MINISTRY OF ENVIRONMENT & TOURISM

AERIAL SURVEY OF WILDLIFE IN KHAUDUM NATIONAL PARK & NEIGHBOURING CONSERVANCIES -– SEPTEMBER 2013

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The 2013 aerial survey and census of Khaudum National Park was commissioned and organized by the World Wildlife Fund, WWF in Namibia, on behalf of the Ministry of Environment and Tourism (MET), Government of Namibia

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SUMMARY

An aerial survey of wildlife and domestic livestock took place in the Khaudum National Park and surrounding conservancies from 17th to the 22nd September 2013. A total area of 15200 km^2 was sampled at an average intensity of 7.1%.

The estimates of numbers of each species (with their 95% confidence range) are given in the table below.

SPECIES	ESTIMATED NUMBER	95% RANGE
Elephants	3638	2490 - 4786
Elephants in bull groups	1063	610 - 1517
Elephants in family groups	2575	1520 - 3630
Total elephant carcasses	107	19 - 194
Elephant carcasses (class 3)	63	4 - 134
Elephant carcasses (class 4)	44	3 - 96
Buffalo	63	4 - 184
Duiker	703	482 - 925
Eland	723	161 - 1284
Giraffe	698	362 - 1035
Hartebeest	492	59 - 1142
Kudu	2016	1222 - 2809
Oryx	1331	837 - 1825
Roan	1800	508 - 3091
Springbok	44	36 - 104
Steenbok	483	308 - 659
Warthog	579	234 - 925
Wildebeest	2247	671 - 3824
Ostrich	615	334 - 895
Horse	576	181 - 972
Donkey	86	12 - 202
Cattle	7449	4514 - 10385
Sheep/goats	1266	169 - 2524
Fields/Cultivation	264	131 - 397
Villages/Huts	365	156 - 574

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1. INTRODUCTION

An assessment and strategy for wildlife protection and law enforcement by the Ministry of Environment and Tourism (Cumming 2012) identified the establishment of an effective monitoring system to be an important objective.

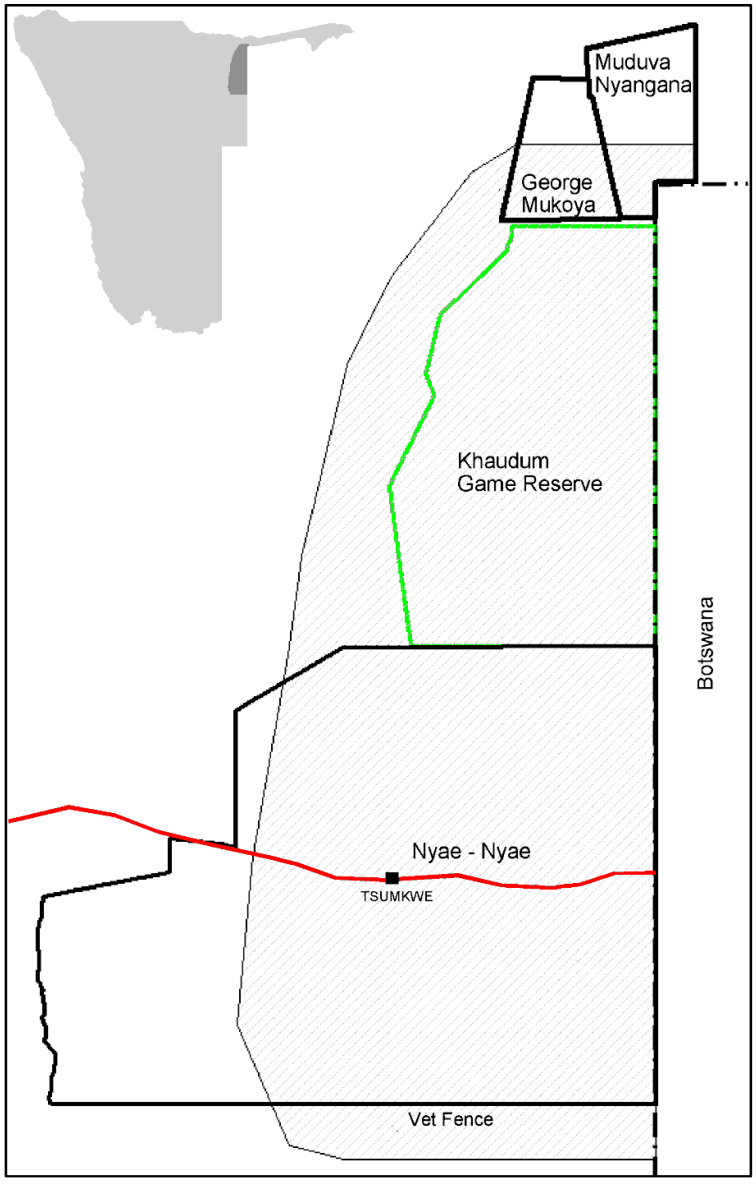


Figure 1 Location of the survey area (hatched)

The recommendation was made that an aerial survey of Bwabwata, Mudumu, Mamili, Khaudum and adjacent areas should be conducted to "establish numbers of live and dead elephant numbers and carcass ratios". Consequently, with the support of Ministry of Environment and Tourism (MET), an aerial survey of Zambezi (Caprivi) region took place in May/June 2013 (Craig and Gibson, 2013).

As a continuation of this, a survey of Khaudum National Park and neighbouring conservancies (Nyae Nyae, George Mukoyo and Muduva Nyangana) (Fig.1) took place in September 2013. That survey is the subject of this report.

The distribution of elephants (Fig. 2) seen during the 2011 dry season survey (MET 2011) provided a basis for dividing the survey area into strata (Fig. 3). This previous distribution was used to select sampling intensities for each stratum within the limits of available resources (Appendix I).

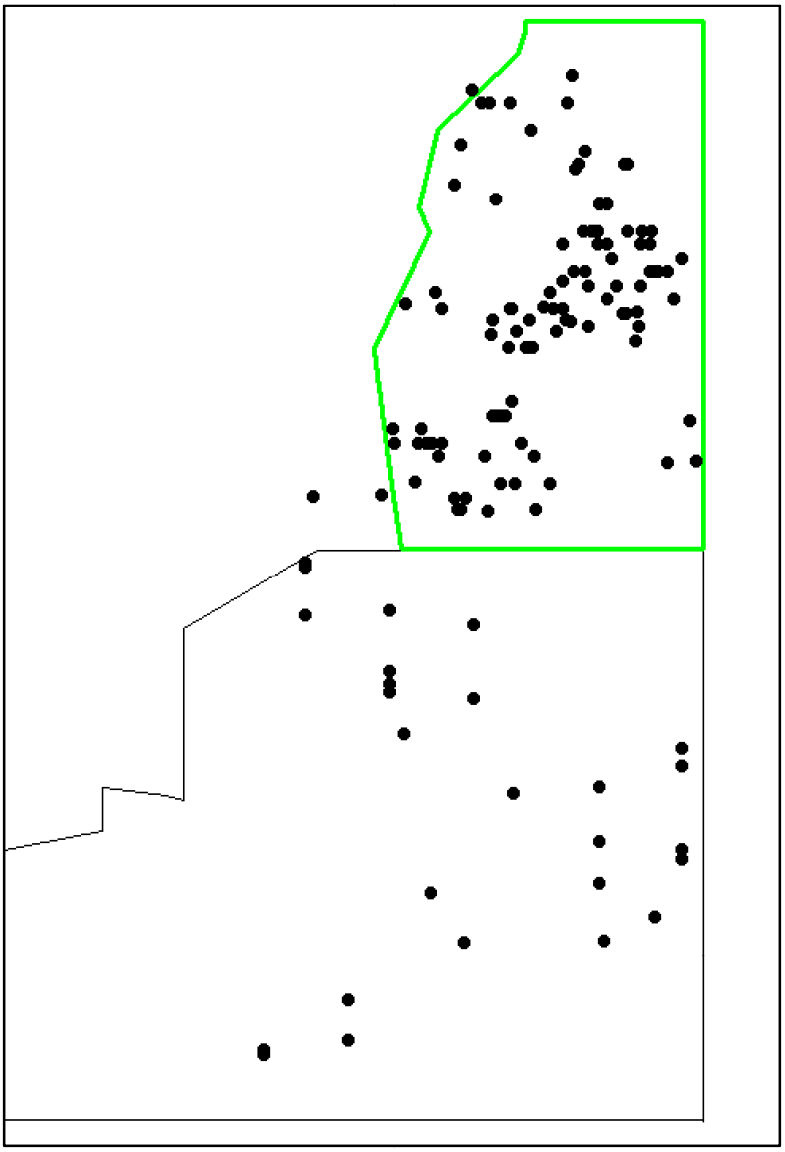


Figure 2 Elephant sightings from the 2011 survey

In each stratum, transects were evenly spaced according to the required sampling intensity from a randomly chosen start point.

They were oriented at right angles to major features (eg omarumbas) as far as possible (Fig. 4). Areas requiring higher sampling (20% and 30%) could not be 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 each, 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.

The strata named Tsum 1 to 7 comprise that part of Nyae Nyae in which elephants were seen in previous surveys. The survey omitted the western part of the conservancy. Stratum Tsum 7 covers the major group of pans in Nyae Nyae – not just the buffalo camp.

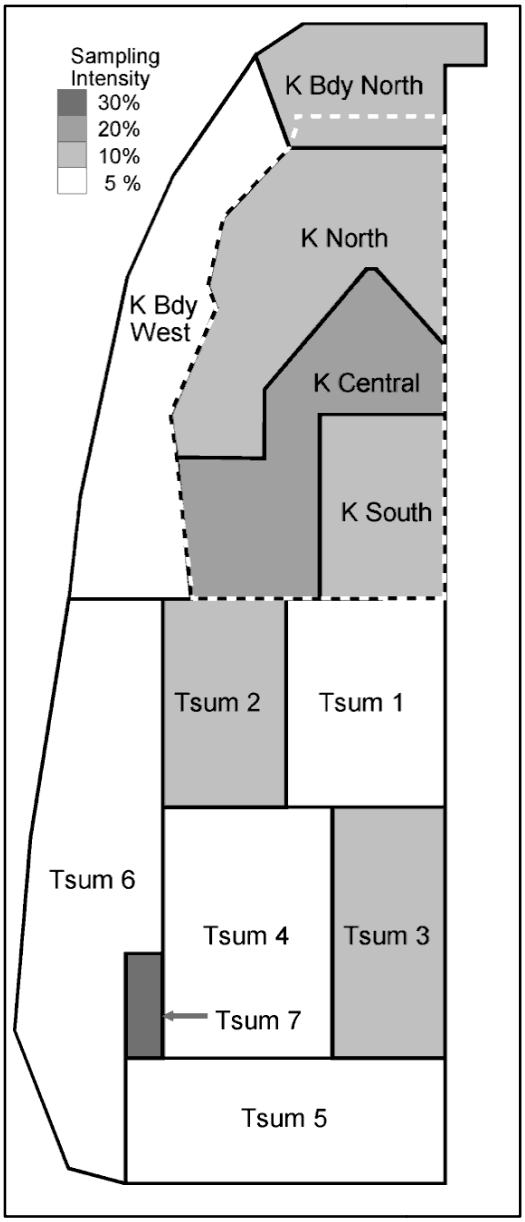


Figure 3 Survey strata used for the 2013 survey

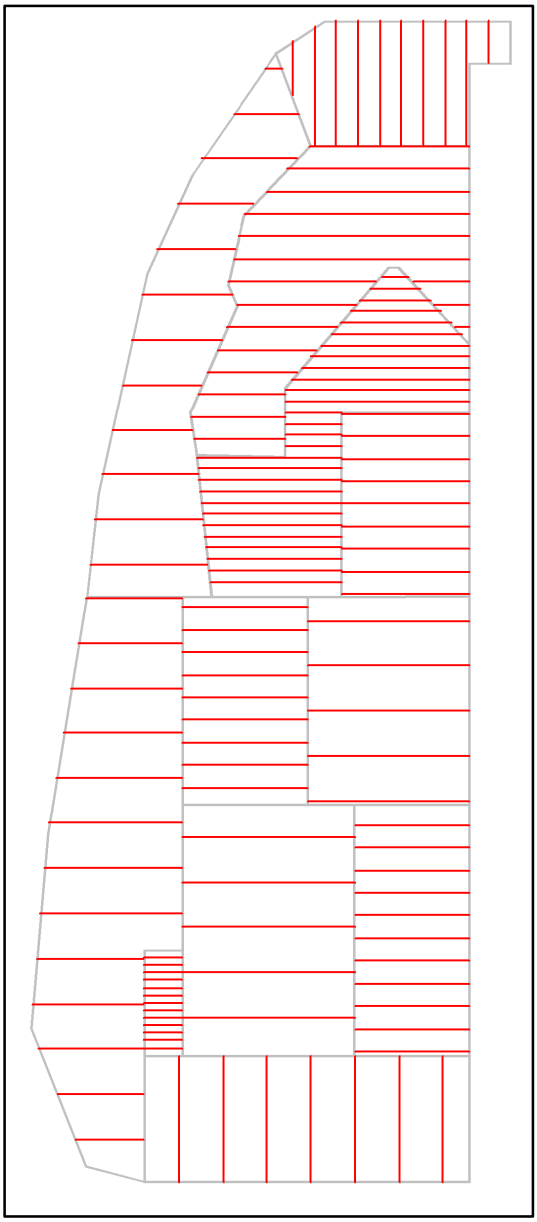


Figure 4 Transects selected for the survey

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 results by stratum are given in Appendix II.

Descriptions of methods are provided in Appendix I. Stratified systematic transect sampling was used (Norton Griffiths, 1978) in a light aircraft (a Cessna 182) flying at a nominal height of 300 feet above the ground.

2. RESULTS AND DISCUSSION

For each species of wildlife in this section a sighting map is provided along with a table of estimates for each stratum. In the table the "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.

"No. seen" 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 made by this method although the record shows that the species occurs.

Wildlife species in this section are arranged in alphabetical order of their common names with the exception of: elephants, which are placed first. Elephant carcasses and carcass ratios are tabulated after elephants. These are followed by domestic animals and other attributes associated with people (eg fields, villages). For each of the species, a map of the locations of sightings is provided.

Details of the results by stratum are given in Appendix II.

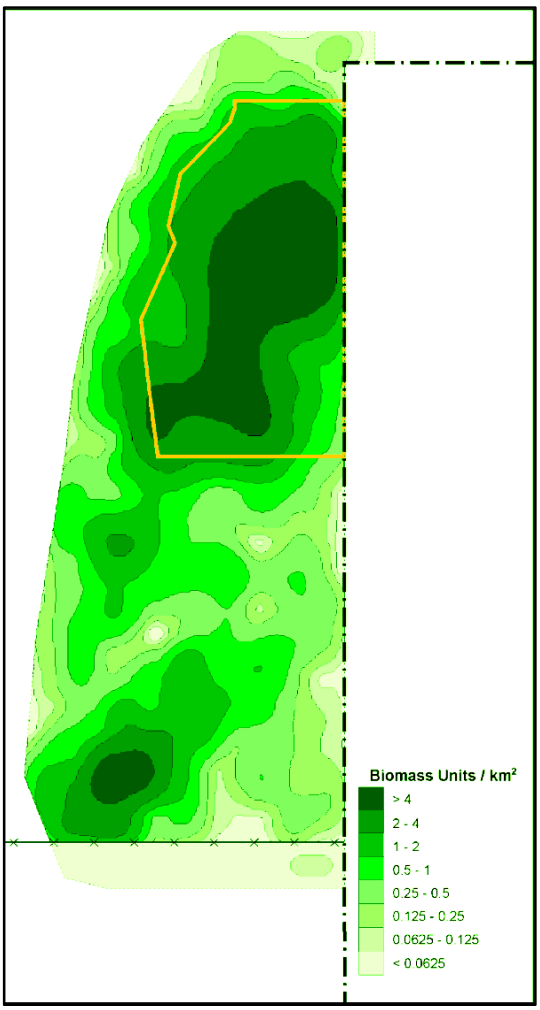


Figure 5 Wildlife biomass distribution

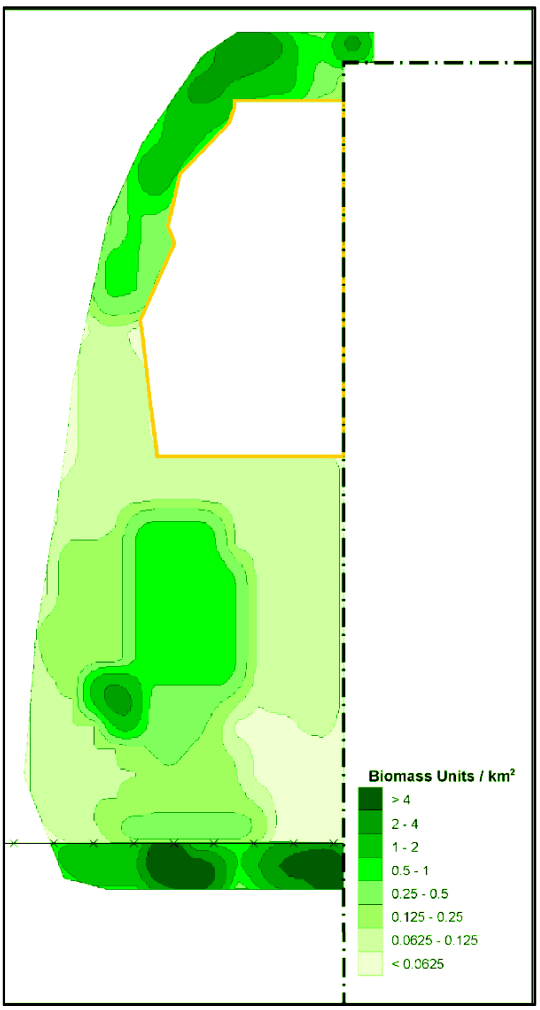


Figure 6 Livestock biomass distribution

Figures 5 and 6 provide a good overview of the contrast in the distributions of wildlife and domestic livestock. This is done by showing biomass density. This takes into account the survey sampling intensity as well as the number of animal sightings. One biomass unit is equivalent to 450kg of metabolic biomass.

The maps below, which show the distribution of sightings of each species, can be misleading as they show concentrations both where animals are more numerous and where there was high sampling intensity. No account is taken of herd size in these maps – they simply show the locations of sightings.

The Foot & Mouth Disease veterinary fence is assumed to be a barrier to wildlife and livestock. Densities have therefore been analysed separately north and south of the fence. Similarly, few livestock were seen in Khaudum NP, so the analysis of livestock biomass excludes that area.

