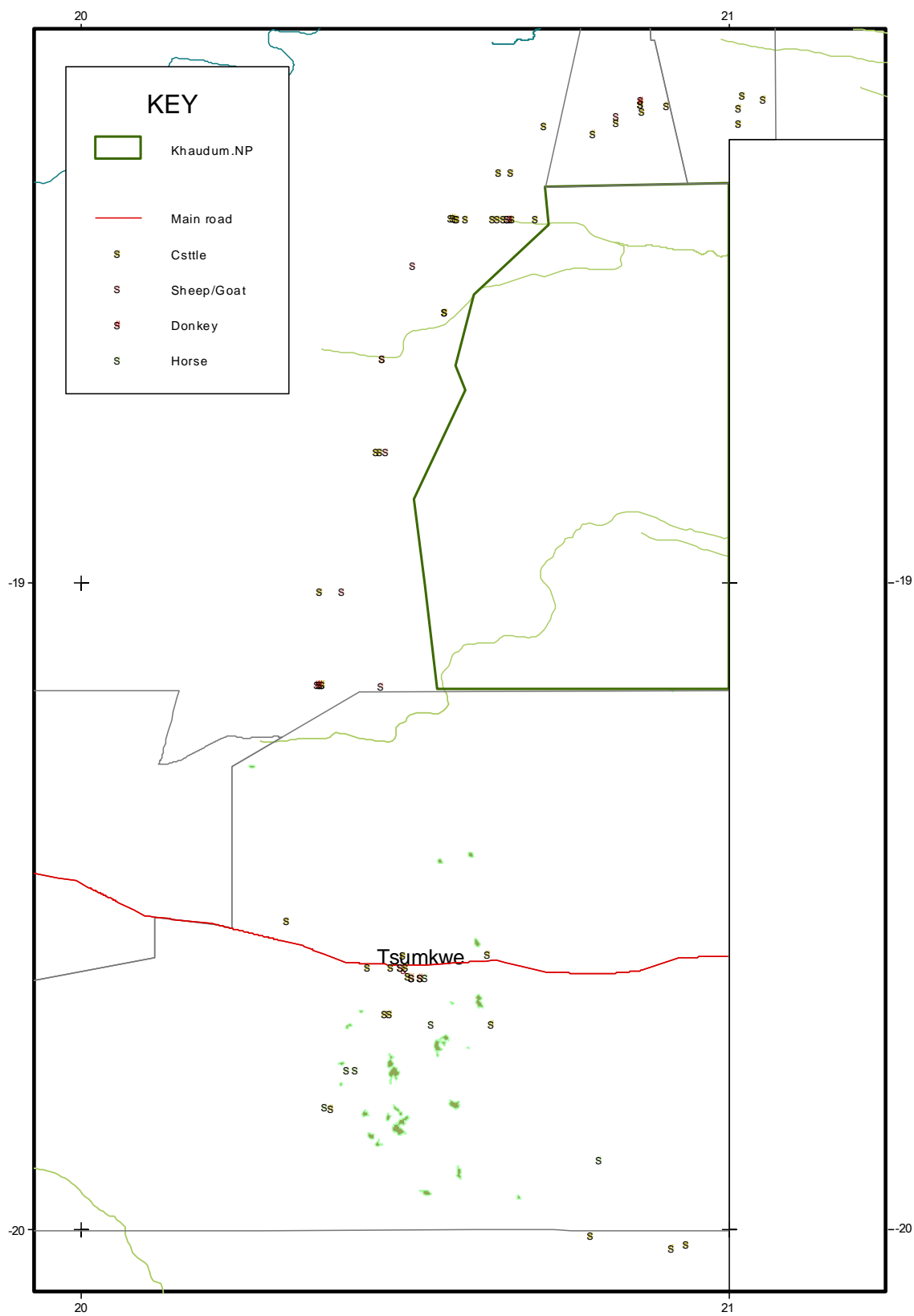


Figure 22 Sightings of domestic livestock

2.2.19. Human habitation

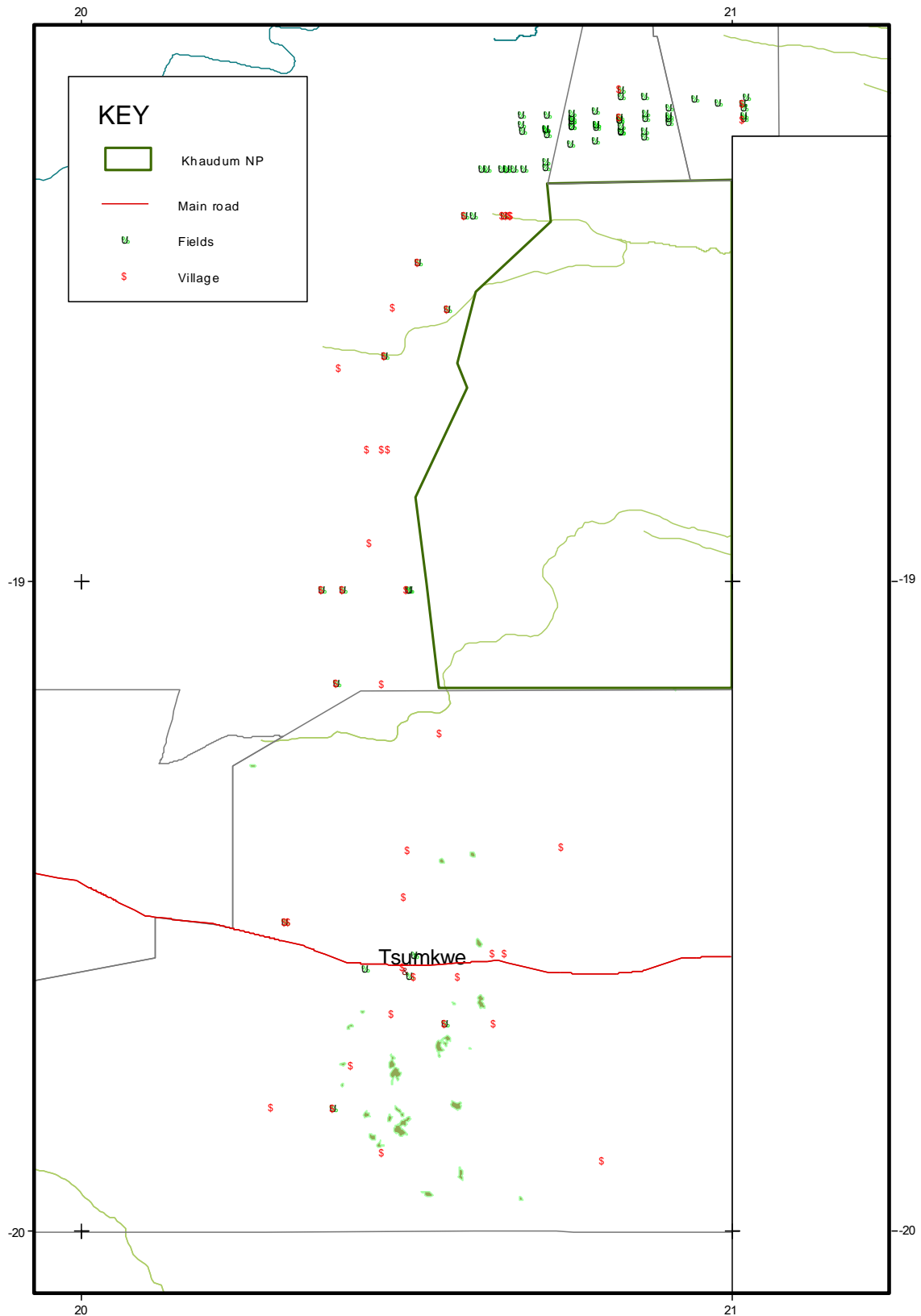


Figure 23 Sightings of human settlements

3. GENERAL

There was a number of difficulties encountered during the survey. These are as follows.

Failure of the laser altimeter recording system necessitated a change of approach to obtain the height data, and some were not recorded as a result. The expedient of using a digital elevation model in conjunction with recorded altitude from the GPS track-log was used to replace the missing heights (note that the pilot always had access to the laser readings to control his height – the problem was the lack of a record of the heights). The amount of bias in mean height likely to result from the chosen approach requires further investigation.

Overall, the addition of a laser altimeter which is recording height continuously is a major improvement on previous options (eg manually recording height once every 30 seconds from a radar altimeter). It substantially reduces the work of the data recorder and thus reduces the possibility of missing the recording of observer sightings. If teething troubles with this system can be eliminated, there will be a major increase in efficiency.

The great variation in elephant estimates between the last two surveys is at least partly due to statistical variation resulting from a small sample operating on a small number of elephant family groups in the Tsumkwe system. Revising stratum boundaries here, and increasing sampling intensity in the areas where elephants are now known to occur, from the results of the last three surveys, should give an improved result.

Comparison of observers shows that one observer consistently detected more groups than the other. It is tempting to conclude that populations are underestimated as a result. However, it can't be shown that one observer is not overestimating, so the existing result is the best compromise. It is not likely that elephant carcasses were over-estimated under any circumstances. A discrepancy between observers here would suggest an under-estimate overall. However, the number seen on this survey is so small that no conclusion can be drawn.