2.1. Observations of Wildlife

2.1.1. Elephant

Table 1: Estimates of total elephant numbers (family and bull groups combined)

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	3089	1998 - 4180	436	875	0.8551
Khaudum NP Bdy W	44	11 - 138	2	9	0.0292
Khaudum NP Bdy N				17	
Nyae Nyae	505	151 - 904	26	125	0.0648
Overall	3638	2490 - 4786	464	1026	0.2664

The density distribution of the estimated 3638 elephant is presented in Fig 7.

Table 2: Estimates of elephant numbers from previous surveys

Strata	Pop. Estimate 1998	95% c.l. as %	Pop. Estimate 2004	95% c.l. as %	Pop. Estimate 2011	95% c.l. as %	Pop. Estimate 2013	95% c.l. as %
Khaudum NP	2224	48.7%	3099	66.0%	2755	45.6%	3089	35.3%
Nyae Nyae	552	75.2%	967	50.0%	1976	75.8%	505	79.0%
Overall	2776	40.5%	4066	51.7%	4731	41.3%	3638	31.6%

The 2013 estimate is less than the 2011 estimate. This is not statistically significant ($p>0.51$). It is possible that the population was smaller at the time of the survey because of the disturbance caused by an elephant capture operation taking place at the time. Several large groups of elephants were seen within Botswana from the ends of the transects in Khaudum. One group was seen crossing the border fence. Some elephants could, therefore, be taking refuge in Botswana and others could have moved to the west, outside the survey area.

The overall change since 1998 (Table 2) indicates an averages 2.7% increase in population size per annum. This trend is not statistically significant ($p>0.03$). However, taking into account the low precision, the number of surveys is insufficient to detect an average annual increase of 5% over the period. Therefore, while there is no statistical evidence of change in population size, it cannot be concluded that no change has taken place.

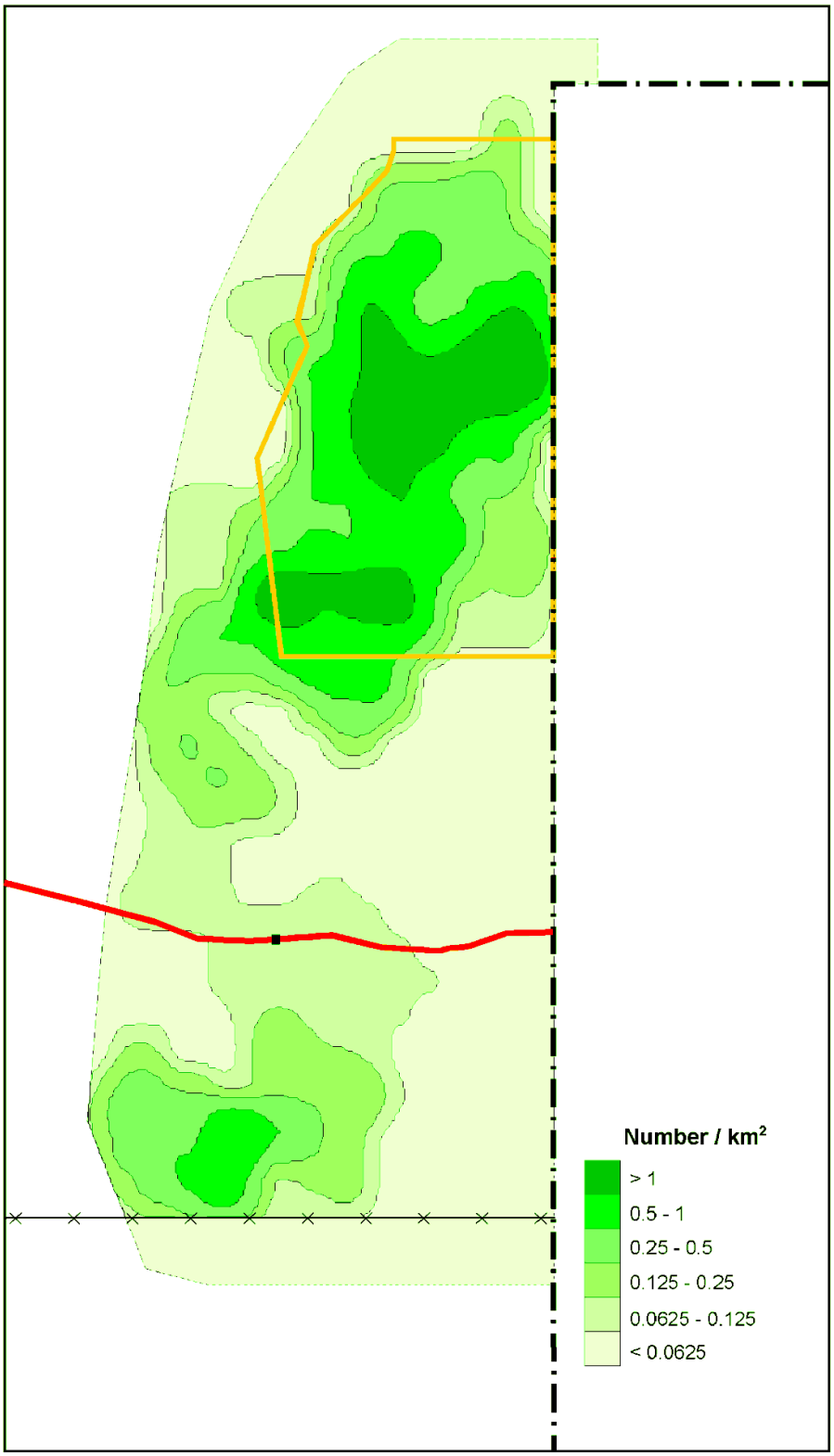
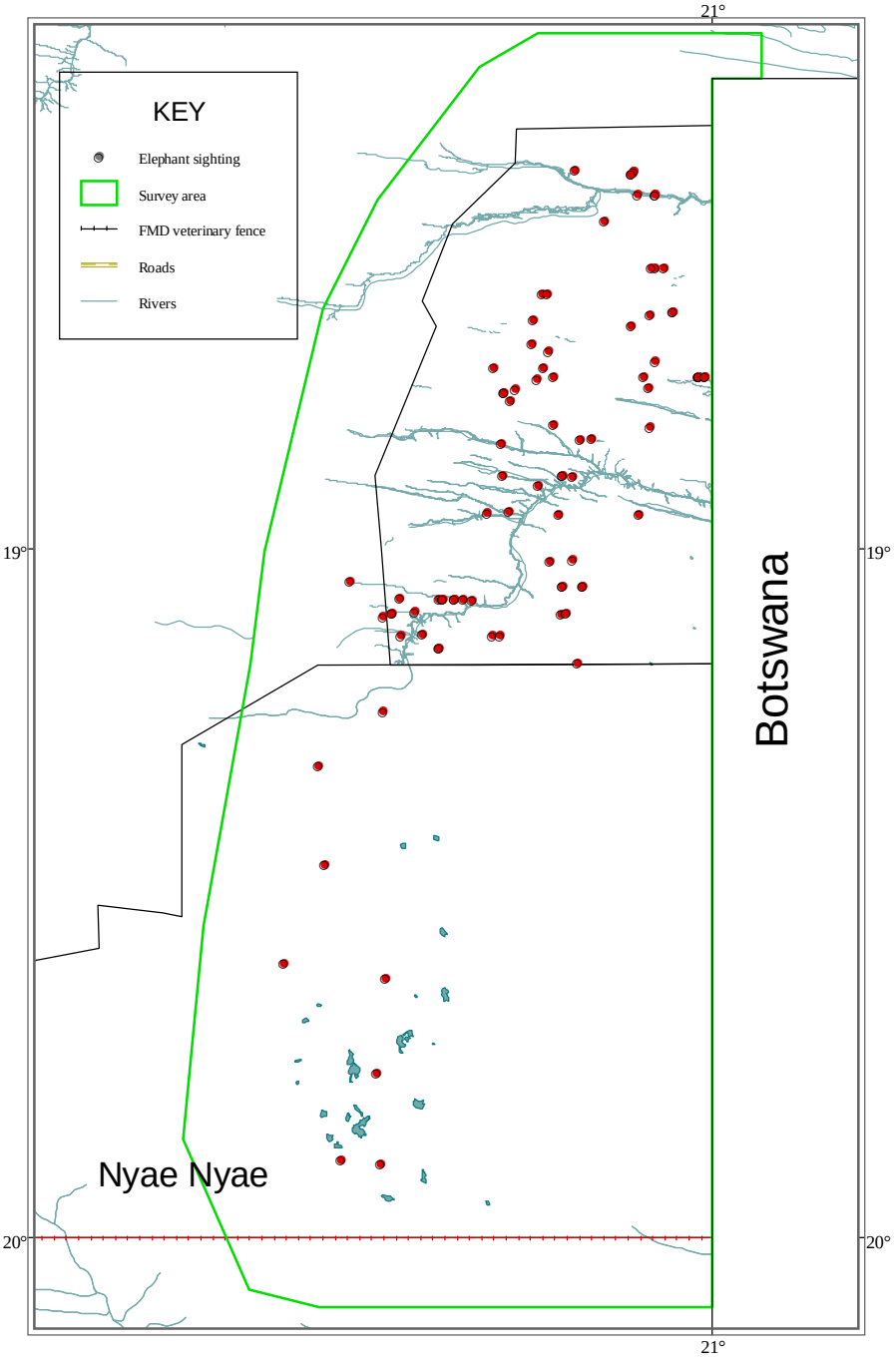


Figure 7 Density distribution of elephants (both family and bull groups)

Table 3: Estimates of elephants in family groups

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	2575	1504 - 3645	364	754	0.7127
Khaudum Bdy W				8	
Khaudum Bdy N				17	
Nyae Nyae				81	
Overall	2575	1520 - 3630	364	860	0.1886



No elephant families were seen in the sample outside of Khaudum National Park. However, visibility was good enough to see elephant herds at a considerable distance beyond the transects so the presence of family groups was noted in other strata.

The number seen serves as a minimum estimate in the absence of better information.

Figure 8 Sightings of elephant family groups

Table 4. Estimates of elephants in bull groups

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	514	303 - 725	72	121	0.1424
Khaudum Bdy W	44	3 - 138	2	1	0.0292
Nyae Nyae	505	106 - 904	26	44	0.0648
Overall	1063	610 - 1517	100	166	0.0779

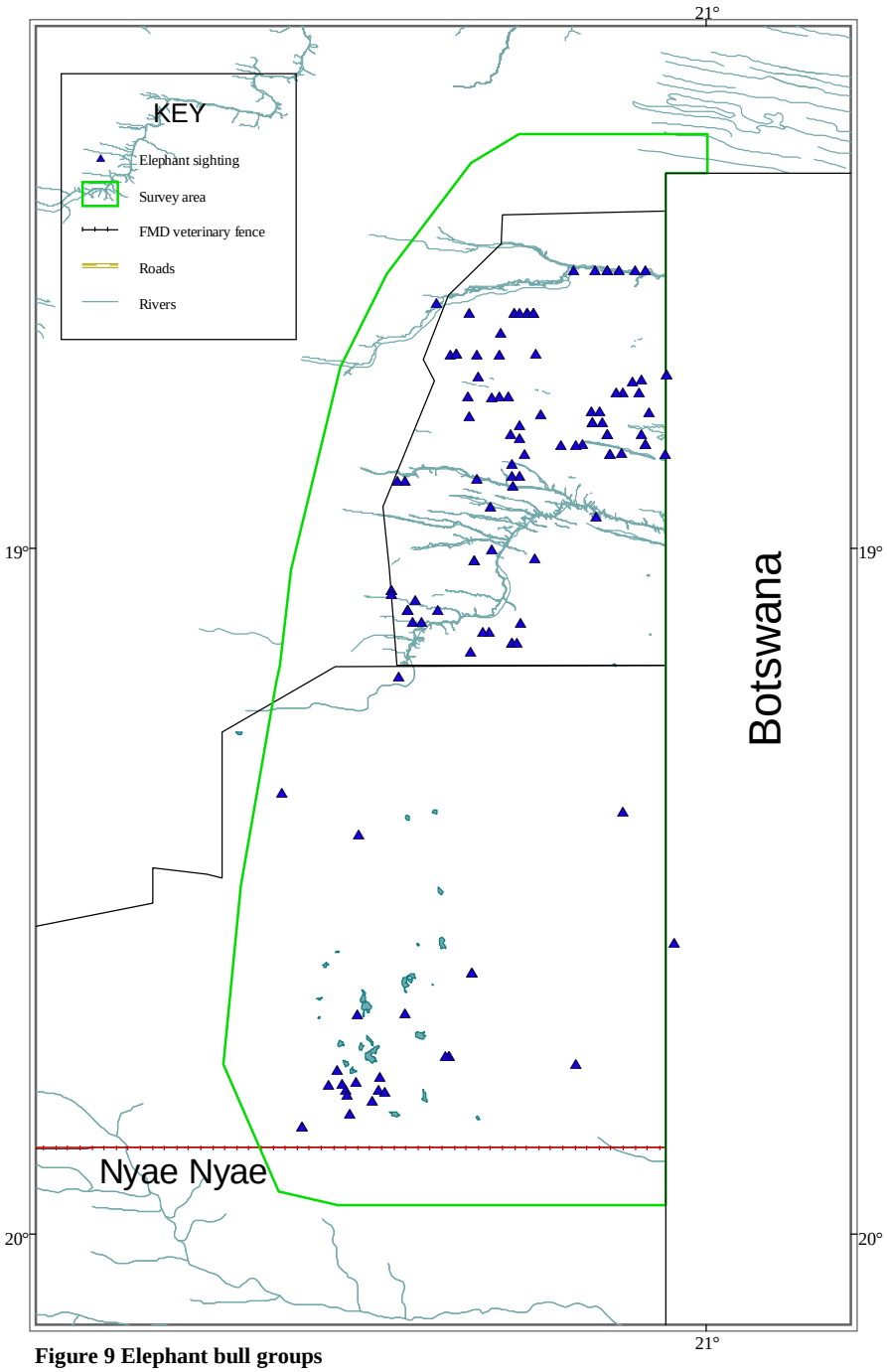


Figure 9 Elephant bull groups

2.1.2. Elephant Carcasses

Table 5. Estimates of total elephant carcasses (all classes combined)

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}	Carcass ratio (%)
Khaudum NP	10	1 - 31	1	0	0.0029	0.32
Khaudum Bdy W	22	1 - 69	1	0	0.0146	33.33
Nyae Nyae	75	5 - 149	5	0	0.0096	12.93
Overall	107	19 - 194	7	0	0.0078	2.86

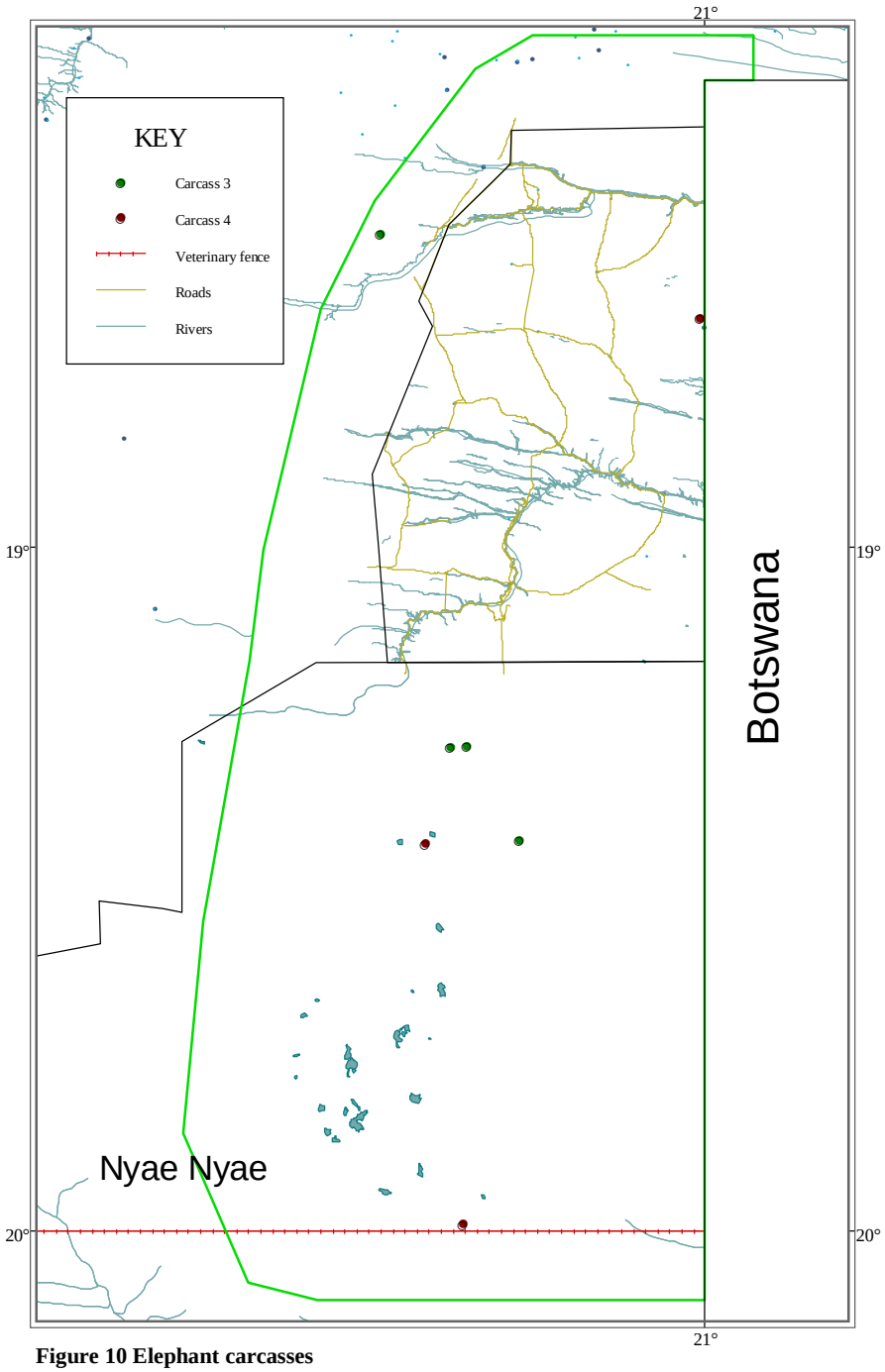


Figure 10 Elephant carcasses

Table 6. Estimates of class 3 elephant carcasses

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum Bdy W	22	1 - 69	1	0	0.0146
Nyae Nyae	42	3 - 98	3	0	0.0053
Overall	63	4 - 134	4	0	0.0046

Table 7. Estimates of class 4 elephant carcasses

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	10	1 - 31	1	0	0.0029
Nyae Nyae	33	2 - 82	2	0	0.0043
Overall	44	3 - 96	3	0	0.0032

Very few carcasses were seen, and the results translate to an overall ratio of 2.86% - an increase since 2011, but not significant ($p > 0.4$).

The high ratios seen in Nyae Nyae and in the Khaudum NP western boundary stratum suggest higher mortality there. This might be a real consequence of trophy hunting, problem animal control or illegal hunting. However, this is based on very small numbers so the data does not provide strong evidence of such an effect.

The overall ratio is in the range that would be expected from natural mortality. There is, therefore, no evidence of any serious impact caused by illegal hunting. However, the data cannot entirely rule out some effect (see 3.1, below).

2.1.3.Buffalo

Table 8. Estimates of buffalo

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Nyae Nyae	63	4 - 184	3	1	0.0081
Overall	63	4 - 184	3	1	0.0042

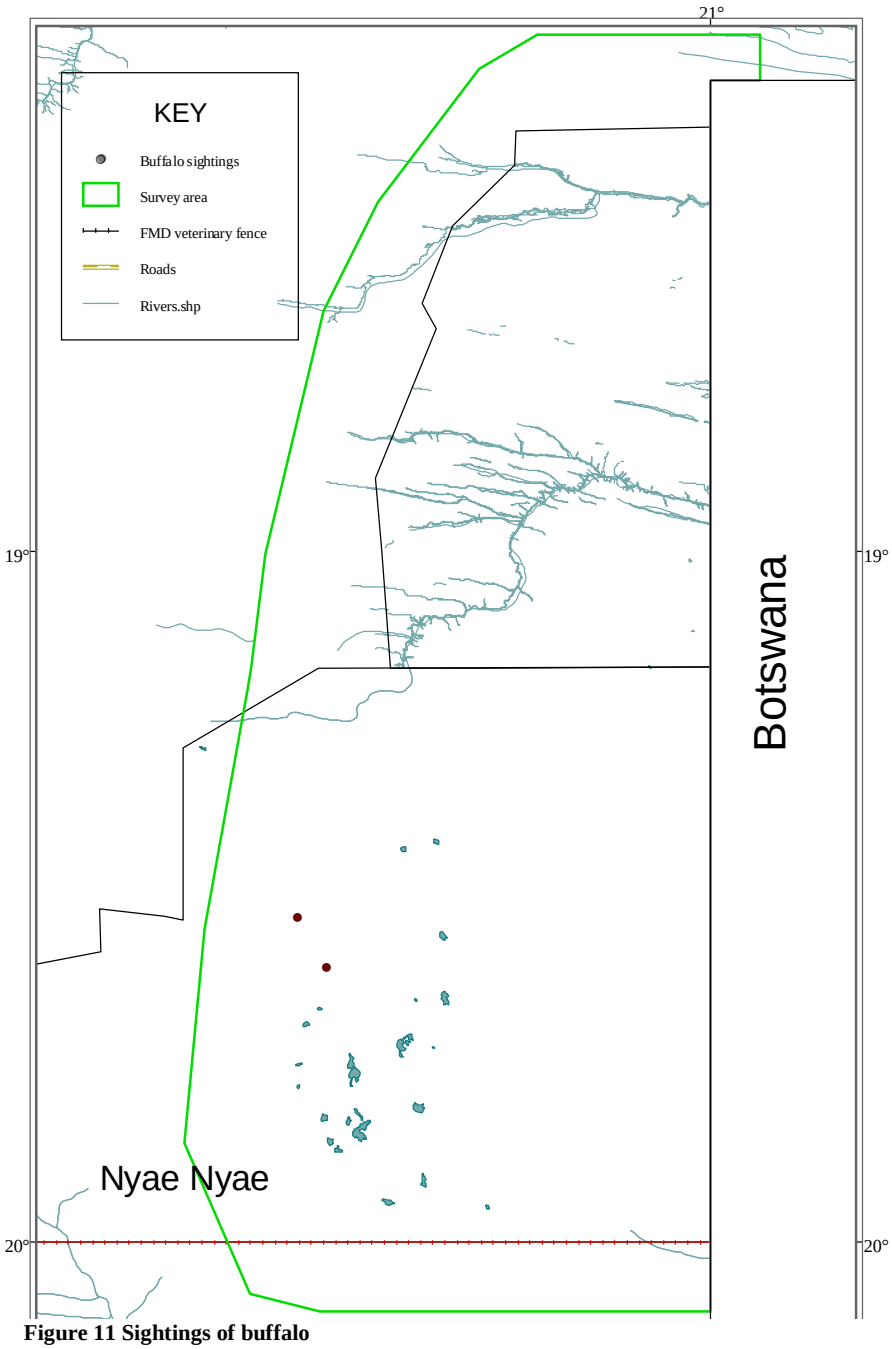


Figure 11 Sightings of buffalo

Sightings are marked on the map as the point where the aircraft was when the sighting was made. The southerly sighting on this map was made from a transect outside the buffalo camp and was of a buffalo that was within the camp.

The buffalo camp was only covered by 5% sampling, so the estimate (based on one sighting) is very imprecise. Previous counts have estimated the number of buffalo to be 169 in 2011 and 202 in 2012 (Beytell & du Preez, 2013)

2.1.4.Eland

Table 9. Estimates of eland

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	531	91 - 1032	73	18	0.1469
Khaudum Bdy W	65	4 - 205	3	1	0.0438
Khaudum Bdy N	127	12 - 396	12	0	0.1673
Overall	723	161 - 1284	88	19	0.0529

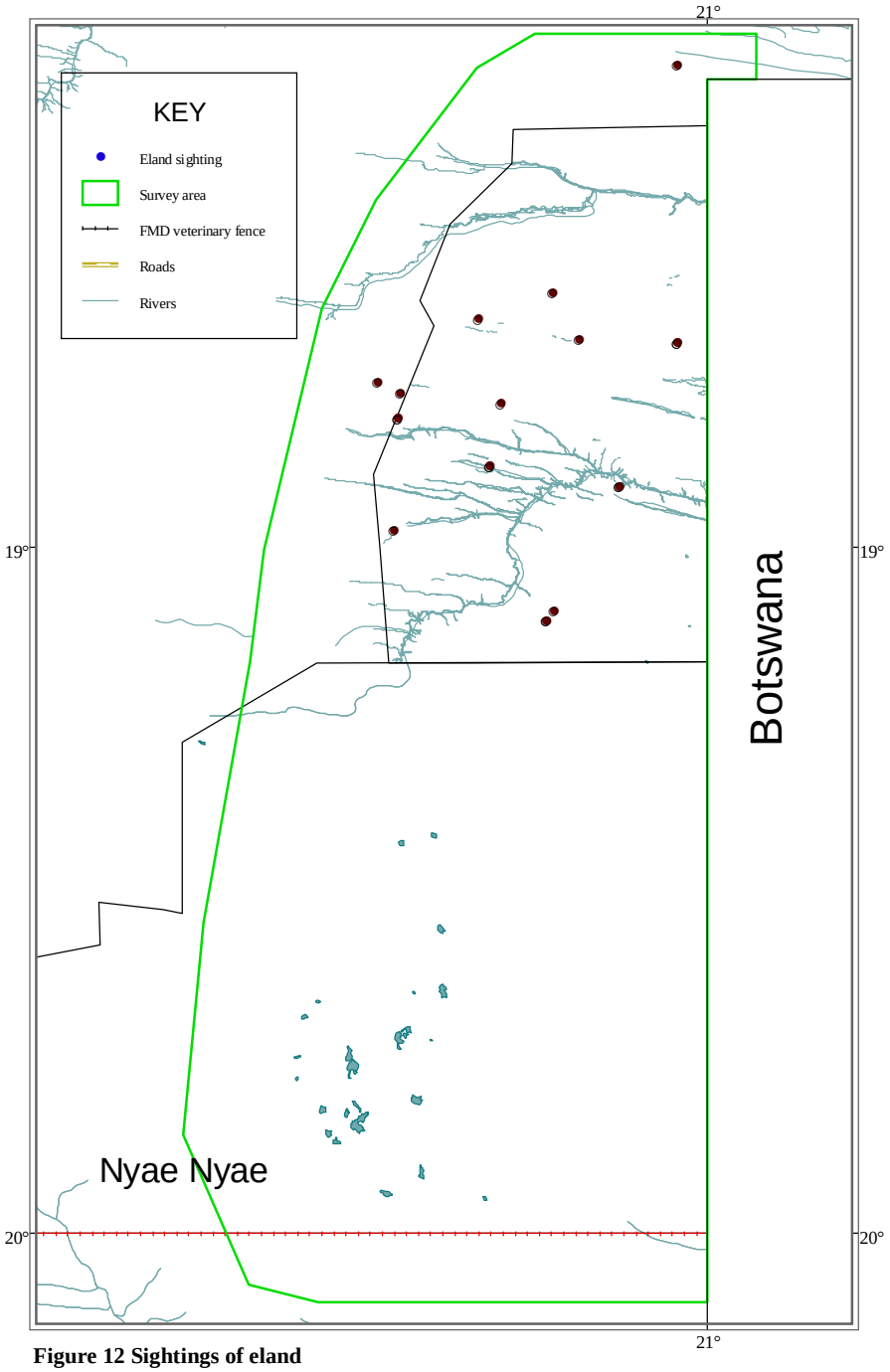


Figure 12 Sightings of eland

2.1.5.Giraffe

Table 10. Estimates of giraffe

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	557	264 - 851	68	63	0.1542
Khaudum Bdy W	109	15 - 294	5	10	0.073
Khaudum Bdy N	11	3 - 33	1	2	0.0139
Nyae Nyae	22	10 - 63	2	8	0.0028
Overall	698	362 - 1035	76	83	0.0511

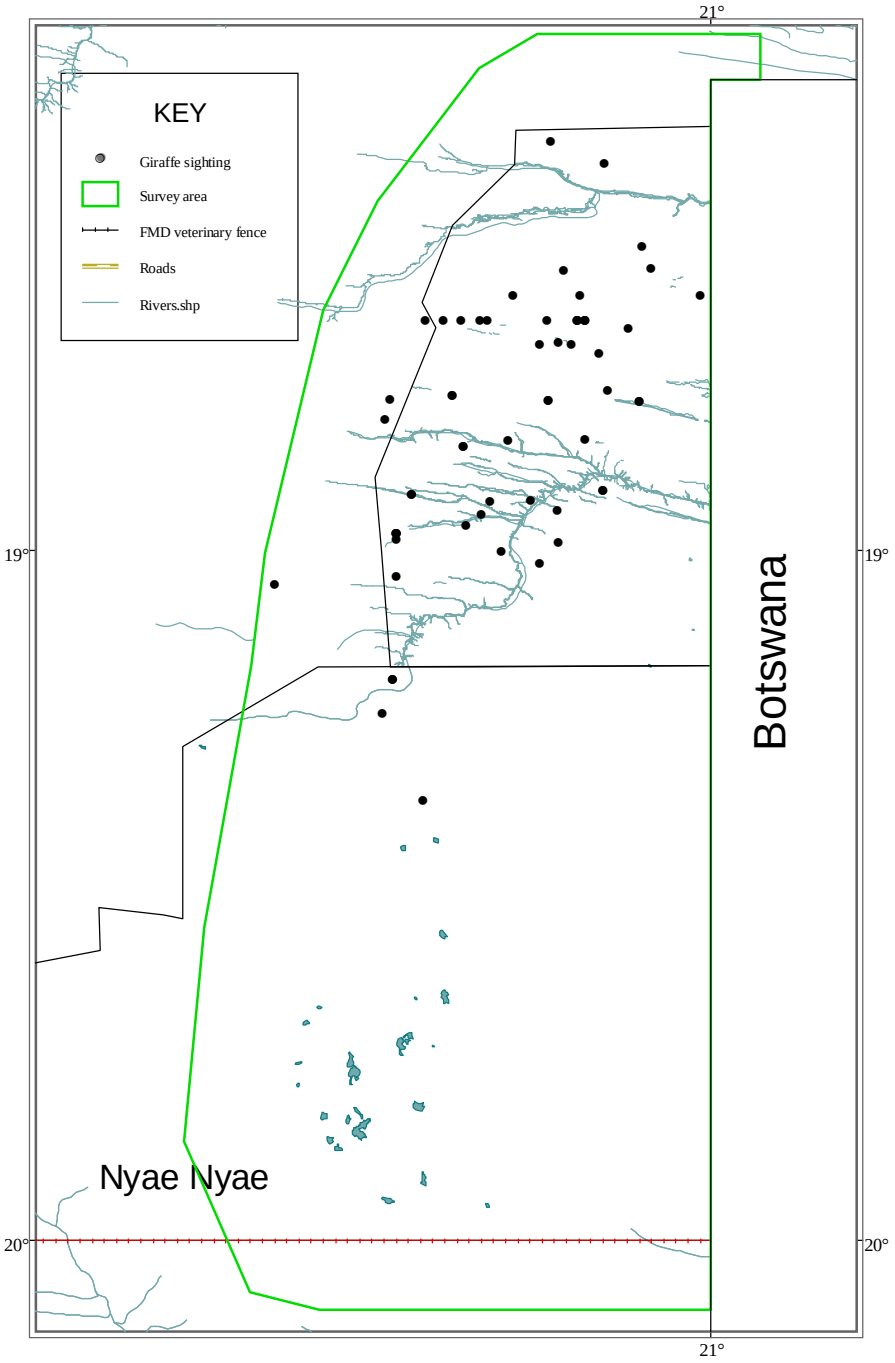


Figure 13 Sightings of giraffe

2.1.6. Hartebeest

Table 11. Estimates of hartebeest

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	22	4 - 62	4	0	0.006
Nyae Nyae	470	55 - 1127	40	15	0.0603
Overall	492	59 - 1142	44	15	0.036

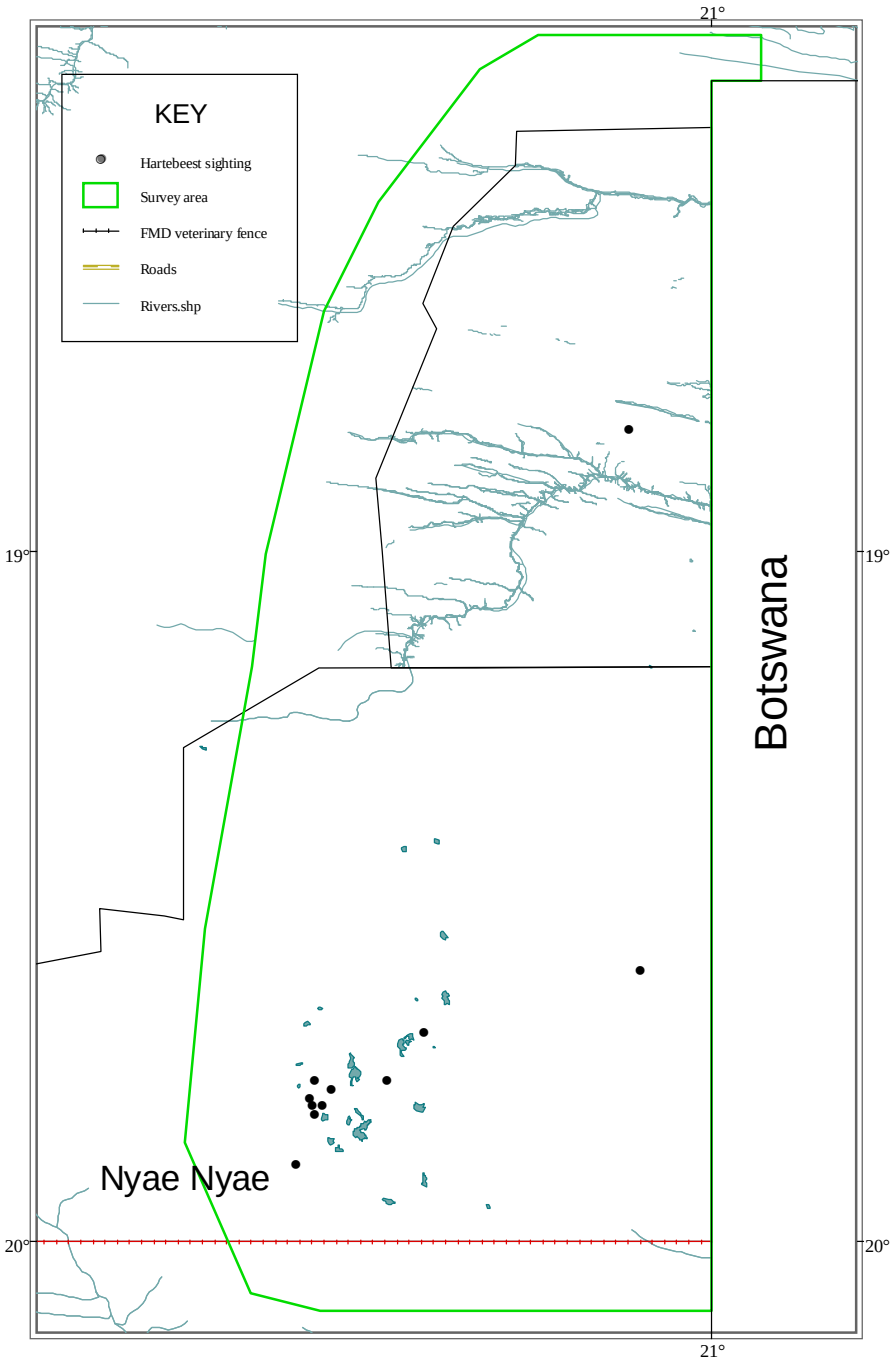


Figure 14 Sightings of hartebeest

2.1.7.Kudu

Table 12. Estimates of kudu

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	457	213 - 701	59	34	0.1265
Khaudum Bdy W	348	16 - 709	16	0	0.2336
Khaudum Bdy N	63	6 - 138	6	0	0.0837
Nyae Nyae	1147	459 - 1836	72	33	0.1472
Overall	2016	1222 - 2809	153	67	0.1476