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5. ACKNOWLEDGEMENTS

We are very grateful to Mr Kenneth Uiseb for his support, encouragement and interest.

WWF funded the entire survey. We are very grateful for the donation by Vulcan of a Flightlogger and Nexus tablet. Jay Lorenzo is due our thanks in particular for long hours he spent helping (by telephone from the USA) when the Tablet collecting the height data failed.

We acknowledge the use of data from the Shuttle Topography Mission of the National Aeronautics & Space Administration.

APPENDIX I: METHODS

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

a. Survey design

The survey area was stratified on the basis of the distribution of elephants seen during the 2011 dry season survey (MET 2011)).

Areas requiring higher sampling (Khaudum Central and the Tsumkwe Pans) could not have been covered in a single flight, which would violate the assumptions of the precision calculation (see Appendix I). Transects in these strata were therefore divided into sets, each representing a separate 10% coverage, the results of which were combined in the final analysis. This had the additional advantage that in the event of the survey not being completed, a full coverage might still be available, albeit at a lower sampling intensity.

b. Selection of transects

Transects were evenly spaced according to the required sampling intensity from a randomly chosen start point and oriented at right angles to major features (eg rivers) in each stratum, as far as possible (Fig. 24).

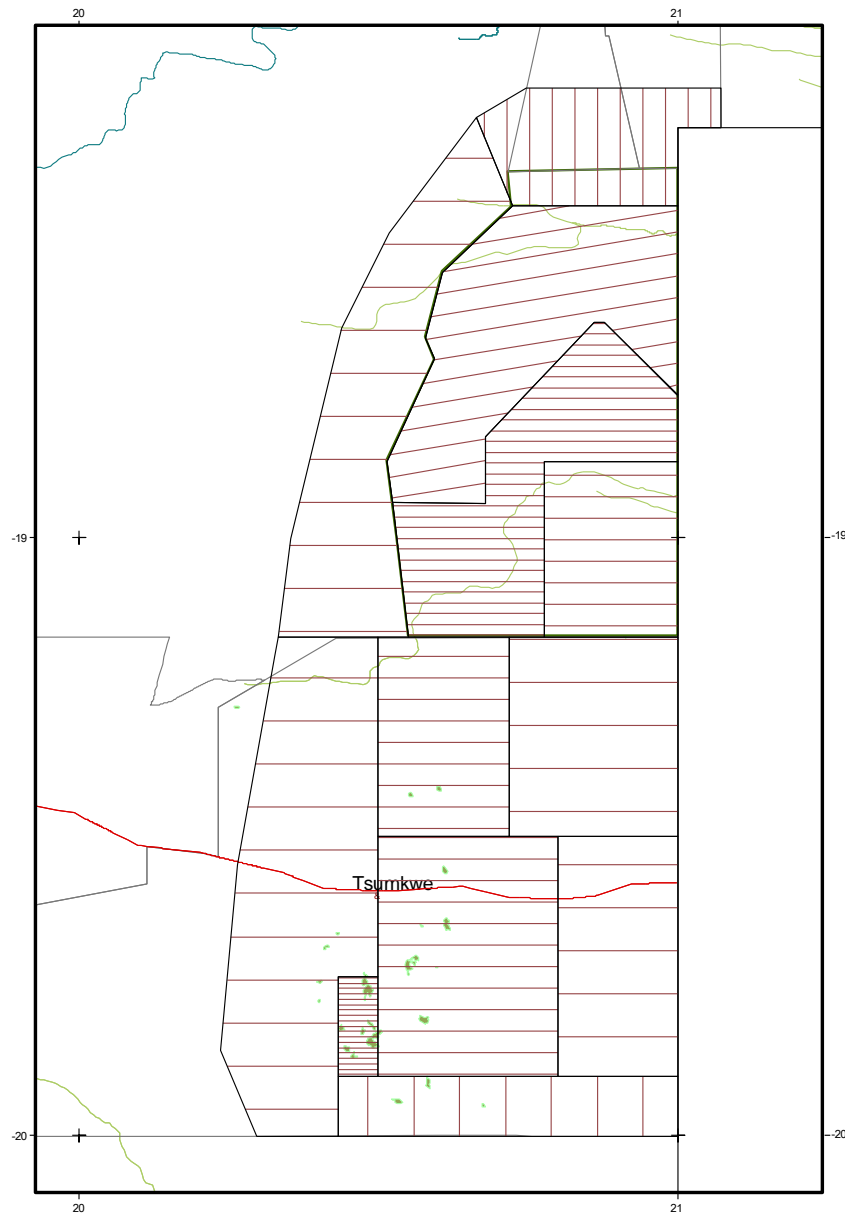


Figure 24 Transects selected for the 2015 survey

c. Data collection

The aircraft, a Cessna 182 was flown at a nominal height of 300 feet above ground level along the transects. Height was maintained using a Lightware SF30 laser rangefinder fitted in the right-hand wing of the aircraft (Fig. 25).