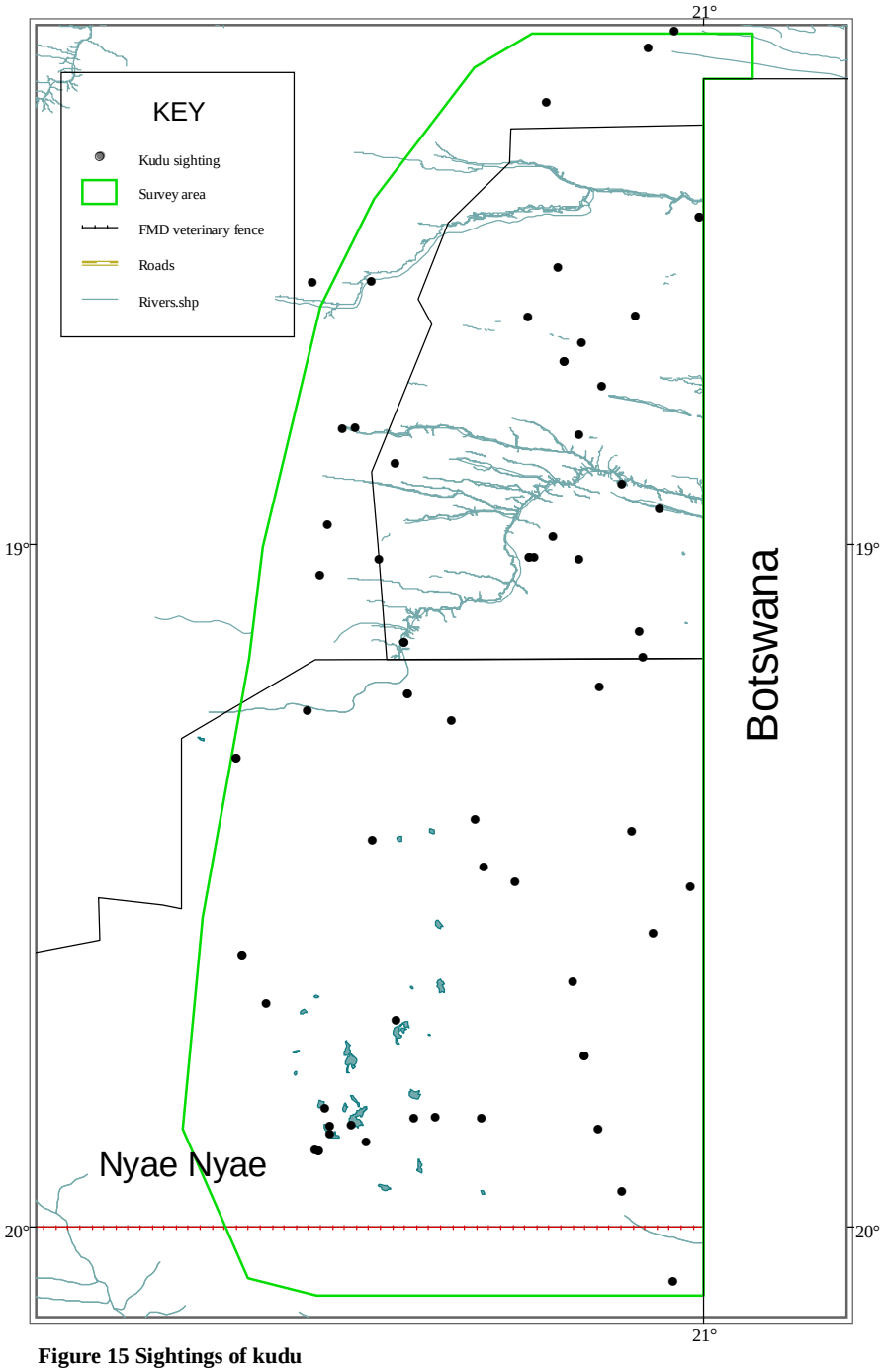


Figure 15 Sightings of kudu

2.1.8.Oryx

Table 13. Estimates of oryx

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	690	347 - 1033	87	34	0.191
Khaudum Bdy W	44	9 - 138	2	7	0.0292
Khaudum Bdy N	116	11 - 363	11	0	0.1534
Nyae Nyae	482	203 - 761	63	8	0.0618
Overall	1331	837 - 1825	163	49	0.0975

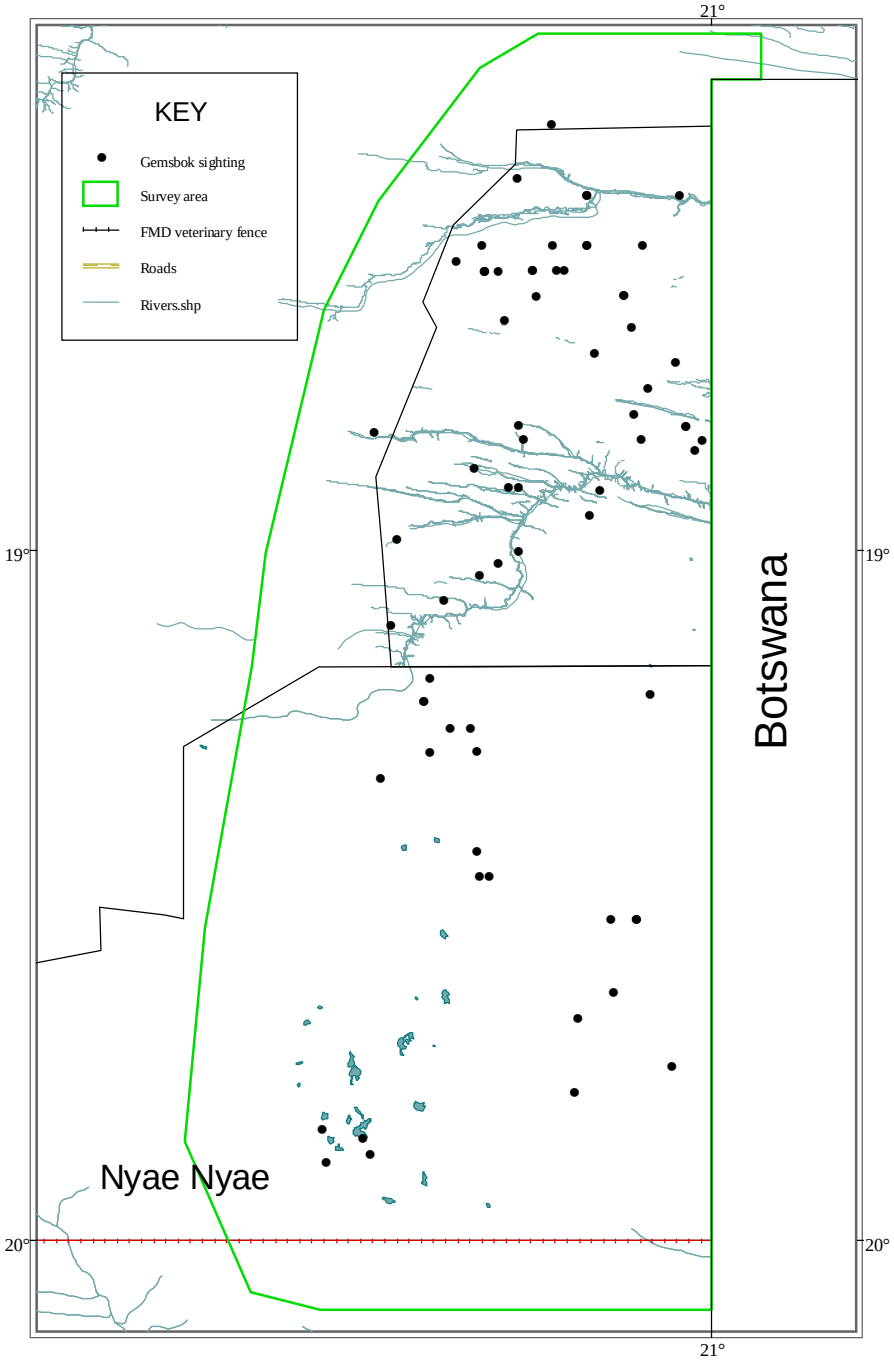


Figure 16 Sightings of oryx

2.1.9. Roan

Table 14. Estimates of roan

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	657	254 - 1060	77	41	0.1818
Khaudum Bdy W	0	3 - 0	0	3	0
Khaudum Bdy N	42	6 - 133	4	2	0.0558
Nyae Nyae	1100	83 - 2343	59	24	0.1412
Overall	1800	508 - 3091	140	70	0.1318

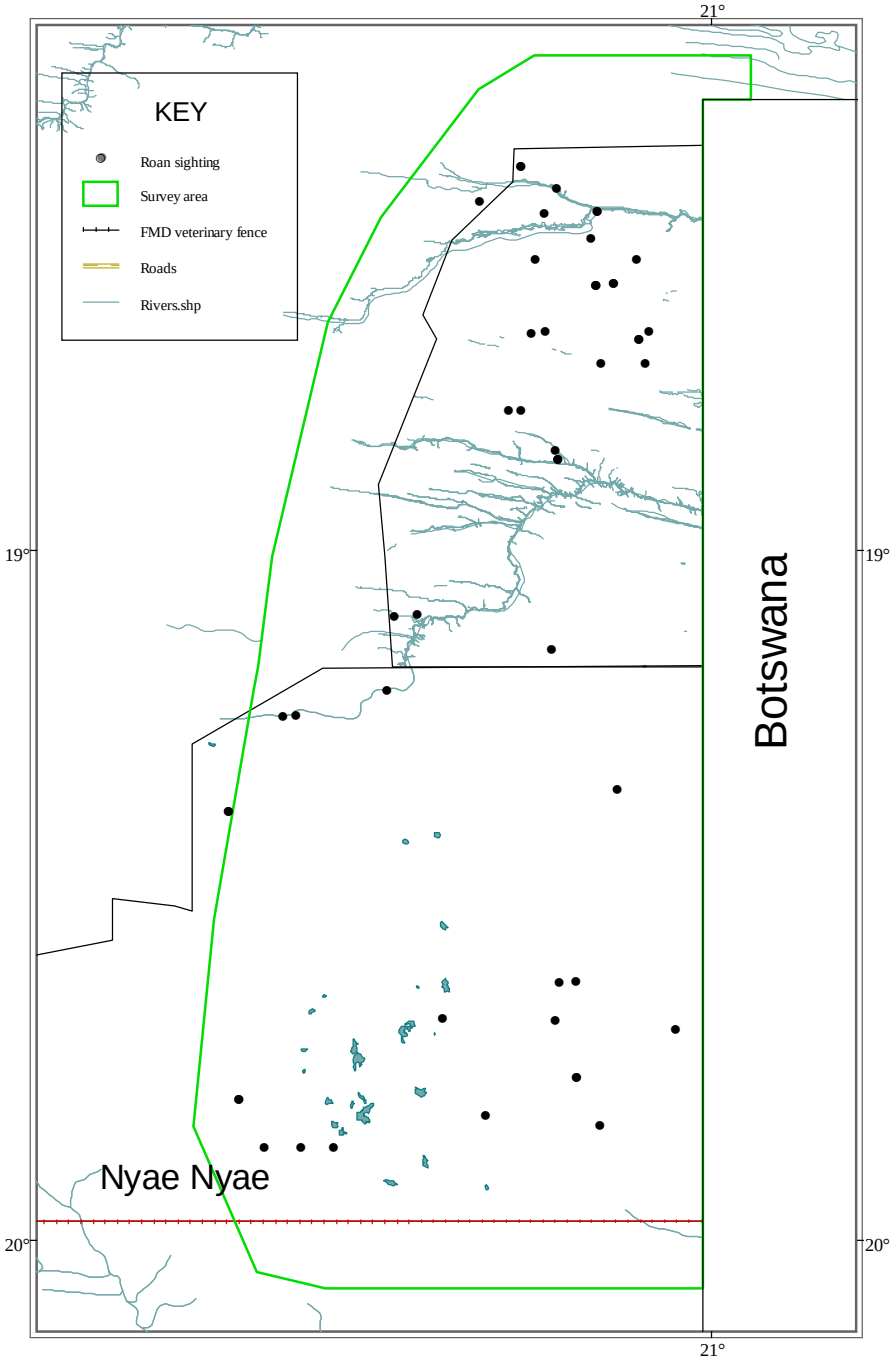


Figure 17 Sightings of roan

2.1.10. Springbok

Table 15. Estimates of springbok

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Nyae Nyae	44	36 - 105	12	24	0.0057
Overall	44	36 - 104	12	24	0.0032

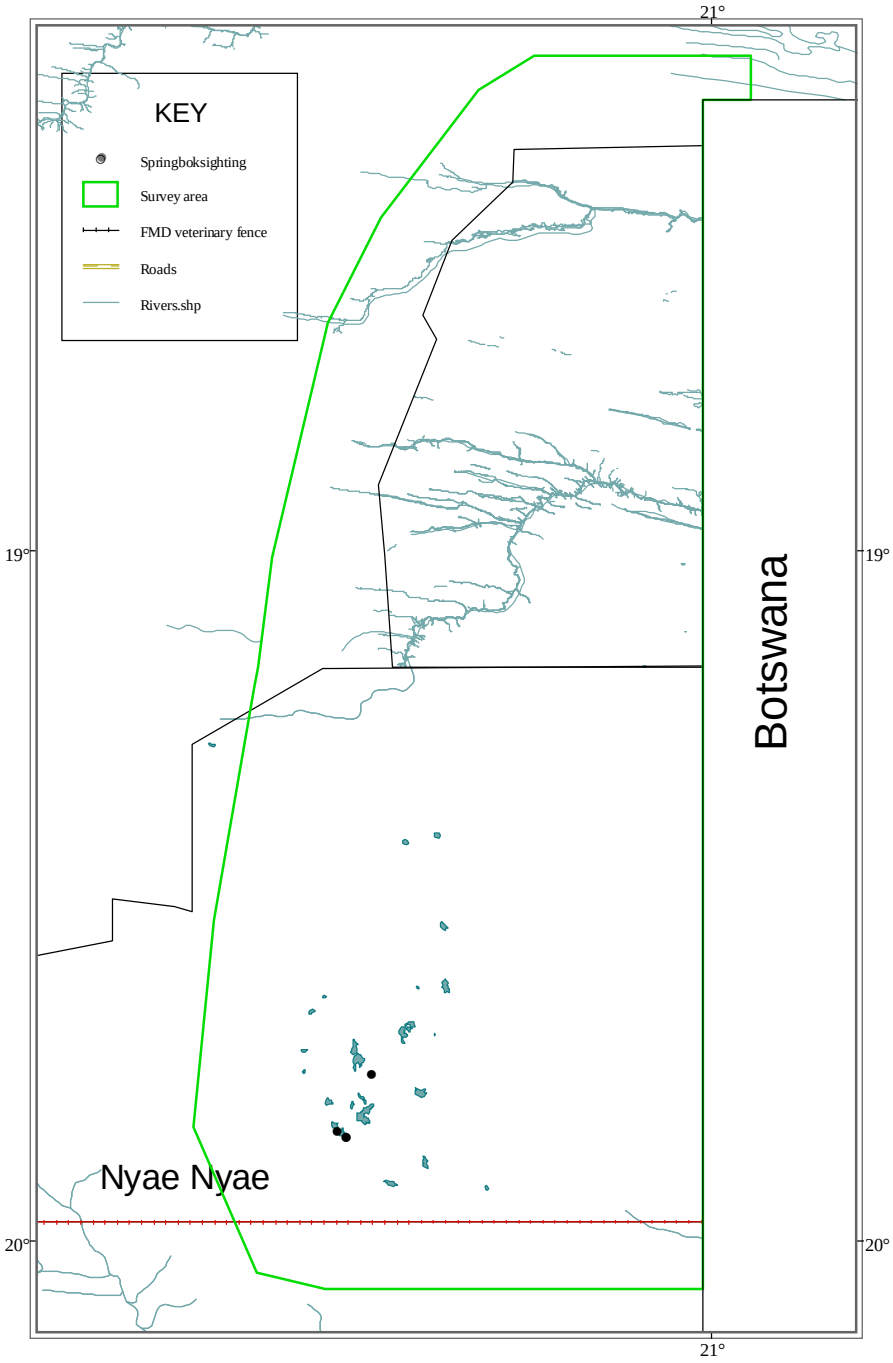


Figure 18 Sightings of springbok

2.1.11. Warthog

Table 16. Estimates of warthog

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	233	99 - 367	29	0	0.0645
Khaudum Bdy W	44	3 - 136	2	1	0.0292
Nyae Nyae	303	20 - 615	20	0	0.0389
Overall	579	234 - 925	51	1	0.0424

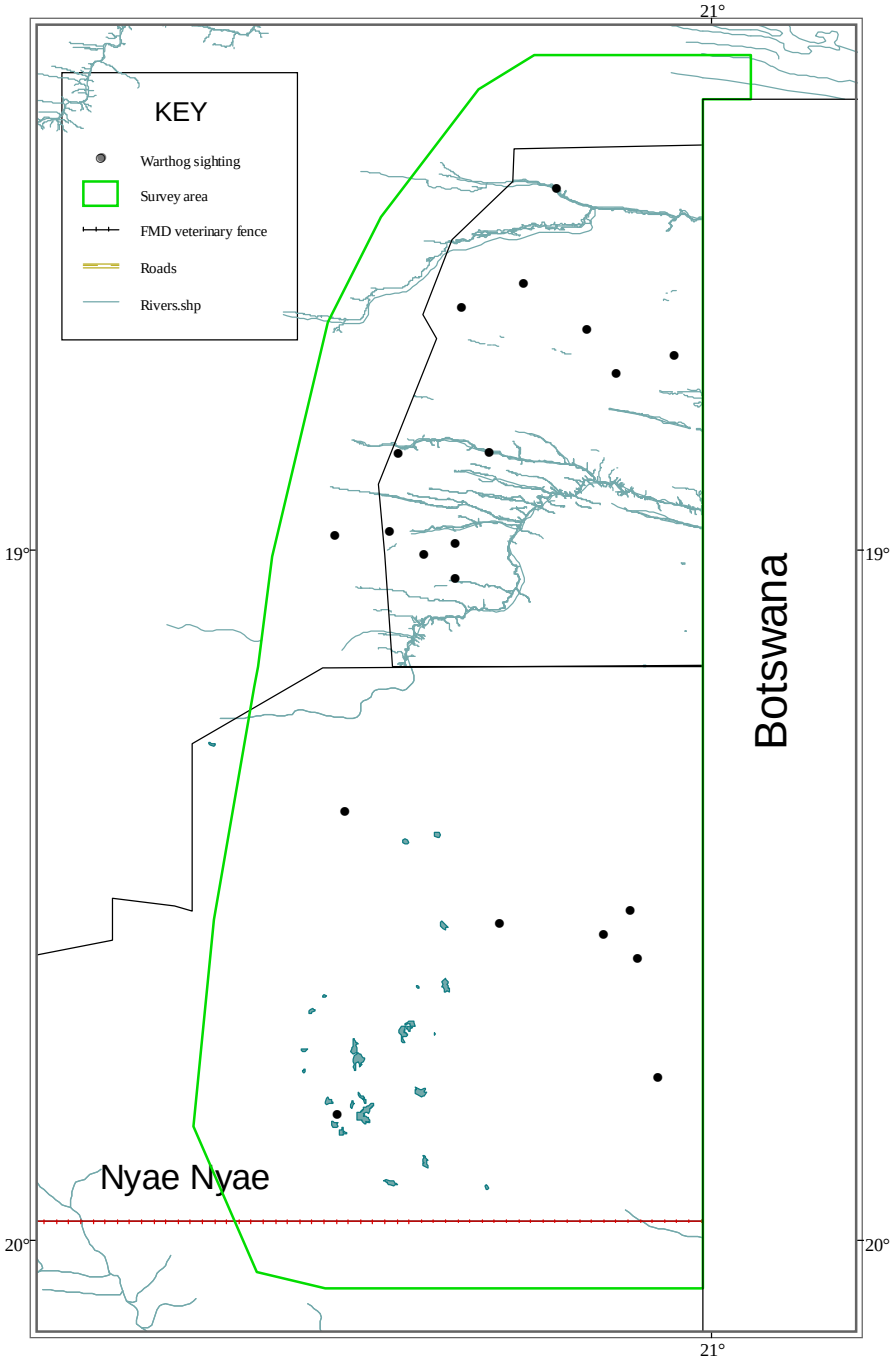


Figure 19 Sightings of warthog

2.1.12. Wildebeest

Table 17. Estimates of wildebeest

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	349	110 - 704	40	70	0.0965
Nyae Nyae	1899	423 - 3456	184	239	0.2436
Overall	2247	671 - 3824	224	309	0.1646

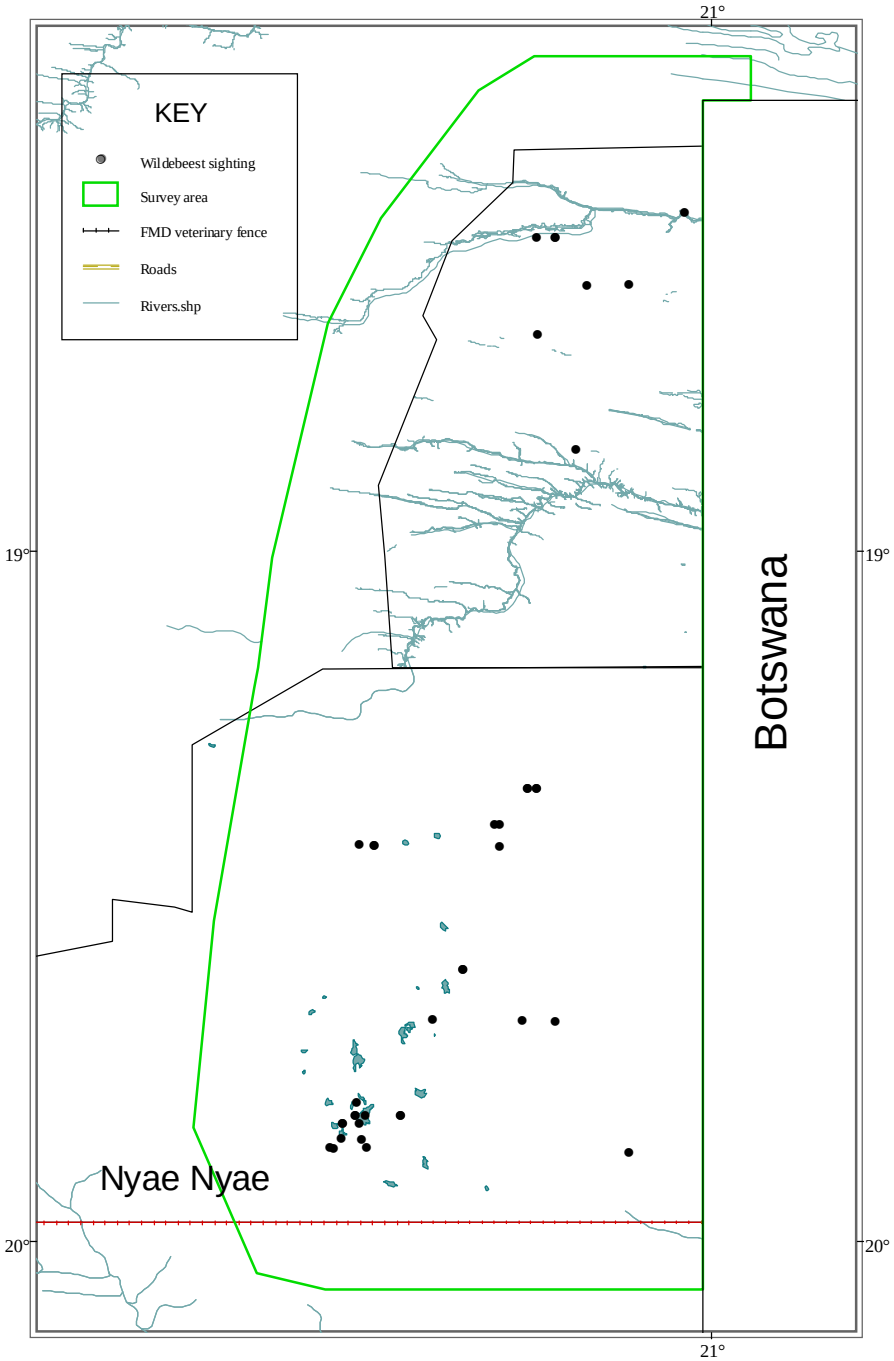


Figure 20 sightings of wildebeest

2.1.13. Ostrich

Table 18. Estimates of ostrich

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	96	20 - 180	14	6	0.0265
Khaudum Bdy W	109	6 - 267	5	1	0.073
Khaudum Bdy N	32	3 - 105	3	0	0.0418
Nyae Nyae	378	157 - 599	21	18	0.0485
Overall	615	334 - 895	43	25	0.045

2.1.14.

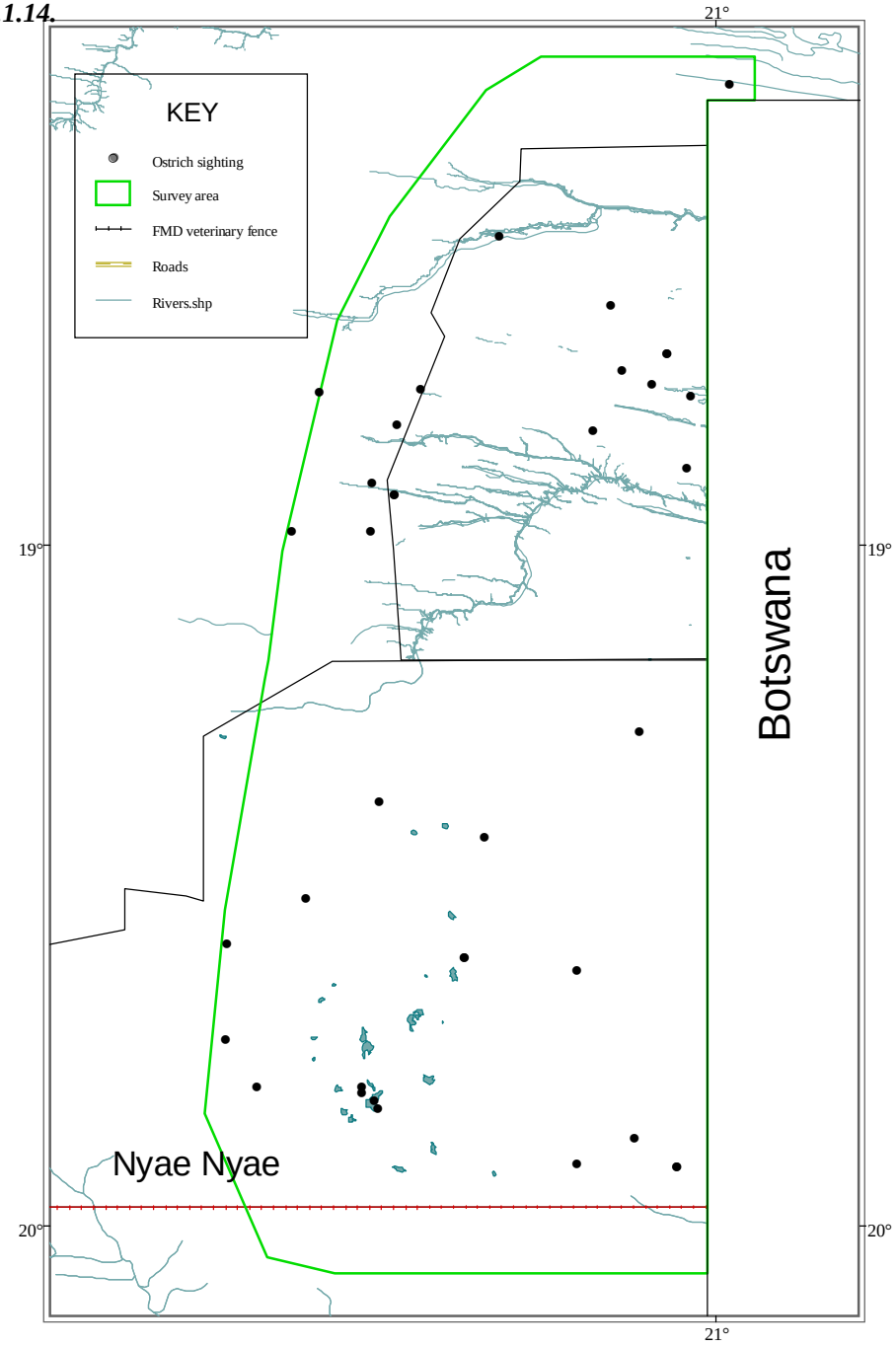
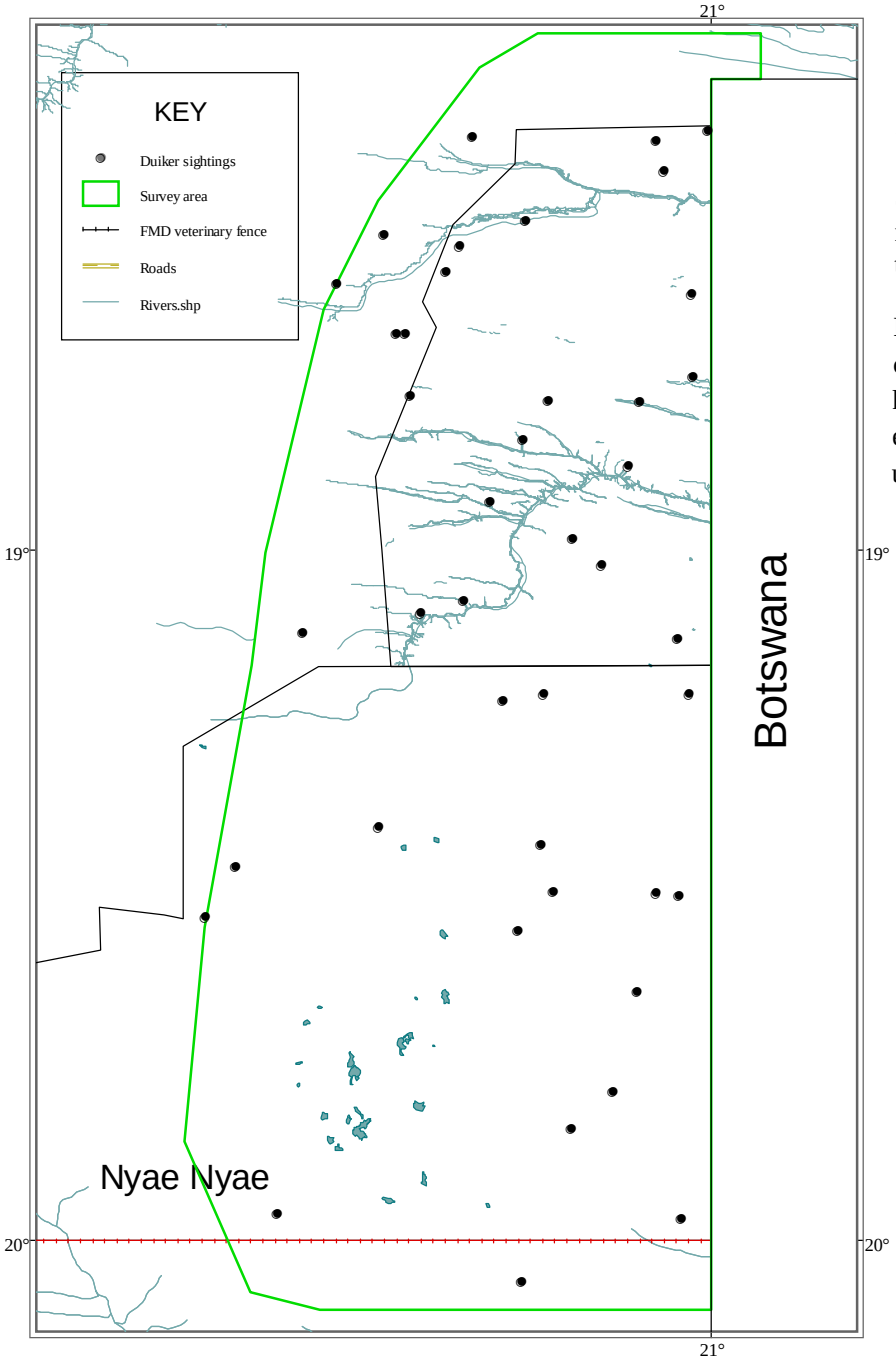


Figure 21 Sightings of ostrich

2.1.15. Small Antelopes

Table 19. Estimates of duiker

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	161	95 - 228	21	0	0.0447
Khaudum Bdy W	152	21 - 283	7	0	0.1022
Khaudum Bdy N	21	2 - 51	2	0	0.0279
Nyae Nyae	369	192 - 545	20	0	0.0473
Overall	703	482 - 925	50	0	0.0515



Results for duiker and steenbok should be viewed together. Both species are small and difficult to see and they may be confused on this type of survey.

Both species are very common in these habitats and these estimates are certainly undercounts.

Figure 22 Sightings of duiker

Table 20. Estimates of steenbok

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP	170	84 - 255	20	2	0.0469
Khaudum Bdy W	87	6 - 168	4	1	0.0584
Khaudum Bdy N	11	3 - 33	1	2	0.0139
Nyae Nyae	216	80 - 352	12	1	0.0278
Overall	483	308 - 659	37	6	0.0354

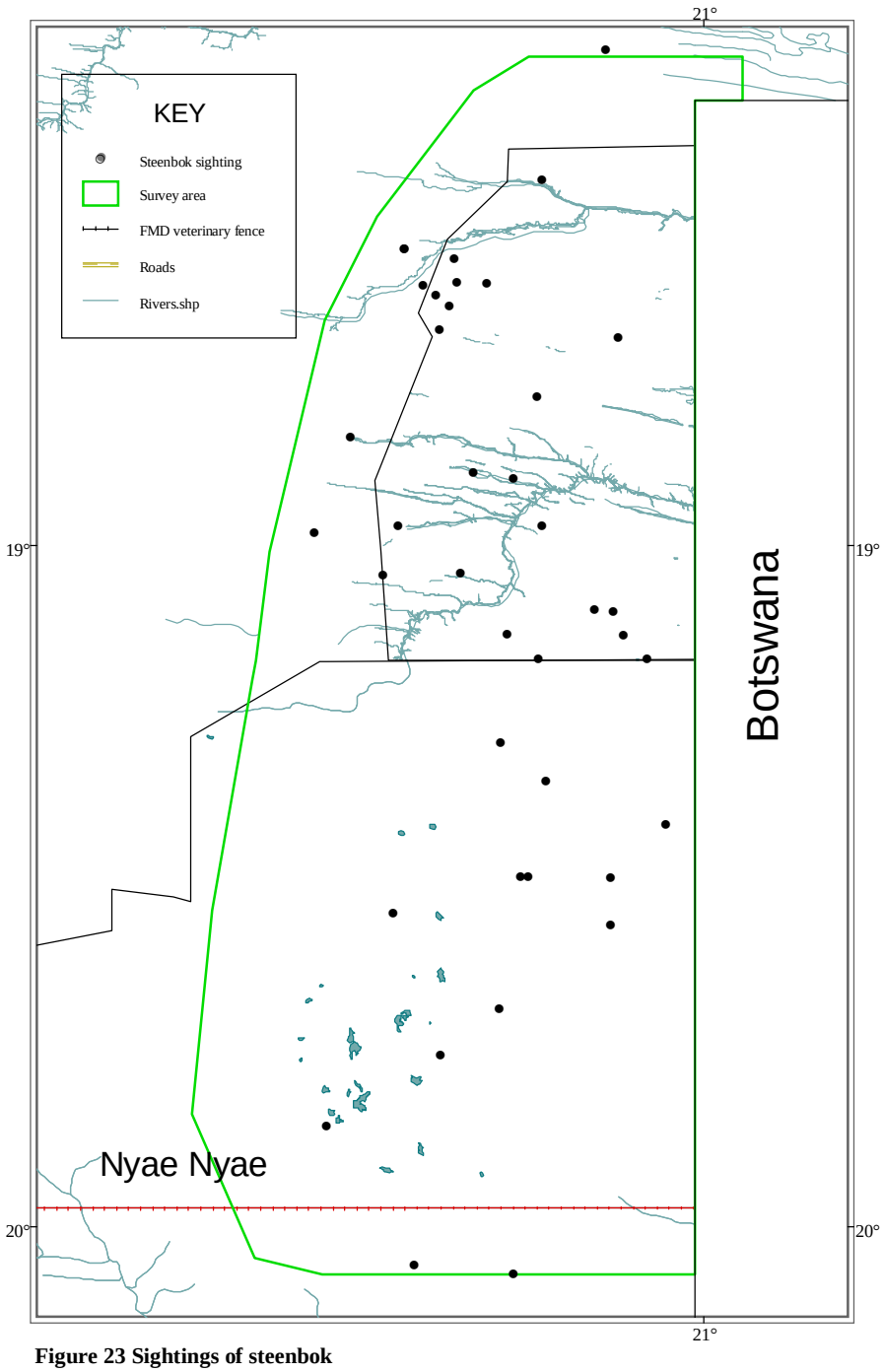


Figure 23 Sightings of steenbok

2.2. Observations of Domestic Animals & Human Influence

2.2.1. Horses

Table 21. Estimates of Horses

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Nyae Nyae	576	176 - 977	27	12	0.0739
Overall	576	181 - 972	27	12	0.0422