Data from the rangefinder was interpreted through a Vulcan Flightlogger. The coordinates of the start and end points of each transect were loaded into dedicated software that displayed height (from the rangefinder) and required direction on a tablet attached to the instrument panel (Fig 26)



Figure 26 Display of height & CDI using the Vulcan Flightlogger

The tablet being used to collect data from the Flightlogger malfunctioned after the first 3 days of the survey. As there was not an alternative available, height data from the laser rangefinder was recorded directly onto a laptop computer and these data (numbers showing the height above ground level) were used to maintain the desired nominal height of 300ft.



Figure 25 Lightware SF30 laser rangefinder installation

All incoming height, speed and location information was recorded for use in later analyses along with a time-stamp for each record. Accurate navigation along each transect was achieved using the Flightlogger with additional support from a Garmin 64S GPS into which transect coordinates had also been up-loaded.

The position of each sighting was “marked” in a Garmin 62S GPS.

Tracklogs of all flights were recorded in both Garmin GPS and the Vulcan Flightlogger.

d. Data analysis

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

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

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

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

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

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

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

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.

Note that the term $N(N-n)/n$ approaches zero as sampling intensity approaches 100%. Its application makes the assumption that all animals in the sample are seen once. This is violated if animals can move between transects during the survey, as can happen if transects are closely spaced or the survey cannot be completed in one flight. This is why some strata have repeated samples at 10%, rather than a single coverage at a higher intensity.

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

e. Calculation of heights above ground level

Height data from the Vulcan Flightlogger were recorded for 5 strata – KLOW2, KHAUN, TS7A, TS7B and KHAUCA. As explained above, after the failure of the tablet that was capturing height data, heights above ground level were maintained using a stream of data from the laser rangefinder which were recorded on a laptop computer. The start and end position of each transect was “marked” on a GPS. Because it was not possible to use the Flightlogger, it was necessary to identify the start and end of each transect height record from the time recorded on the GPS for each marked start and end position. The heights recorded within the start and end times were used to provide an average height for each transect.

For four strata, KLOW1, TS2, KHAUCB and KHAUS, there were no records of heights from the laser altimeter (although it was possible to use these to maintain heights a.g.l.). For these, a digital elevation model (DEM) from the Shuttle Radar Topography Mission (STRM) was downloaded from a NASA website. These were used to provide altitudes (heights above sea-level) of the ground for the entire survey area. The DEM altitudes for each GPS location along each transect were selected for height calculations.

The GPS altitudes appear to vary with time. To adjust the flight altitudes for this and obtain calibrated GPS heights above ground level, the mean GPS altitude of Tsumkwe airstrip for each day was calculated. This was subtracted from each GPS flight altitude to give GPS heights above the airstrip. Similarly, the STRM altitude of the airstrip was subtracted from each modelled ground altitude to give ground profile height above the airstrip. The profile data were subtracted from each adjusted GPS flight altitude to give GPS heights above ground level which were then used to provide a mean height for each transect.

f. Sampling intensity

Higher sampling intensities were selected for the areas likely to contain large numbers of animals, because a high precision was required for these areas. In order to achieve sampling intensities of over 15% that was desired for such areas, it would be necessary to space transects as little as 1km apart with strip widths of 200m per side. With a 100m dead zone under the aircraft, this would leave a distance between transects of 600m outside the strip markers and would require extremely accurate navigation. Any deviation could lead to double

counting of animals between closely spaced transects as well as disturbing animals on adjacent transects, which would violate the assumptions of the method of calculating precision. It was decided, therefore, to conduct multiple independent surveys of the relevant strata at 10% sampling intensity. Thus TS7 was sampled 4 times to give an overall 40% sampling intensity, and KHAUC was sampled twice to give a 20% sample. The estimated numbers of animals were calculated as a mean of the individual estimates. The combined variances were calculated as $V = \Sigma v/n^2$ (n is the number of surveys).

g. 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).

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.

h. Searching rate

The searching rate (km²/hr) was calculated for each transect and the mean for each stratum provided as an objective indication the survey quality.

i. Mapping wildlife distribution

For most species, 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.

A contoured map was produced to show the distribution of elephant densities. This was done by calculating the density of animals in cells measuring 0.025 degrees. These cells were filtered using a moving average. Empty cells were filled using Voronoi polygons surrounding the nearest filled cells. Resolution was doubled four times, filtering each time and cell values were converted to integer values of log (base2) density. Contours were produced by making vectors of the boundaries between integer density values.

j. Other information provided

The following are provided separately to the report:

- Original data sheets
- Original calibration sheets
- Digital list of all sightings
- Digital list of all transects
- Shape files for strata
- Shape files for track logs
- Digital copy of the report

APPENDIX II: RESULTS

The survey crew comprised M. Jansen van Rensburg (pilot), D. Gibson (front-seat recorder/coordinator), N. Chitemamuswe (left hand observer) and F. Muroki (right hand observer), K.Killian (driver/data capture).

Track logs of the transects flown are shown in Fig. 28.