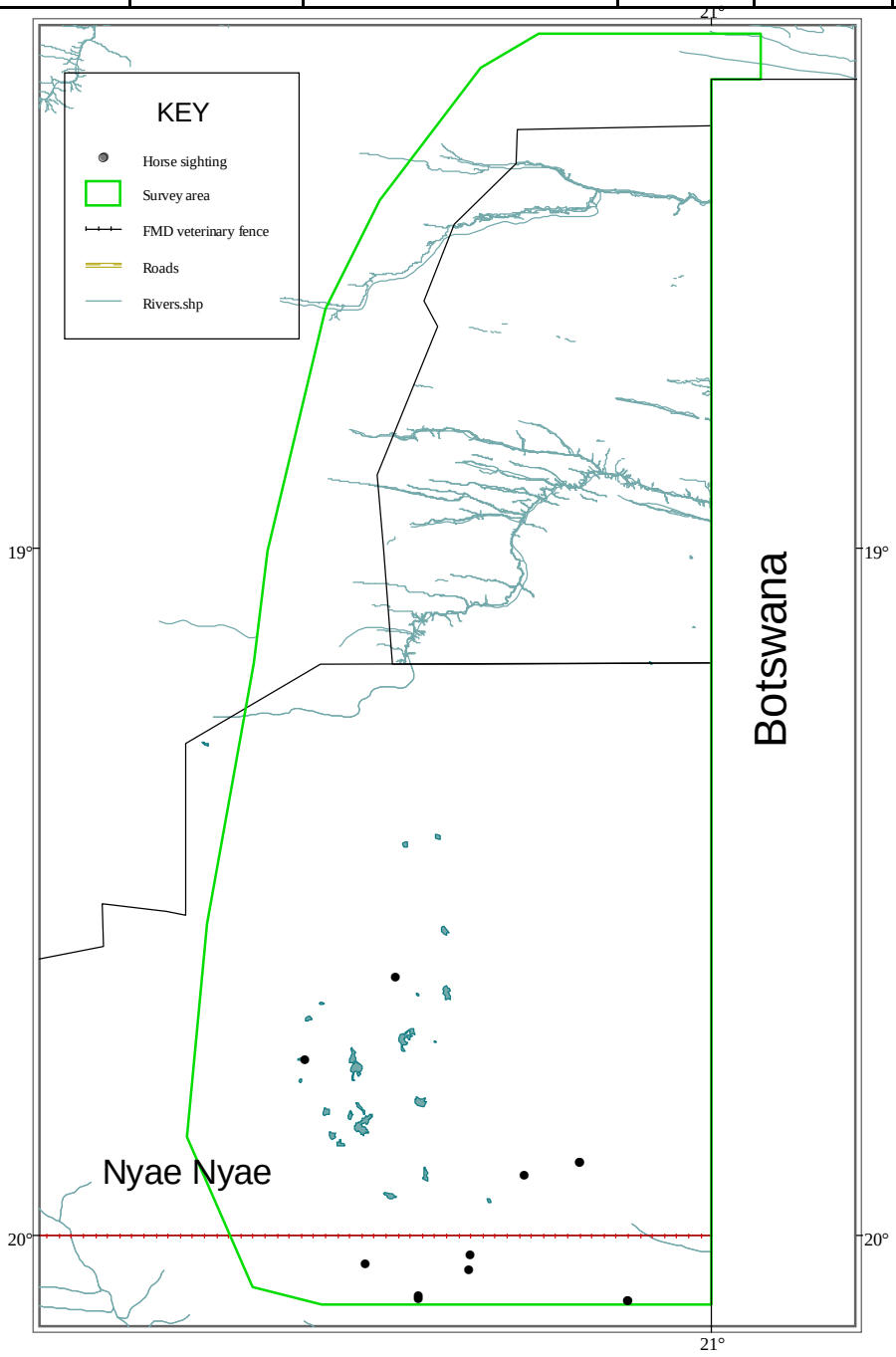


Figure 24 Sightings of horses

2.2.2. Donkeys

Table 22. Estimates of donkeys

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum Bdy N	63	6 - 186	6	0	0.0837
Nyae Nyae	22	6 - 66	1	5	0.0029
Overall	86	12 - 202	7	5	0.0063

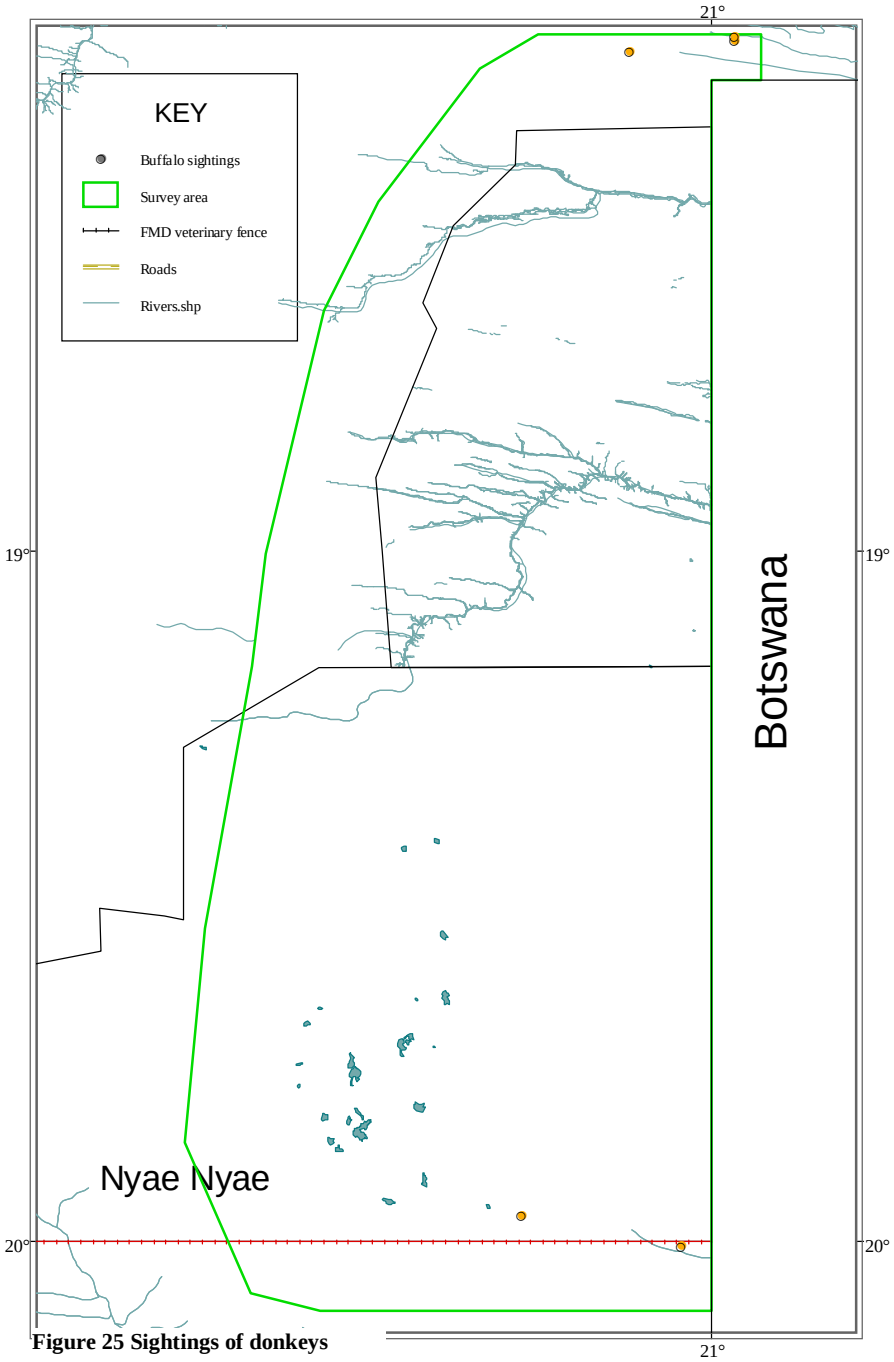
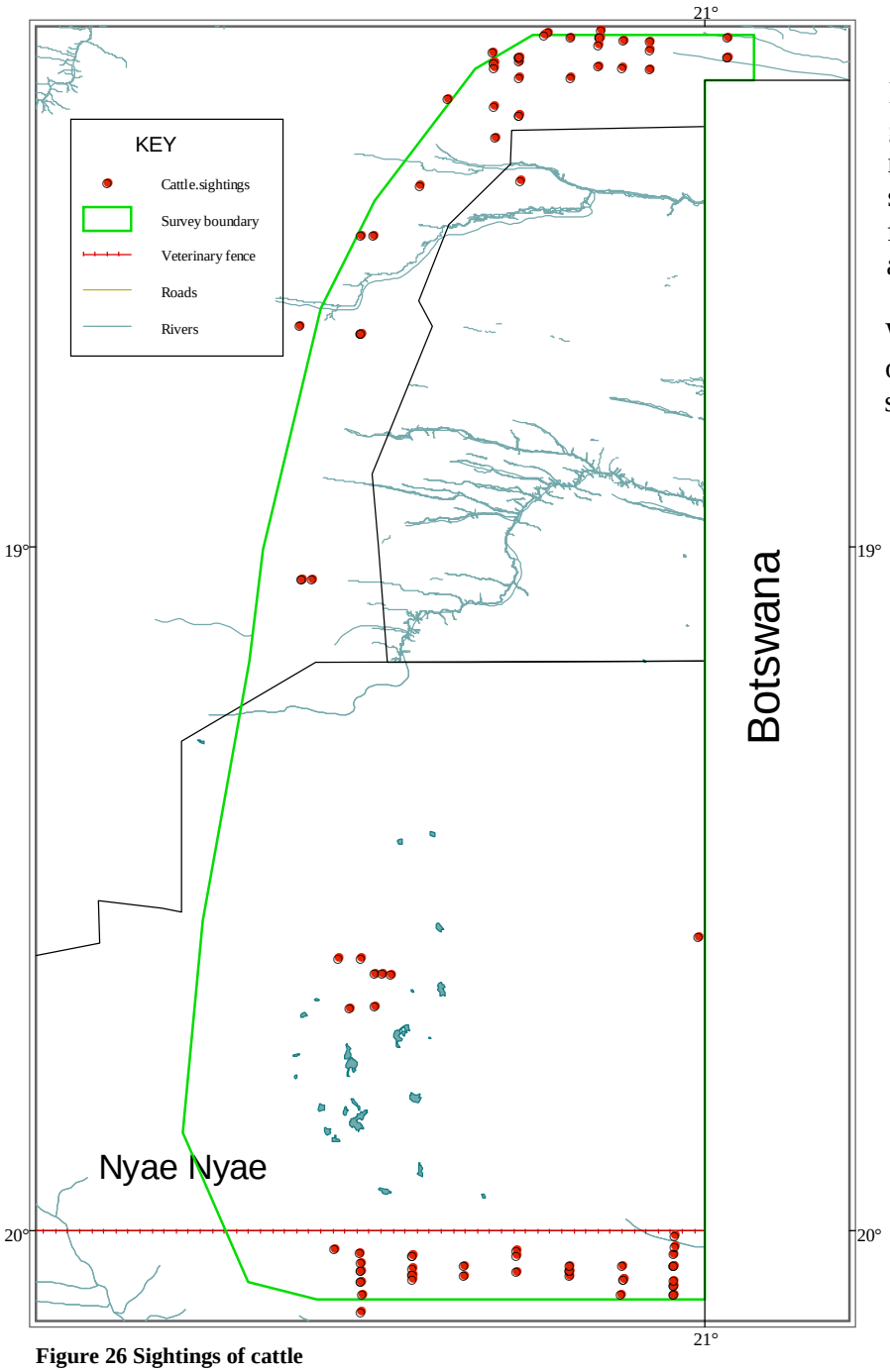


Figure 25 Sightings of donkeys

2.2.3.Cattle

Table 23. Estimates of Cattle

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum Bdy W	1501	155 - 3289	69	86	1.0074
Khaudum Bdy N	1394	315 - 2842	132	183	1.8407
Nyae Nyae	4554	2422 - 6685	206	173	0.5843
Overall	7449	4514 - 10385	407	442	0.5456



Cattle densities, and livestock densities in general, are low except north of Khaudum, south of the veterinary fence and immediately around Nyae Nyae.

Wildlife dominates over most of the surveyed area.

Figure 26 Sightings of cattle

2.2.4.Sheep/Goats

Table 24. Estimates of small stock (sheep/goats)

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum Bdy W	457	91 - 1435	21	70	0.3066
Khaudum Bdy N	285	49 - 896	27	22	0.3765
Nyae Nyae	524	29 - 1258	24	5	0.0673
Overall	1266	169 - 2524	72	97	0.0927

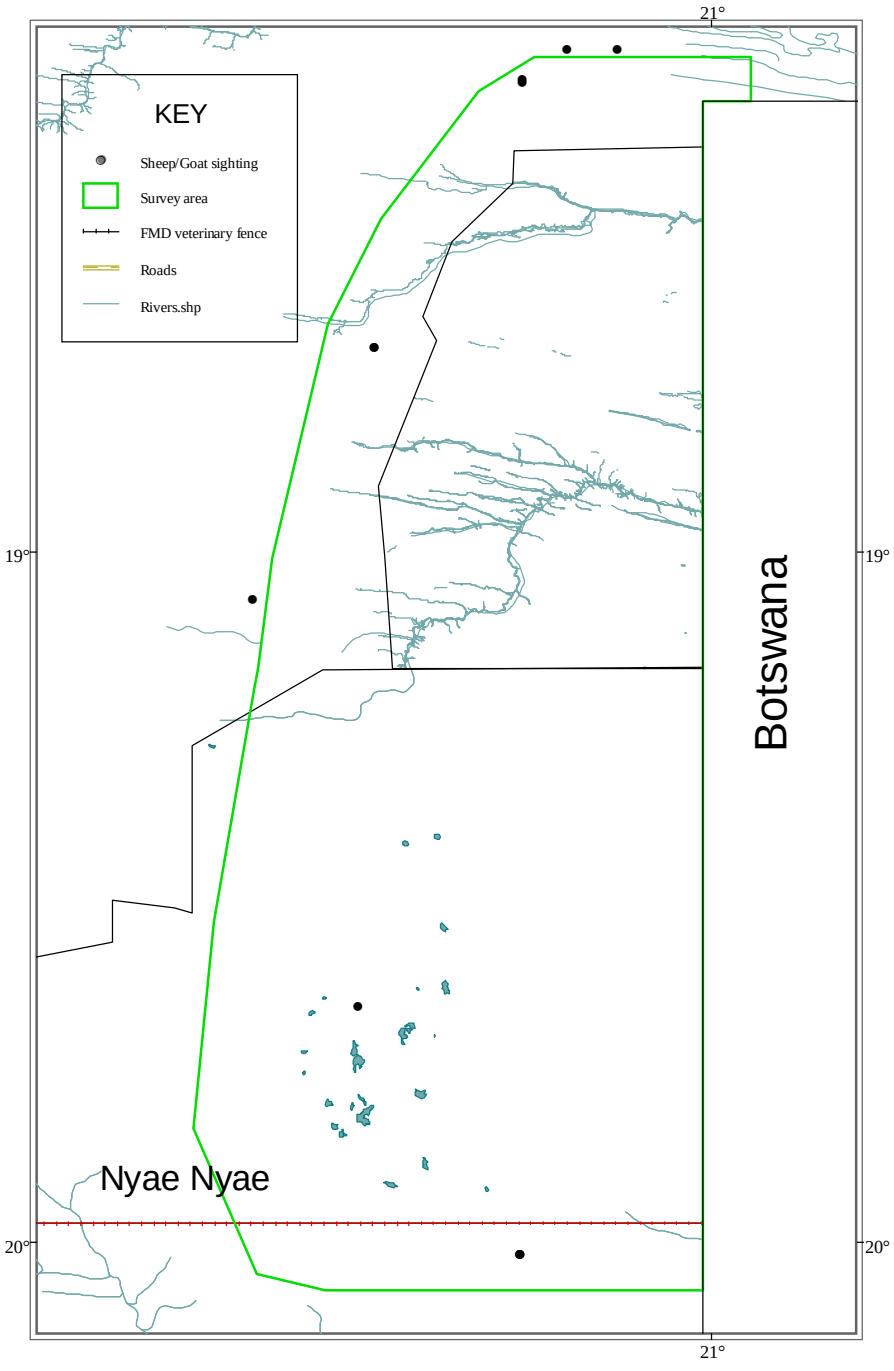


Figure 27 Sightings of sheep/goats

2.2.5. Human attributes

Table 25. Camps and water points observed

Strata	No. camps seen	No. water points seen
Khaudum NP	2	6
Khaudum NP Bdy W	0	1
Khaudum NP Bdy N	1	3
Nyae Nyae	1	8
Overall	4	18

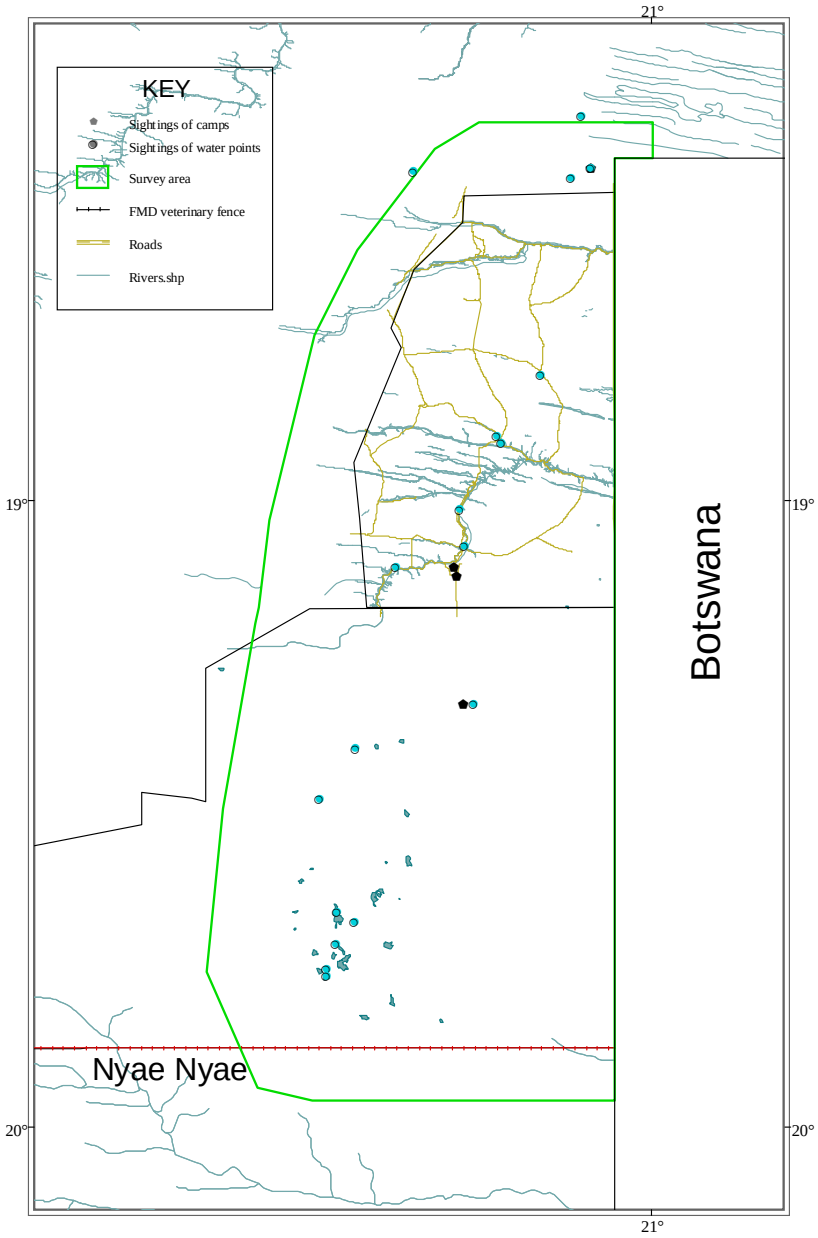


Figure 28 Camps and waterpoints

Table 26, Observations of cultivation (estimates of numbers of fields)

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP Bdy W		-		2	
Khaudum NP Bdy N	264	112 - 417	25	4	0.3486
Nyae Nyae				1	
Overall	264	131 - 397	25	7	0.0193

Table 27. Observations of habitation (estimates of numbers of villages and huts)

Strata	Pop. Est	95%Range	No. seen	No. out	No. km^{-2}
Khaudum NP Bdy W	65	6 - 162	3	3	0.0438
Khaudum NP Bdy N	63	9 - 124	6	3	0.0837
Nyae Nyae	236	51 - 421	11	14	0.0303
Overall	365	156 - 574	20	20	0.0267

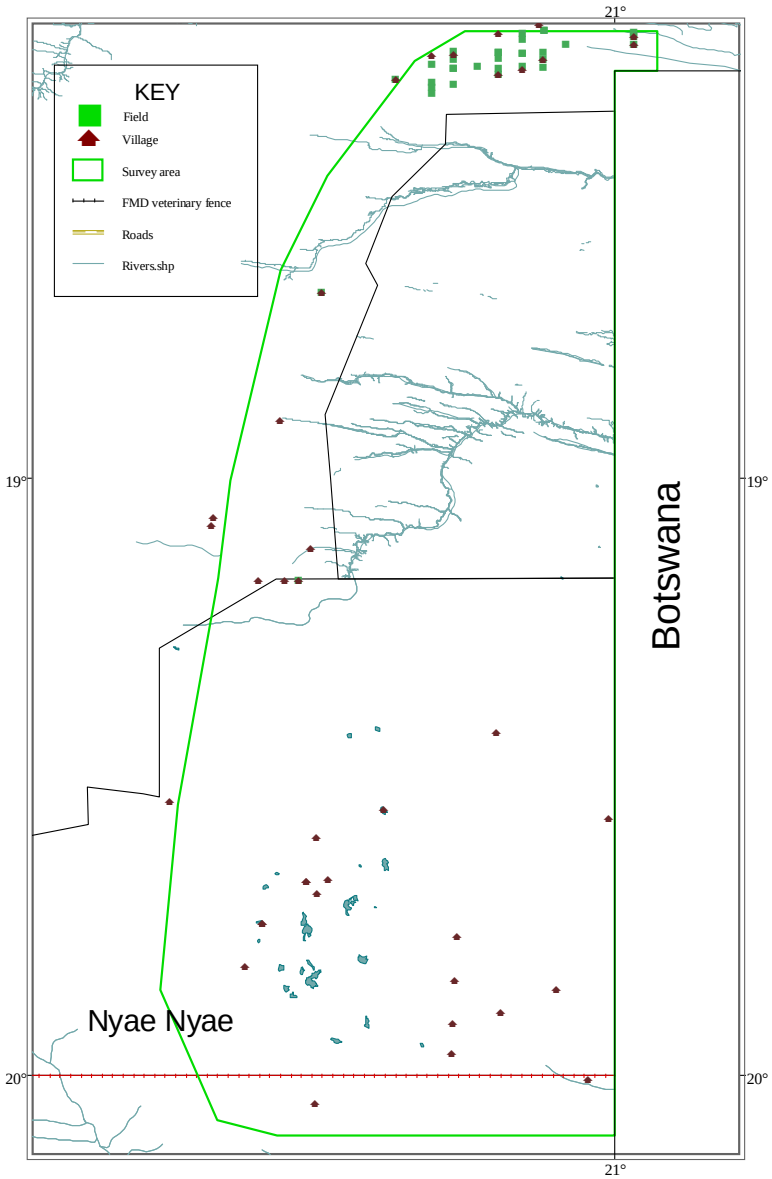


Figure 29 Villages and fields seen on the survey

3. GENERAL

3.1. Elephant Mortality

A major objective of this survey was to estimate elephant mortality with a view to detecting any increase in illegal hunting, as was found in Zambezi district (Caprivi) (Craig & Gibson 2013) which felt the effects of a recent Africa-wide upsurge in ivory poaching. There was an increase in the carcass estimates for the survey area over 2011 (107 against 62) but this is not statistically significant ($p < 0.4$). Numbers seen were very small, so precision is low and one must beware of concluding that the non - significant result implies no increase in mortality. With current precision, an increase of 159 carcasses would have been detectable; this would be equivalent to a 2.5% per annum overall death rate, which would be sustainable: an unsustainable rate of loss would have produced an increase of about 300 carcasses over two years. Therefore, even with the small numbers in the samples, any serious effect should have been detected. The confidence interval on the difference between 2011 and 2013 estimates (45 ± 112) also implies an upper limit on the annual overall mortality of 2.5%. The increase from 2011 to 2013 (45) is very significantly ($p < 0.001$) less than the 300 carcasses expected if death rates were unsustainable. Therefore, on the evidence of these surveys, mortality is well within acceptable limits. This does not tell us there is *no* illegal hunting, however, as the observed increase may be real, although statistically non-significant.

3.2. Elephant Population

The population estimate is lower than the 2011 result. The change is not significant and the deviation is what might be expected in the series of surveys since 1998. While there is no evidence of a statistically significant trend since 1998, a trend is not ruled out because small upward and downward changes would not be detectable with the prevailing precision and the limited number of surveys that have taken place. Surveys should be conducted more frequently in future and at improve sampling intensities.

The present result could still have been an underestimate as available elephant range goes beyond the boundary of the survey area, although the number outside was expected to be few, based on previous results. Counting more widely would have diluted the result in the core range with the resources available. The possibility of disturbance from the elephant capture taking place in Khaudum NP at the time of the survey has been mentioned. This could have caused some elephants to move out of the survey area. It became apparent that there were a considerable number of elephants in Botswana, across the border from Khaudum NP and that crossing was taking place. This could be a temporary movement, or the Khaudum NP elephants could be making more regular use of that range. From personal experience, there were few, if any, elephants in that part of Botswana during the 1990s, so the likelihood that those there now are part of the Khaudum NP population is high.

Distribution within Namibia is still concentrated in Khaudum NP along the southwest-northeast axis which follows the distribution of artificial waterpoints. Nyae Nyae has low numbers similar to most previous surveys, but the estimate of around 500 could be too low – even if one family group among those known to be present had been seen in the sample, this could have boosted the estimate by a few hundred.

Elephants had been reported independently in the adjacent northern conservancies, but numbers must have been low, as none were seen. Those seen in the most northern stratum were actually within Khaudum, where that stratum overlapped with the National Park.

3.3. Other species and attributes

Buffalo only occur in the fenced buffalo camp within Nyae Nyae. For such a closed population in a small area, it makes sense to perform a total count. The present survey result cannot be considered a realistic estimate. As reported above, total counts of the buffalo camp have given estimates of around 200 buffalos (Beytell & du Preez).

The other key wildlife species is roan antelope. These are shown to be very widespread over the survey area. The precision of the estimate is low and a better result would require a dedicated survey stratified for high and low density range.

Attributes of human influence (cultivation, habitation and livestock) show that this is low over most of the area, except north of Khaudum NP and south of the veterinary fence. Wildlife conservation is the dominant landuse in the surveyed area.

3.4. Accuracy of results

Although visibility was very good over most of the area, most species other than elephants will have been significantly undercounted. Even giraffe are easy to miss within the sample. An indicator of visibility is the comparison of left and right observers (Appendix II) which contrasts the results of more and less experienced observers. It is a concern that when visibility is good, too much attention is focused outside the counting strip. However, the relatively high counts of small antelope within the strip suggest that attention within the sample is adequate.

As addressed in the Caprivi survey report (Craig & Gibson 2013) accurate ground counts in at least part of the area may provide a guide to the level of undercounting in the aerial survey. Investigation of this using available ground count results would be useful.

3.5. Methodology caveats

- In the time available it was not possible to assemble the crew with most experience. This will have affected the result for the more cryptic species
- The flying time and resources available limited the extent of the surveyed area to that where most elephants had been seen on previous surveys.
- Sampling intensity was likewise limited. Higher sampling was applied where it was thought elephants should be located. For some strata, the effort was not ideal, although the overall result shows an improvement in precision.
- Strata could have been better designed in places. A medium density of elephants spills out of the southwest of Khaudum NP into the 5% sample (low density) stratum. Design should take better account of this. The northernmost stratum takes in part of Khaudum, meaning that estimates for the National Park itself are incomplete. This was done to make the northernmost stratum a reasonable size and also to limit the

flying time of the northernmost stratum of Khaudum, which is at close to the maximum range from base.

- Transects in Khadum National Park north should have been oriented north-south
- Land south of the red line (veterinary) fence was included through an oversight. This could well have been left out, although the contrast between north and south of the fence is interesting.
- The highest sampling was placed around Nyae Nyae pans, which appears to be a focus of wildlife distribution in Nyae Nyae because of the pumped water, even though the pans themselves were dry. The boundaries of this stratum could well have been extended.

4. ACKNOWLEDGEMENTS

This survey was supported by funding from WWF and by MET who provided the survey aircraft. We are very grateful to Dr R Taylor and Mr K Uiseb who were instrumental in arranging for the survey to take place.

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APPENDIX I: METHODS

Methods followed CITES aerial survey standards using Jolly's method for unequal size sampling units (Jolly, 1969). In this survey rods were used to delimit strips, rather than the streamers used for the Caprivi survey. Track logs of the transects flown are shown in Fig. 30.

a. 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:

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

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

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

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

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

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

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.

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 were sampled repeatedly, each time 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 $Y \pm t \,.\, SE$, where *t* is Student's t for a two-tailed probability of 0.05 and *n*-1 degrees of freedom.

Detectable difference, δ, is calculated from: $\delta = (t_\alpha + t_\beta) \,.\, SE_{diff}$. Where *t* is the *t* value for the probabilities of type I (α) and type II (β) errors, which are conventionally 0.05 (two-tailed) and 0.2 (one-tailed) respectively.

b. Sampling intensity

High sampling intensities were selected for the areas likely to contain large numbers of elephants and elephant carcasses, because a high precision was required for these areas. In order to achieve the 30% sampling intensity that was desired, it would be necessary to space transects 1.3 km 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 four independent surveys of the "40%" strata and three of the "20%" strata at 10% sampling intensity. 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).

c. 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 1996). 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.

d. Searching rate

The searching rate (km^2/hr) was calculated for each transect and the mean for each stratum provided as an objective indication the survey quality.

e. Maintenance of height

The target height was maintained using a radar altimeter. This instrument malfunctioned initially. After repair, it failed spasmodically during the survey. This was dealt with by flying on the pressue altimeter until the radar altimeter came back on line, usually after some seconds.
Heights were recorded every minute or more to obtain a mean height for each transect.
Mean height and its range are reported below.

f. Distribution maps

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.
For more numerous species, the density of animals in cells measuring 0.025 degrees was calculated. These 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. These vectors were converted into Word Perfect graphics format (.WPG files) and plotted using the programme Corel Presentations.

g. Other information provided

The following are provided separately to the report:

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

APPENDIX II: RESULTS

The survey crew comprised R Desmond (pilot), C. Craig (coordinator and front-seat observer), N. Chitemamuswe (left hand observer) and T. Greyling (right hand observer).

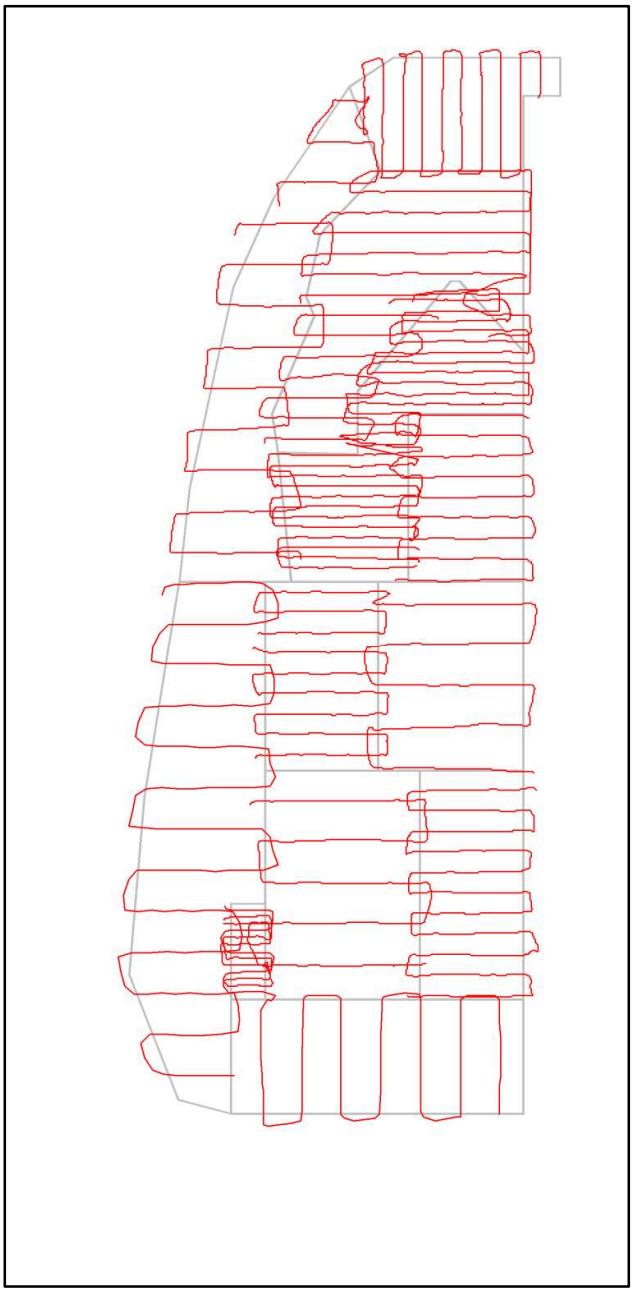

Figure 30 Track log from flight lines along transects

Supporting data indicating survey quality are given below.

a. Stratum Statistics

Stratum Name	Area	No. of Transect s	Sampling intensity %	Transect time(min)	Sample Area (km^2)	Transect length (km)	Mean Ground speed (knots)	Search Rate
KhauCA	1287.9	14	9.24	109	119.03	317.07	94.25	1.09
KhauCB	1287.9	14	8.85	120	113.96	303.54	81.96	0.95
KhauN	1562	17	9.65	140	150.77	400.90	92.78	1.08
KhauS	762.6	9	10.38	72	79.15	210.53	94.74	1.10
KhauLow1	1490.2	12	4.6	65	68.55	182.46	90.95	1.05
KhauLow2	757.5	10	9.48	62	71.77	191.58	100.11	1.16
Tsum1	1093	5	5.06	50	55.33	147.66	95.68	1.11
Tsum2	848.6	9	9.19	73	77.94	206.38	91.60	1.07
Tsum3	929.9	11	9.29	80	86.37	230.30	93.27	1.08
Tsum4	1394.8	5	4.26	52	59.42	157.04	97.85	1.14
Tsum5	1314.8	7	4.48	55	58.90	155.68	91.71	1.07
Tsum6	2083.6	13	4.73	94	98.63	263.65	90.87	1.05
Tsum7A	129.1	5	10.17	11	13.12	34.87	102.72	1.19
Tsum7B	129.1	4	8.25	11	10.65	27.90	82.18	0.97
Tsum7c	129.1	4	8.12	11	10.48	27.90	82.17	0.95
TOTAL / MEAN	15199.7	139	7.07	1005	1074.07	2857.46	92.12	1.07

b. Maintenance of height

The target height was 300ft above ground. Mean height flown was 300.2. 95% of recorded heights were within 19.4 feet of this value.

c. Calibration of strip widths

#	Height AGL(ft)	L in	L out	R in	R out	Width L	Width R	Corrected L	Corrected R	Total Width
1	280	3	22	14	28	200	150	214.29	160.71	375
2	290	12	29	5	26	180	220	186.21	227.59	413.79
3	290	8	26	10	26	190	170	196.55	175.86	372.41
4	290	11	32	6	22	220	170	227.59	175.86	403.45
5	300	10	29	9	26	200	180	200	180	380
6	280	8	25	6	21	180	160	192.86	171.43	364.29
7	300	8	26	8	25	190	180	190	180	370
8	320	9	29	8	28	210	210	196.88	196.88	393.75
9	300	10	28	7	23	190	170	190	170	360
10	300	9	27	10	28	190	190	190	190	380
11	280	6	23	8	23	180	160	192.86	171.43	364.29
12	300	7	25	10	25	190	160	190	160	350
13	300	8	26	7	21	190	150	190	150	340
14	310	9	28	9	27	200	190	193.55	183.87	377.42
15	280	6	24	8	21	190	140	203.57	150	353.57
16	300	7	24	12	32	180	210	180	210	390
17	300	8	26	8	25	190	180	190	180	370
18	305	7	24	12	29	180	180	177.05	177.05	354.1
19	310	7	24	11	31	180	210	174.19	203.23	377.42
20	290	6	23	11	30	180	200	186.21	206.9	393.1
21	310	9	27	9	25	190	170	183.87	164.52	348.39
22	290	8	27	10	28	200	190	206.9	196.55	403.45
23	320	10	29	10	29	200	200	187.5	187.5	375
24	290	8	26	10	29	190	200	196.55	206.9	403.45
									Mean	**375.54**
									Variance	**385.11**
									SE Mean	**4.01**
									%CL	**2.21**

d. Comparison of observers

	Observed		Expected				
Species	**L**	**R**	**L**	**R**	**Chi²**	**p**	
Buffalo	1	1	1.029	0.971	0.002	0.9674	
Duiker	36	6	21.607	20.393	19.747	0.00001	***
Eland	8	3	5.659	5.341	1.995	0.15785	
EleCarcass	4	3	3.601	3.399	0.091	0.76291	
ElephantBull	30	17	24.179	22.821	2.886	0.08933	
ElephantFamily	17	14	15.948	15.052	0.143	0.70532	
Giraffe	21	9	15.433	14.567	4.135	0.042	*
Hartebeest	7	1	4.116	3.884	4.164	0.0413	*
Kudu	37	12	25.208	23.792	11.361	0.00075	***
Oryx	25	25	25.722	24.278	0.042	0.83809	
Roan	21	11	16.462	15.538	2.576	0.10849	
Springbok	1	1	1.029	0.971	0.002	0.9674	
Steenbok	16	19	18.006	16.994	0.46	0.4976	
Warthog	9	10	9.774	9.226	0.126	0.72223	
Wildebeest	12	9	10.803	10.197	0.273	0.60132	
Ostrich	16	8	12.347	11.653	2.226	0.13567	
Horse	5	4	4.63	4.37	0.061	0.80508	
Donkey	4	0	2.058	1.942	3.775	0.05201	
Cattle	30	20	25.722	24.278	1.465	0.2261	
Sheep/goats	4	3	3.601	3.399	0.091	0.76291	
Overall	304	176	246.933	233.067	27.162	0.0000002	***