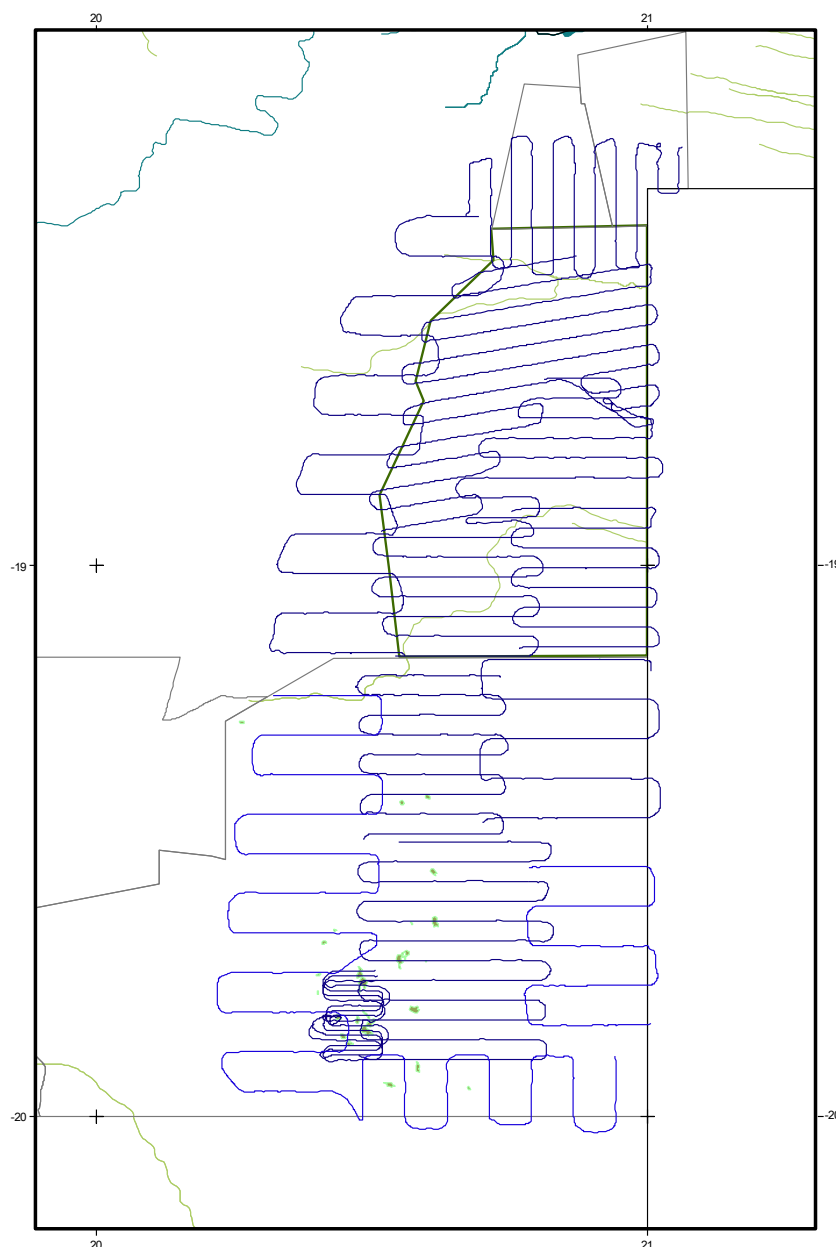


Figure 27 Tracks flown during the 2015 survey

a. **Stratum statistics:**

Supporting data indicating survey quality are given in Table 47 below.

Table 47. Stratum statistics:

Area = km² ; No. trans = number of transects in stratum; SI% = sampling intensity; trans time = total flight time on transects; total length = total length of transects in km; ground speed = knots; search rate = km²/min

No	Name	Area	No. Trans	SI%	Trans time	Sample area	Length	GS	SR	Mean ht
1	KLOW1	1486.6	12	5.831	1.2833	86.6820	194.53	149.89	1.1257	337.29
2	KLOW2	755.5	11	10.09	1.2000	76.2389	189.97	158.92	1.0589	306.33
3	KHAUN	1558	17	9.778	2.4667	152.3432	390.30	195.08	1.0293	294.52
4	KHAUCA	1284.9	15	10.46	1.9333	134.37782	328.02	170.36	1.1584	309.92
5	KHAUCB	1284.9	15	9.396	1.8167	120.7305	319.62	173.07	1.1076	284.65
6	KHAUS	760.8	8	10.22	1.0000	77.74325	186.60	188.45	1.2957	315.40
7	TS1	1090.5	5	5.388	0.8667	58.75985	147.25	170.27	1.1210	302.06
8	TS2	846.7	9	10.63	1.1167	89.96635	205.75	189.55	1.3428	330.98
9	TS3	927.8	5	4.587	0.5667	42.5591	104.39	186.42	1.2517	308.60
10	TS4	1391.7	12	11.19	2.0833	155.7672	375.77	181.32	1.2461	313.77
11	TS5	656.2	7	5.077	0.4833	33.3185	77.62	167.92	1.1489	324.90
12	TS6	1963.1	11	5.155	1.4167	101.1971	232.79	167.17	1.1906	329.52
13	TS7A	128.8	5	10.94	0.2167	14.0949	34.79	166.98	1.0842	306.69
14	TS7B	128.8	5	11.07	0.2667	14.2631	34.79	132.19	0.8914	310.37
15	TS7C	128.8	4	8.583	2.1622	11.0555	27.83	125.66	0.0852	300.74
16	TS7D	128.8	5	10.85	0.1928	13.9790	34.78	184.05	1.2086	304.22
TOTALS		12850.6	146	8.15	19.0717	1183.0761	2884.77			
MEANS								169.21	1.0847	311.25

The target height was 300 feet above ground level (a.g.l.). The mean height flown for the whole survey was 311 feet a.g.l. 95% of the heights were within 24ft of this value.

b. Calculation of strip width

The results of the strip width calibration are given below. Messrs Muroki and Chitemamuswe were right and left observers respectively.

	Height	L		R		Width		Corrected to 300ft		Total Width
		in	out	in	out	L	R	L	R	
1	287	6	24	10	25	190	160	198.61	167.25	365.85
2	295	8	27	10	30	200	210	203.39	213.56	416.95
3	311	8	29	14	34	220	210	212.22	202.57	414.79
4	284	7	26	12	30	200	190	211.27	200.70	411.97
5	298	6	25	13	33	200	210	201.34	211.41	412.75
6	288	9	28	12	30	200	190	208.33	197.92	406.25
7	288	4	23	13	31	200	190	208.33	197.92	406.25
8	289	6	26	13	28	210	160	217.99	166.09	384.08
9	307	5	23	16	35	190	200	185.67	195.44	381.11
10	255	7	22	12	26	160	150	188.24	176.47	364.71
11	313	6	26	13	34	210	220	201.28	210.86	412.14
12	327	8	29	14	33	220	200	201.83	183.49	385.32
13	293	8	26	13	35	190	230	194.54	235.49	430.03
14	291	5	24	14	33	200	200	206.19	206.19	412.37
15	295	6	25	14	35	200	220	203.39	223.73	427.12
16	303	7	28	13	30	220	180	217.82	178.22	396.04
17	317	4	19	12	30	160	190	151.42	179.81	331.23
18	278	9	27	8	24	190	170	205.04	183.45	388.49
19	287	4	21	11	27	180	170	188.15	177.70	365.85
20	254	8	27	6	20	200	150	236.22	177.17	413.39
						Mean		202.06	194.27	396.33
								Var		632.598
								Varmn		31.6299
								SEmn		5.6240
								t		2.09302
								PRP%		2.97

c. Comparison of observers

As shown in the following table, the overall difference between observers was not significant. There were significant differences between the observers only for duiker and oryx.

SPECIES	OBSERVED		EXPECTED	Chi ²	P
	Left	Right			
Buffalo	2	2	2	0	1.0000
Duiker	22	7	14.5	3.87931	**0.0053
Eland	9	7	8	0.125	0.6171
Ele Carcasses	5	1	3	1.333333	0.1025
Elephant Bull	103	74	88.5	2.375706	0.0293
Elephant Family	56	42	49	1	0.1573
All elephants	159	116	137.5	3.361818	0.0347
Giraffe	33	27	30	0.3	0.4386
Oryx	57	15	36	12.25	***0.0000
Hartebeest	2	1	1.5	0.166667	0.5637
Kudu	18	14	16	0.25	0.4795
Ostrich	32	16	24	2.666667	0.0209
Roan	22	11	16.5	1.833333	0.0555
Steenbok	5	0	2.5	2.5	0.0253
Warthog	7	1	4	2.25	0.0339
Wildebeest	34	30	32	0.125	0.6171
Zebra	1	1	1	0	1.0000
OtherCarcass 4	2	2	2	0	1.0000
Cattle	29	23	26	0.346154	0.4054
Donkey	3	1	2	0.5	0.3173
Sheep/goats	4	6	5	0.2	0.5271
Horse	3	3	3	0	1.0000
OVERALL	452	286	369	18.66938	*0.0154

APPENDIX III: RESULTS BY 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. These are the individual stratum results which have been combined, reordered and abbreviated to give the results by species reported in the results section above. The original analysis produces a comma delimited file, which is read into a spreadsheet. The spreadsheet is pasted into the following pages without retyping.

SI refers to the sampling intensity for the stratum. Results for all species and attributes counted are given. 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 first. Component coverages have italicised titles.

For species or attributes where no meaningful estimate can be given, only number seen is reported.

Khaudum Tsumkwe 2015 Overall Estimates

Area: 12850.6 km² SI: 9.2 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Springbok	49	20	0	972.4	124.7	20 - 111	0.38
Buffalo	565	58	26	173348.2	145.8	58 - 1389	4.4
Oryx	1475	170	68	75812.0	36.9	930 - 2020	11.48
Duiker	319	30	2	3997.7	39.2	194 - 444	2.49
Eland	1250	85	29	312031.3	88.4	145 - 2355	9.73
EleCarcass 3	13	2	0	84.7	135.8	2 - 32	0.1
EleCarcass 4	16	3	1	90.0	117.4	3 - 35	0.12
All Ele Carcasses	29	5	1	174.7	88.9	5 - 56	0.23
ElephantBull	1322	148	259	83930.1	43.3	749 - 1895	10.29
ElephantFamily	5091	723	856	1598282.0	49.1	2590 - 7592	39.61
All Elephants	6413	871	1115	1682212.0	40	3847 - 8979	49.9
Giraffe	1066	103	51	58192.1	44.8	589 - 1544	8.3
Hartebeest	122	7	0	6639.0	132.4	7 - 283	0.95
Kudu	531	76	23	14871.4	45.5	289 - 772	4.13
Monkey	87	9	0	6154.0	177.9	9 - 242	0.68
Roan	1253	163	28	122652.8	55.3	560 - 1946	9.75
Steenbok	51	6	0	553.4	91.8	6 - 97	0.39
Warthog	142	16	0	3748.3	85.3	21 - 263	1.1
Wildebeest	2638	360	267	480891.3	52	1266 - 4010	20.53
Zebra	46	9	0	1104.5	143.7	9 - 112	0.36
Jackal BB	17	1	0	289.5	192.8	1 - 51	0.14
GroundHornbill	39	4	0	1258.2	181	4 - 109	0.3
Ostrich	450	45	35	14572.3	53	211 - 689	3.5
Bird	19	2	0	303.9	177.9	2 - 54	0.15
Donkey	151	10	0	7031.2	110.1	10 - 317	1.17
Cattle	4702	350	386	1971200.0	59.1	1925 - 7480	36.59
Sheep/goats	984	72	20	150501.0	78	216 - 1751	7.66
Horse	37	7	10	426.7	109.9	7 - 78	0.29
OtherCarcass 4	34	4	0	391.0	113.8	4 - 73	0.27

Stratum KLOW1

Area: 1486.6 km² SI: 6.2 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	146	9	5	8643.0	140.5	9 - 350	9.8
Duiker	49	3	0	1152.2	153.9	3 - 123	3.27
Eland	227	14	2	24114.7	150.8	14 - 568	15.24
ElephantBull	32	2	25	399.8	135.9	2 - 76	2.18
All Elephants	32	2	25	399.8	135.9	2 - 76	2.15
Giraffe	340	21	6	28647.7	109.6	21 - 712	22.87
Roan	0	0	1	0.0	0	0 - 0	0
Ostrich	81	5	7	4003.4	172.1	5 - 220	5.44
Donkey	129	8	0	6642.4	138.5	8 - 309	8.71
Cattle	2104	130	217	1239226.0	116.4	130 - 4554	141.55
Sheep/goats	664	41	20	113044.8	111.5	41 - 1404	44.64

Stratum KLOW2

Area: 755.5 km² SI: 9.5 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Duiker	42	4	0	449.7	111.7	4 - 90	5.6
ElephantBull	32	3	18	879.3	208.3	3 - 98	4.2
ElephantFamily	127	12	64	14054.6	208.2	12 - 391	16.8
All Elephants	159	15	82	14933.9	171.7	15 - 431	21.05
Roan	254	24	2	17014.8	114.5	24 - 544	33.59
Steenbok	11	1	0	97.2	207.7	1 - 33	1.4
Warthog	42	4	0	1561.6	208.2	4 - 130	5.6
Donkey	21	2	0	388.8	207.7	2 - 65	2.8
Cattle	645	61	1	102572.2	110.6	61 - 1359	85.38
Sheep/goats	53	5	0	2440.0	208.2	5 - 163	7

Stratum KHAUN

Area: 1558 km² SI: 10.3 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	746	77	15	46504.8	61.3	289 - 1203	47.9
Duiker	68	7	0	711.9	83.4	11 - 124	4.35
Eland	271	28	27	23668.2	120.2	28 - 598	17.42
ElephantBull	262	27	34	9597.5	79.4	54 - 469	16.8
ElephantFamily	1037	107	149	567752.8	154	107 - 2634	66.57
All Elephants	1299	134	183	577350.3	124	134 - 2910	83.38
Giraffe	465	48	14	24139.2	70.8	136 - 795	29.86
Kudu	126	13	4	6622.0	136.9	13 - 299	8.09
Monkey	87	9	0	6154.0	190.6	9 - 254	5.6
Roan	446	46	0	56366.5	112.9	46 - 949	28.62
Warthog	48	5	0	1522.4	170.7	5 - 131	3.11
Wildebeest	417	43	0	27813.8	84.8	63 - 770	26.75
Zebra	10	1	0	80.1	195.7	1 - 29	0.62
GroundHornbill	39	4	0	1258.2	193.9	4 - 114	2.49
Ostrich	0	0	1	0.0	0	0 - 0	0
Bird	19	2	0	303.9	190.6	2 - 56	1.24

Stratum KHAUCA

Area: 1284.9 km² SI: 11.1 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	180	20	25	5315.6	86.7	24 - 337	14.04
Duiker	18	2	0	130.4	135.8	2 - 43	1.4
ElephantBull	253	28	82	13635.9	99.2	28 - 503	19.65
ElephantFamily	1713	190	375	603116.8	97.2	190 - 3379	133.35
All Elephants	1966	218	457	616752.6	85.7	282 - 3650	153.01
Giraffe	72	8	19	464.1	64	26 - 118	5.61
Kudu	144	16	4	4607.4	100.9	16 - 290	11.23
Roan	424	47	1	47193.0	109.9	47 - 890	32.99
Steenbok	27	3	0	333.8	144.8	3 - 66	2.11
Warthog	18	2	0	308.3	208.8	2 - 56	1.4
Wildebeest	243	27	0	52398.8	201.6	27 - 734	18.95
Zebra	72	8	0	4681.8	203.4	8 - 219	5.61
Ostrich	45	5	2	1080.0	156.3	5 - 116	3.51

Stratum KHAUCB

Area: 1284.9 km² SI: 10.0 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	291	29	0	14613.5	89.1	32 - 550	22.66
Duiker	30	3	1	422.8	146.5	3 - 74	2.34
Eland	10	1	0	95.7	209.1	1 - 31	0.78
EleCarcass 3	10	1	0	103.7	217.6	1 - 32	0.78
All Ele Carcasses	20	2	0	188.0	146.5	2 - 49	1.56
EleCarcass 4	10	1	0	84.3	196.2	1 - 30	0.78
ElephantBull	151	15	38	4621.7	96.8	15 - 296	11.72
ElephantFamily	2188	218	101	325859.2	55.9	964 - 3413	170.31
All Elephants	2339	233	139	330480.9	52.7	1106 - 3572	182.04
Giraffe	130	13	8	2695.9	85.3	19 - 242	10.16
Kudu	30	3	0	802.4	201.8	3 - 91	2.34
Roan	141	14	10	11267.6	162	14 - 368	10.94
Warthog	10	1	0	90.0	202.7	1 - 30	0.78
Wildebeest	201	20	0	28039.5	178.9	20 - 560	15.62
Ostrich	30	3	3	387.0	140.1	3 - 72	2.34
OtherCarcass 4	10	1	0	90.3	203	1 - 30	0.78

Khaudum Central Mean Estimates

Area: 1284.9 km² SI: 21.1 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	236	49	25	4412.3	57.7	100 - 372	18.35
Duiker	24	5	1	122.6	94.2	5 - 47	1.87
Eland	5	1	0	21.3	188.3	1 - 14	0.39
EleCarcass 3	5	1	0	23.1	196	1 - 15	0.39
EleCarcass 4	5	1	0	18.7	176.7	1 - 14	0.39
All Ele Carcasses	10	2	0	41.8	131.9	2 - 23	0.78
ElephantBull	202	43	120	4011.4	64.4	72 - 331	15.69
ElephantFamily	1951	408	476	204425.5	47.5	1025 - 2877	151.83
All Elephants	2152	451	596	208436.9	43.4	1217 - 3088	167.48
Giraffe	101	21	27	701.0	53.5	47 - 156	7.89
Kudu	87	19	4	1186.6	80.9	19 - 158	6.79
Roan	282	61	11	12832.0	82.2	61 - 514	21.96
Steenbok	14	3	0	73.0	129.4	3 - 31	1.05
Warthog	14	3	0	87.5	136.5	3 - 33	1.09
Wildebeest	222	47	0	17700.2	122.7	47 - 495	17.29
Zebra	36	8	0	1024.5	181.8	8 - 102	2.81
Ostrich	38	8	5	322.4	97.8	8 - 74	2.93
OtherCarcass 4	5	1	0	20.1	182.8	1 - 14	0.39

Stratum KHAUS

Area: 760.8 km² SI: 10.8 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	18	2	1	305.5	224	2 - 60	2.42
Duiker	9	1	0	76.5	224.2	1 - 30	1.21
ElephantBull	37	4	19	1221.9	224	4 - 120	4.85
ElephantFamily	470	51	3	101789.4	160.4	51 - 1225	61.83
All Elephants	507	55	22	103011.3	149.6	55 - 1266	66.64
Giraffe	46	5	1	1211.7	178.5	5 - 128	6.06
Roan	28	3	0	340.4	157.7	3 - 71	3.64
Ostrich	18	2	0	302.7	223	2 - 60	2.42

Stratum TS1

Area: 1090.5 km² SI: 5.7 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	52	3	0	2556.1	268	3 - 193	4.8
Eland	419	24	0	165541.7	269.6	24 - 1549	38.43
ElephantBull	0	0	1	0.0	0	0 - 0	0
ElephantFamily	664	38	14	418020.1	270.5	38 - 2459	60.85
All Elephants	664	38	15	418020.1	270.5	38 - 2459	60.89
Giraffe	87	5	0	2882.1	170.7	5 - 236	8.01
Wildebeest	122	7	10	14184.9	270.5	7 - 453	11.21
Jackal BB	17	1	0	289.5	270.5	1 - 65	1.6
Ostrich	70	4	2	4544.2	268	4 - 257	6.4

Stratum TS2

Area: 846.7 km² SI: 11.3 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	97	11	5	2319.1	114	11 - 208	11.5
Duiker	27	3	0	160.9	110.1	3 - 56	3.14
EleCarcass 4	9	1	0	68.8	216.1	1 - 28	1.05
All Ele Carcasses	9	1	0	68.8	216.1	1 - 28	1.06
ElephantBull	27	3	3	622.0	216.5	3 - 84	3.14
All Elephants	27	3	3	622.0	216.5	3 - 84	3.19
Giraffe	27	3	3	610.4	214.5	3 - 84	3.14
Wildebeest	44	5	0	1712.2	216.5	5 - 140	5.23
Ostrich	53	6	4	1102.8	144.2	6 - 130	6.27

Stratum TS3

Area: 927.8 km² SI: 4.9 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./100 km ²
EleCarcass 4	0	0	1	0.0	0	0 - 0	0
All Ele Carcasses	0	0	1	0.0	0	1 - 76	0
ElephantBull	20	1	0	402.2	272.1	1 - 76	2.21
All Elephants	20	1	0	402.2	272.1	1 - 76	2.16
Roan	0	0	11	0.0	0	0 - 0	0
Wildebeest	0	0	4	0.0	0	0 - 0	0
Ostrich	41	2	0	1619.0	272.9	2 - 153	4.41

Stratum TS4

Area: 1391.7 km² SI: 11.9 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./100km ²
Springbok	8	1	0	62.0	206.7	1 - 26	0.6
Buffalo	419	50	0	153854.8	205.9	50 - 1283	30.13
Oryx	143	17	0	10476.9	158	17 - 368	10.24
Duiker	25	3	1	152.2	107.9	3 - 52	1.81
EleCarcass 3	8	1	0	61.6	206	1 - 26	0.6
All Ele Carcasses	8	1	0	61.6	206	1 - 26	0.57
ElephantBull	252	30	8	15739.8	109.8	30 - 528	18.08
ElephantFamily	260	31	66	59212.3	206	31 - 796	18.68
All Elephants	512	61	74	74952.1	117.8	61 - 1114	36.79
Hartebeest	17	2	0	248.8	207	2 - 51	1.21
Kudu	210	25	0	3653.4	63.5	77 - 343	15.07
Roan	243	29	2	36099.0	171.9	29 - 661	17.48
Steenbok	8	1	0	61.9	206.5	1 - 26	0.6
Warthog	17	2	0	247.6	206.5	2 - 51	1.21
Wildebeest	419	50	11	74219.6	143	50 - 1019	30.13
Ostrich	59	7	4	731.4	101.4	7 - 118	4.22
Cattle	805	96	78	259342.3	139.2	96 - 1926	57.85
Sheep/goats	176	21	0	27310.1	206.5	21 - 540	12.65
Horse	8	1	2	61.9	206.5	1 - 26	0.6
OtherCarcass 4	8	1	0	61.6	206	1 - 26	0.6

Stratum TS5

Area: 656.2 km² SI: 4.8 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	0	0	17	0.0	0	0 - 0	0
Duiker	21	1	0	418.8	238.5	1 - 71	3.2
ElephantBull	105	5	13	2785.6	123	5 - 234	16
ElephantFamily	0	0	66	0.0	0	0 - 0	0
All Elephants	105	5	79	2785.6	123	5 - 234	16
Hartebeest	105	5	0	6390.3	186.3	5 - 301	16
Kudu	0	0	5	0.0	0	0 - 0	0
Wildebeest	630	30	0	159841.0	155.3	30 - 1608	95.99
Ostrich	21	1	2	418.8	238.5	1 - 71	3.2
Cattle	0	0	20	0.0	0	0 - 0	0
Horse	0	0	5	0.0	0	0 - 0	0

Stratum TS6

Area: 1963.1 km² SI: 5.5 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Buffalo	146	8	26	19493.4	213.4	8 - 457	7.43
Oryx	36	2	0	594.3	149	2 - 91	1.86
Duiker	55	3	0	752.8	111.8	3 - 116	2.78
Eland	328	18	0	98685.5	213.4	18 - 1028	16.71
ElephantBull	328	18	11	48021.4	148.8	18 - 816	16.71
ElephantFamily	474	26	0	226537.9	223.8	26 - 1534	24.14
All Elephants	802	44	11	274559.3	145.6	44 - 1969	40.85
Kudu	73	4	10	3197.0	172.8	4 - 199	3.71
Roan	0	0	1	0.0	0	0 - 0	0
Steenbok	18	1	0	321.3	219.2	1 - 58	0.93
Warthog	18	1	0	326.7	221	1 - 58	0.93
Wildebeest	437	24	58	171814.8	211.2	24 - 1361	22.28
Ostrich	55	3	2	1486.2	157.1	3 - 141	2.78
Cattle	1148	63	70	370059.5	118.1	63 - 2503	58.48
Sheep/goats	91	5	0	7706.1	214.7	5 - 287	4.64
Horse	18	1	0	306.0	213.9	1 - 57	0.93
OtherCarcass 4	18	1	0	304.6	213.4	1 - 57	0.93

Stratum TS7AArea: 128.8 km² SI: 11.7 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
ElephantBull	86	10	2	6405.9	259.1	10 - 308	66.58
All Elephants	86	10	2	6405.9	259.1	10 - 308	66.77
Wildebeest	540	63	16	207272.9	234	63 - 1804	419.47
Ostrich	17	2	0	260.9	261.4	2 - 62	13.32

Stratum TS7BArea: 128.8 km² SI: 11.8 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Horse	42	5	0	1571.3	259.7	5 - 152	32.9
EleCarcass 4	8	1	0	63.9	262	1 - 31	6.58
All Ele Carcasses	8	1	0	63.9	262	1 - 31	6.21
ElephantBull	0	0	2	0.0	0	0 - 0	0
All Elephants			2				
All Elephants	0	0	2	0.0	0	2 - 61	0
Kudu	85	10	0	2492.5	163.6	10 - 223	65.8
Wildebeest	8	1	30	61.7	257.4	1 - 30	6.58
Ostrich	17	2	7	251.4	259.7	2 - 61	13.16

Stratum TS7CArea: 128.8 km² SI: 9.1 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
ElephantBull	11	1	2	109.2	304.2	1 - 44	8.49
All Elephants	11	1	2	109.2	304.2	1 - 44	8.54
Kudu	55	5	0	2730.6	304.2	5 - 221	42.44
Wildebeest	273	25	41	37524.2	225.6	25 - 890	212.2
Ostrich	0	0	1	0.0	0	0 - 0	0
OtherCarcass 4	11	1	0	107.8	302.3	1 - 44	8.49

Stratum TS7D

Area: 128.8 km² SI: 11.6 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Springbok	164	19	0	23972.8	261.7	19 - 594	127.54
ElephantBull	9	1	1	65.0	258.9	1 - 31	6.71
ElephantFamily	432	50	18	170868.4	265.5	50 - 1580	335.63
All Elephants	441	51	19	170933.3	260.3	51 - 1589	342.39
Warthog	9	1	0	64.9	258.6	1 - 31	6.71
Wildebeest	562	65	97	109046.4	163.1	65 - 1479	436.31
Horse	0	0	3	0.0	0	0 - 0	0
Ostrich	26	3	0	584.8	258.9	3 - 93	20.14

Tsumkwe Pans Mean Estimates

Area: 128.8 km² SI: 44.2 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Springbok	41	19	0	910.4	156.6	19 - 105	31.88
EleCarcass 4	2	1	0	2.4	155.6	1 - 5	1.64
All Ele Carcasses	2	1	0	2.4	155.6	1 - 5	1.55
ElephantBull	26	12	7	249.1	127.7	12 - 60	20.45
ElephantFamily	108	50	18	6489.0	158.9	50 - 280	83.91
All Elephants	134	62	25	6738.0	130.2	62 - 309	104.04
Kudu	35	15	0	212.4	89.1	15 - 66	27.06
Warthog	2	1	0	2.5	154.8	1 - 6	1.68
Wildebeest	346	154	184	13604.9	71.9	154 - 595	268.64
Ostrich	15	7	8	41.5	91.4	7 - 29	11.65
Horse	11	5	3	58.8	154.3	5 - 27	8.22
OtherCarcass 4	3	1	0	4.7	169.1	1 - 7	2.12

N&W Neighbours

Area: 2242.1 km² SI: 7.3 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	146	9	5	8643.0	132.7	9 - 339	6.5
Duiker	91	7	0	1601.9	91.6	8 - 174	4.05
Eland	227	14	2	24114.7	142.5	14 - 550	10.11
ElephantBull	64	5	43	1279.1	116	5 - 138	2.86
ElephantFamily	127	12	64	14054.6	194.3	12 - 373	5.66
All Elephants	191	17	107	15333.7	134.8	17 - 448	8.52
Giraffe	340	21	6	28647.7	103.6	21 - 692	15.16
Roan	254	24	3	17014.8	106.9	24 - 525	11.32
Steenbok	11	1	0	97.2	193.9	1 - 31	0.47
Warthog	42	4	0	1561.6	194.3	4 - 124	1.89
Ostrich	81	5	7	4003.4	162.6	5 - 213	3.61
Donkey	151	10	0	7031.2	115.8	10 - 325	6.72
Cattle	2749	191	218	1341798.0	87.6	340 - 5158	122.62
Sheep/goats	717	46	20	115484.8	98.6	46 - 1423	31.96

Khaudum NP Overall Estimates

Area: 3603.7 km² SI: 10.5 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	1001	128	41	51222.5	45.4	546 - 1455	27.76
Duiker	101	13	1	911.0	59.9	41 - 162	2.81
Eland	276	29	27	23689.5	111.8	29 - 585	7.67
EleCarcass 3	5	1	0	23.1	192.1	1 - 15	0.14
EleCarcass 4	5	1	0	18.7	173.2	1 - 14	0.14
All Ele Carcasses	10	2	0	41.8	129.3	2 - 23	0.28
ElephantBull	500	74	173	14830.8	48.9	256 - 745	13.88
ElephantFamily	3458	566	628	873967.7	54.3	1582 - 5335	95.97
All Elephants	3959	640	801	888798.4	47.8	2066 - 5851	109.86
Giraffe	613	74	42	26051.9	52.9	289 - 937	17
Kudu	213	32	8	7808.6	83.2	36 - 391	5.92
Monkey	87	9	0	6154.0	180.5	9 - 245	2.42
Roan	756	110	11	69538.9	70.1	226 - 1285	20.97
Steenbok	14	3	0	73.0	126.8	3 - 31	0.38
Warthog	63	8	0	1609.9	128.9	8 - 143	1.73
Wildebeest	639	90	0	45513.9	67	211 - 1067	17.73
Zebra	46	9	0	1104.5	145.8	9 - 112	1.27
GroundHornbill	39	4	0	1258.2	183.7	4 - 110	1.08
Ostrich	56	10	6	625.1	89.6	10 - 106	1.56
Bird	19	2	0	303.9	180.5	2 - 54	0.54
OtherCarcass 4	5	1	0	20.1	179.2	1 - 14	0.14

Khaudum NP + N&W Neighbours

Area: 5845.8 km² SI: 9.3 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Oryx	1146	137	46	59865.5	42.6	658 - 1634	19.61
Duiker	192	20	1	2513.0	52	92 - 292	3.28
Eland	503	43	29	47804.1	86.6	67 - 939	8.6
EleCarcass 3	5	1	0	23.1	190.7	1 - 15	0.09
EleCarcass 4	5	1	0	18.7	172	1 - 14	0.09
All Ele Carcasses	10	2	0	41.8	128.4	2 - 23	0.17
ElephantBull	564	79	216	16109.8	44.8	311 - 817	9.65
ElephantFamily	3585	578	692	888022.3	52.4	1707 - 5464	61.33
All Elephants	4150	657	908	904132.1	45.7	2254 - 6045	70.99
Giraffe	953	95	48	54699.6	48.9	486 - 1419	16.3
Kudu	213	32	8	7808.6	82.6	37 - 389	3.65
Monkey	87	9	0	6154.0	179.3	9 - 244	1.49
Roan	1010	134	14	86553.8	58.1	423 - 1596	17.27
Steenbok	24	4	0	170.2	107.9	4 - 50	0.41
Warthog	105	12	0	3171.5	107.1	12 - 217	1.79
Wildebeest	639	90	0	45513.9	66.6	214 - 1064	10.93
Zebra	46	9	0	1104.5	144.8	9 - 112	0.78
GroundHornbill	39	4	0	1258.2	182.4	4 - 109	0.66
Ostrich	137	15	13	4628.5	99	15 - 273	2.34
Bird	19	2	0	303.9	179.3	2 - 54	0.33
Donkey	151	10	0	7031.2	111	10 - 318	2.58
Cattle	2749	191	218	1341798.0	84	440 - 5058	47.03
Sheep/goats	717	46	20	115484.8	94.5	46 - 1394	12.26
OtherCarcass 4	5	1	0	20.1	177.9	1 - 14	0.09

Tsumkwe Overall Estimates

Area: 7004.8 km² SI: 8.1 %

SPECIES	Pop. est.	No. In	No. Out	Variance	PRP%	95%Range	No./ 100km ²
Springbok	49	20	0	972.4	126.2	20 - 112	0.71
Buffalo	565	58	26	173348.2	147.5	58 - 1399	8.07
Oryx	329	33	22	15946.5	76.9	76 - 582	4.69
Duiker	127	10	1	1484.7	60.5	50 - 205	1.82
Eland	747	42	0	264227.2	137.7	42 - 1776	10.67
EleCarcass 3	8	1	0	61.6	187.4	1 - 24	0.12
EleCarcass 4	11	2	1	71.2	154	2 - 28	0.16
All Ele Carcasses	19	3	1	132.9	119.2	3 - 42	0.27
ElephantBull	758	69	43	67820.2	68.8	237 - 1279	10.82
ElephantFamily	1505	145	164	710259.3	112.1	145 - 3192	21.49
All Elephants	2263	214	207	778079.6	78	498 - 4029	32.31
Giraffe	114	8	3	3492.5	103.9	8 - 232	1.63
Hartebeest	122	7	0	6639.0	134	7 - 285	1.74
Kudu	317	44	15	7062.8	53	149 - 486	4.53
Roan	243	29	14	36099.0	156.4	29 - 624	3.47
Steenbok	27	2	0	383.2	147.3	2 - 66	0.38
Warthog	37	4	0	576.8	129.4	4 - 85	0.53
Wildebeest	1999	270	267	435377.4	66.1	678 - 3320	28.54
Jackal BB	17	1	0	289.5	195	1 - 52	0.25
Ostrich	313	30	22	9943.9	63.7	114 - 513	4.47
Cattle	1953	159	168	629401.8	81.3	365 - 3541	27.88
Sheep/goats	267	26	0	35016.2	140.2	26 - 642	3.82
Horse	37	7	10	426.7	111.1	7 - 79	0.53
OtherCarcass 4	29	3	0	370.9	131.4	3 - 68	0.42