APPENDIX III: RESULTS BY STRATUM

Khaudum/Tsmkwe Overall

Combined Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range			Dens: No./km^2
Buffalo	63	3	1	3726.4	190.7	4	-	184	0.0042
Duiker	703	50	0	12565.9	31.5	482	-	925	0.0515
Eland	723	88	19	80514.5	77.7	161	-	1284	0.0529
EleCarcass 3	63	4	0	1262.3	111.1	4	-	134	0.0046
EleCarcass 4	44	3	0	689.7	119.2	3	-	96	0.0032
All E carcasses	107	7	0	1952	81.8	19	-	194	0.0078
ElephantBull	1063	100	166	52485.2	42.7	610	-	1517	0.0779
ElephantFamily	2575	364	860	284041.6	41	1520	-	3630	0.1886
All Elephants	3638	464	1026	336526.9	31.6	2490	-	4786	0.2664
Giraffe	698	76	83	28941.6	48.2	362	-	1035	0.0511
Hartebeest	492	44	15	107749.2	132.1	59	-	1142	0.036
Kudu	2016	153	67	160656.1	39.4	1222	-	2809	0.1476
Oryx	1331	163	49	62328.7	37.1	837	-	1825	0.0975
Roan	1800	140	70	426026.2	71.8	508	-	3091	0.1318
Springbok	44	12	24	913.4	134.9	36	-	104	0.0032
Steenbok	483	37	6	7896.1	36.4	308	-	659	0.0354
Warthog	579	51	1	30470.3	59.6	234	-	925	0.0424
Wildebeest	2247	224	309	634737.2	70.2	671	-	3824	0.1646
Ostrich	615	43	25	20098.3	45.7	334	-	895	0.045
Horse	576	27	12	39947.8	68.7	181	-	972	0.0422
Donkey	86	7	5	3428.5	135.2	12	-	202	0.0063
Cattle	7449	407	442	2199706	39.4	4514	-	10385	0.5456
Sheep/goats	1266	72	97	404035.6	99.4	169	-	2524	0.0927
Safari Camp			4						
Waterpoint			18						
Field/Cult	264	25	7	4544.7	50.5	131	-	397	0.0193
Village/Hut	365	20	20	11149.2	57.3	156	-	574	0.0267

Results of strata making up the above overall results follow:

Khaudum NP and Surrounds Area: 5860 km^2

Combined Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km^2
Duiker	335	30	0	4812.89	41.34	196 - 473	0.0571
Eland	723	88	19	80514.48	78.32	157 - 1288	0.1233
EleCarcass 3	22	1	0	461.25	196.88	1 - 65	0.0037
EleCarcass 4	10	1	0	105.62	197.68	1 - 31	0.0018
All E carcasses	32	2	0	566.87	147.81	2 - 80	0.0055
ElephantBull	558	74	122	12885.42	40.59	331 - 784	0.0952
ElephantFamily	2575	364	779	284041.6	41.28	1512 - 3638	0.4394
All Elephants	3132	438	901	296927.1	34.69	2046 - 4219	0.5345
Giraffe	677	74	75	28510.17	49.78	340 - 1013	0.1154
Hartebeest	22	4	0	401.41	184.5	4 - 62	0.0037
Kudu	869	81	34	42750.33	47.48	456 - 1281	0.1482
Oryx	850	100	41	42942.86	48.65	436 - 1263	0.145
Roan	699	81	46	41830.31	58.34	291 - 1107	0.1193
Steenbok	267	25	5	3289.31	42.82	153 - 382	0.0456
Warthog	277	31	1	6188.65	56.74	120 - 433	0.0472
Wildebeest	349	40	70	31232.73	101.06	110 - 701	0.0595
Ostrich	236	22	7	7966.37	75.32	58 - 414	0.0403
Donkey	63	6	0	2953.23	171.02	6 - 172	0.0108
Cattle	2895	201	269	1069450	71.23	833 - 4958	0.4941
Sheep/goats	742	48	92	270220.7	139.71	140 - 1779	0.1266
Safari Camp			3				
Waterpoint			10				
Field/Cult	264	25	6	4544.73	50.92	130 - 399	0.0451
Village/Hut	129	9	6	2636.28	79.6	26 - 231	0.022

"Khaudum NP and Surrounds" is made up of Khaudum NP and two strata around the boundary, Khaudum NP W Boundary and Khaudum NP N Boundary:

Khaudum NP Area: 3612 km^2

Combined Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km^2
Duiker	161	21	0	1099.71	41.29	95 - 228	0.0447
Eland	531	73	18	62333.56	94.52	91 - 1032	0.1469
EleCarcass 4	10	1	0	105.62	199.08	1 - 31	0.0029
ElephantBull	514	72	121	11040.42	41.04	303 - 725	0.1424
ElephantFamily	2575	364	754	284041.6	41.58	1504 - 3645	0.7127
All Elephants	3089	436	875	295082.1	35.32	1998 - 4180	0.8551
Giraffe	557	68	63	21366.11	52.7	264 - 851	0.1542
Hartebeest	22	4	0	401.41	185.82	4 - 62	0.006
Kudu	457	59	34	14770.86	53.41	213 - 701	0.1265
Oryx	690	87	34	29177.74	49.73	347 - 1033	0.191
Roan	657	77	41	40231.13	61.33	254 - 1060	0.1818
Steenbok	170	20	2	1822.01	50.57	84 - 255	0.0469
Warthog	233	29	0	4420.77	57.31	99 - 367	0.0645
Wildebeest	349	40	70	31232.73	101.78	110 - 704	0.0965
Ostrich	96	14	6	1735.83	87.3	20 - 180	0.0265
Camp			2				
Waterpoint			6				

Stratum Khaudum NP North Area: 1562 km² Sampling intensity: 9.6%
Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	62	6	0	241.7539	53	29 - 95	0.0398
Eland	207	20	12	8269.4	93	32 - 400	0.1328
EleCarcass 4	10	1	0	105.6189	210.1	1 - 32	0.0066
All E carcasses	10	1	0	105.6189	210.1	1 - 32	0.0066
ElephantBull	228	22	36	5369.208	68.1	73 - 383	0.146
ElephantFamily	1089	105	130	145241.3	74.2	281 - 1897	0.697
All Elephants	1317	127	166	150610.5	62.5	494 - 2140	0.8431
Giraffe	342	33	41	17374.9	81.7	74 - 622	0.2191
Kudu	124	12	18	2790.086	90	30 - 236	0.0797
Oryx	446	43	22	23765.3	73.3	119 - 773	0.2854
Roan	498	48	26	35920.05	80.7	96 - 899	0.3186
Steenbok	83	8	2	973.8743	79.8	17 - 149	0.0531
Warthog	156	15	0	3572.356	81.5	29 - 282	0.0996
Wildebeest	270	26	70	25935.27	126.6	96 - 611	0.1726
Ostrich	21	2	6	213.6847	149.4	8 - 52	0.0133

Stratum Khaudum NP Central Area: 1287.92 km²
Mean Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	61	11	0	463.2	73.1	16 - 105	0.047
Eland	265	47	2	51067.52	175.1	49 - 730	0.206
ElephantBull	267	48	85	5338.254	56.3	133 - 417	0.2072
ElephantFamily	1361	246	516	132547.7	55	762 - 2109	1.0564
All Elephants	1628	294	601	137886	46.9	895 - 2391	1.2637
Giraffe	167	30	21	3034.14	67.9	54 - 280	0.1295
Hartebeest	22	4	0	401.414	190.2	4 - 63	0.0168
Kudu	169	30	6	7405.939	104.9	36 - 346	0.131
Oryx	244	44	10	5412.44	62	93 - 395	0.1895
Roan	159	29	15	4311.074	84.8	44 - 294	0.1236
Steenbok	38	7	0	262.9014	86.8	7 - 72	0.0298
Warthog	77	14	0	848.4166	77.3	18 - 137	0.0602
Wildebeest	79	14	0	5297.462	189	14 - 229	0.0615
Ostrich	56	10	0	1189.848	127	10 - 127	0.0433
Camp			2				
Waterpoint			6				

The above estimates for Khaudum NP Central are the means of two results as follows:

Khaudum NP Central A Area: 1288 km² Sampling intensity: 9.2 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	76	7	0	1326.16	103.8	7 - 154	0.0589
Eland	22	2	2	423.5758	205.3	4 - 66	0.0168
ElephantBull	206	19	49	3924.242	65.8	70 - 341	0.1597
ElephantFamily	1375	127	219	303132	86.5	346 - 2565	1.0678
All Elephants	1581	146	268	307056.2	75.7	414 - 2778	1.2275
Giraffe	130	12	14	4922.762	116.6	26 - 282	0.1009
Hartebeest	43	4	0	1605.656	199.9	4 - 130	0.0336
Kudu	43	4	2	1706.051	206	6 - 133	0.0336
Oryx	217	20	6	7548.707	86.7	29 - 404	0.1682
Roan	217	20	14	11868.05	108.7	34 - 452	0.1682
Steenbok	54	5	0	845.1022	116	5 - 117	0.042
Warthog	76	7	0	1477.529	109.6	7 - 159	0.0589
Ostrich	32	3	0	479.5838	145.6	3 - 80	0.0252
Camp			1				
Waterpoint			1				

Khaudum NP Central B Area: 1288 km² Sampling intensity: 8.8 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	45	4	0	526.6364	109.6	4 - 95	0.0351
Eland	509	45	0	203846.5	191.6	45 - 1484	0.3952
ElephantBull	328	29	36	17428.78	87	65 - 613	0.2547
ElephantFamily	1346	119	297	227058.9	76.5	416 - 2375	1.0451
All Elephants	1674	148	333	244487.6	63.8	606 - 2742	1.2998
Giraffe	204	18	7	7213.798	90.1	25 - 387	0.1581
Kudu	294	26	4	27917.71	122.7	30 - 655	0.2283
Oryx	271	24	4	14101.05	94.5	28 - 528	0.2108
Roan	102	9	1	5376.243	155.6	10 - 260	0.079
Steenbok	23	2	0	206.5033	137.2	2 - 54	0.0176
Warthog	79	7	0	1916.138	119.4	7 - 174	0.0615
Wildebeest	158	14	0	21189.85	198.6	14 - 473	0.123
Ostrich	79	7	0	4279.807	178.5	7 - 221	0.0615
Safari Camp			1				
Waterpoint			5				

Stratum Khaudum NP South Area: 763 km² Sampling intensity: 10.4 %
Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	39	4	0	394.7556	118.8	4 - 84	0.0506
Eland	58	6	4	2996.644	218.2	10 - 184	0.0759
ElephantBull	19	2	0	332.9604	218.2	2 - 61	0.0253
ElephantFamily	125	13	108	6252.596	145.5	121 - 308	0.1644
All Elephants	145	15	108	6585.557	129.4	123 - 332	0.1897
Giraffe	48	5	1	957.069	148	6 - 120	0.0632
Kudu	164	17	10	4574.832	95.1	27 - 320	0.215
Oryx			2				
Steenbok	48	5	0	585.2333	115.7	5 - 104	0.0632
Ostrich	19	2	0	332.2943	218	2 - 61	0.0253

Stratum Khaudum NP W Boundary Area: 1490 km² Sampling intensity: 4.6 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	152	7	0	3542.97	86	21 - 283	0.1022
Eland	65	3	1	4020.99	213.8	4 - 205	0.0438
EleCarcass 3	22	1	0	461.25	217.3	1 - 69	0.0146
ElephantBull	44	2	1	1845.00	217.3	3 - 138	0.0292
ElephantFamily			8				
All Elephants	44	2	9	1845.00	217.3	11 - 138	0.0292
Giraffe	109	5	10	7045.25	169.8	15 - 294	0.073
Kudu	348	16	0	26901.29	103.7	16 - 709	0.2336
Oryx	44	2	7	1831.23	216.5	9 - 138	0.0292
Roan			3				
Steenbok	87	4	1	1368.67	93.6	6 - 168	0.0584
Warthog	44	2	1	1767.88	212.7	3 - 136	0.0292
Ostrich	109	5	1	5185.76	145.7	6 - 267	0.073
Cattle	1501	69	86	659843	119.1	155 - 3289	1.0074
Sheep/goats	457	21	70	197358	214	91 - 1435	0.3066
Waterpoint			1				
Field/Cult			2				
Village/Hut	65	3	3	1926.05	148	6 - 162	0.0438

Stratum Khaudum NP N Boundary Area: 757 km² Sampling intensity: 9.5 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km^2
Duiker	21	2	0	170.2085	139.7	2 - 51	0.0279
Eland	127	12	0	14159.92	212.4	12 - 396	0.1673
ElephantFamily			17				
Giraffe	11	1	2	98.80174	212.9	3 - 33	0.0139
Kudu	63	6	0	1078.182	117.2	6 - 138	0.0837
Oryx	116	11	0	11933.89	212.7	11 - 363	0.1534
Roan	42	4	2	1599.181	214.1	6 - 133	0.0558
Steenbok	11	1	2	98.62719	212.7	3 - 33	0.0139
Ostrich	32	3	0	1044.786	230.8	3 - 105	0.0418
Donkey	63	6	0	2953.229	194	6 - 186	0.0837
Cattle	1394	132	183	409607.5	103.8	315 - 2842	1.8407
Sheep/goats	285	27	22	72862.67	214.1	49 - 896	0.3765
Safari Camp			1				
Waterpoint			3				
Field/Cult	264	25	4	4544.731	57.8	112 - 417	0.3486
Village/Hut	63	6	3	710.224	95.1	9 - 124	0.0837

Nyae Nyae Overall Area: 7794 km²

Combined Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Buffalo	63	3	1	3726.43	190.71	4 - 184	0.0081
Duiker	369	20	0	7752.99	47.87	192 - 545	0.0473
EleCarcass 3	42	3	0	801.05	136.53	3 - 98	0.0053
EleCarcass 4	33	2	0	584.11	145.79	2 - 82	0.0043
All E carcasses	75	5	0	1385.16	99.76	5 - 149	0.0096
ElephantBull	505	26	44	39599.78	78.94	106 - 904	0.0648
ElephantFamily			81				
All Elephants	505	26	125	39599.78	78.94	151 - 904	0.0648
Giraffe	22	2	8	431.41	191.09	10 - 63	0.0028
Hartebeest	470	40	15	107347.8	139.69	55 - 1127	0.0603
Kudu	1147	72	33	117905.8	60.01	459 - 1836	0.1472
Oryx	482	63	8	19385.85	57.95	203 - 760	0.0618
Roan	1100	59	24	384195.8	112.93	83 - 2343	0.1412
Springbok	44	12	24	913.43	136.67	36 - 105	0.0057
Steenbok	216	12	1	4606.77	62.92	80 - 352	0.0278
Warthog	303	20	0	24281.66	103.14	20 - 615	0.0389
Wildebeest	1899	184	239	603504.5	82.03	423 - 3456	0.2436
Hyeana Br			1				
Ostrich	378	21	18	12131.98	58.39	157 - 599	0.0485
Horse	576	27	12	39947.77	69.54	176 - 977	0.0739
Donkey	22	1	5	475.25	195.66	6 - 66	0.0029
Cattle	4554	206	173	1130255	46.81	2422 - 6685	0.5843
Sheep/goats	524	24	5	133814.9	139.92	29 - 1258	0.0673
Safari Camp			1				
Waterpoint			8				
Fenceline			5				
Field/Cult			1				
Village/Hut	236	11	14	8512.92	78.39	51 - 421	0.0303

Nyae Nyae is made up of the following strata (Nyae Nyae 1,2,3,4,5,6 and 7):

Stratum Nyae Nyae 1 Area: 1093 km² Sampling intensity: 5.1 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	138	7	0	3345.83	116.1	7 - 299	0.1266
EleCarcass 3	20	1	0	371.92	270.8	1 - 73	0.0181
ElephantBull	40	2	0	1487.68	270.8	2 - 147	0.0362
Kudu	138	7	9	7974.18	179.2	16 - 386	0.1266
Oryx	40	2	0	1483.2	270.4	2 - 146	0.0362
Roan	59	3	0	3337.37	270.4	3 - 220	0.0543
Steenbok	99	5	1	2784.39	148.2	6 - 245	0.0904
Wildebeest	652	33	16	403821.9	270.4	49 - 2417	0.5969
Ostrich			2				
Safari Camp			1				
Waterpoint			1				
Village/Hut	20	1	0	371.92	270.8	1 - 73	0.0181

Stratum Nyae Nyae 2 Area: 849 km² Sampling intensity: 9.2 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	22	2	0	188.836	145.4	2 - 53	0.0257
EleCarcass 3	22	2	0	429.1304	219.2	2 - 70	0.0257
EleCarcass 4	11	1	0	108.1019	220	1 - 35	0.0128
All E carcasses	33	3	0	537.2323	163.5	3 - 86	0.0385
ElephantBull			5				
Giraffe	22	2	5	431.4095	219.8	7 - 70	0.0257
Kudu	76	7	10	1890.814	131.5	17 - 177	0.0899
Oryx	196	18	2	4372.608	77.7	44 - 349	0.2311
Steenbok	11	1	0	107.2826	219.2	1 - 35	0.0128
Wildebeest	381	35	63	90181.99	181.6	98 - 1074	0.4494
Ostrich			2				
Waterpoint			1				

Stratum Nyae Nyae 3 Area: 930 km² Sampling intensity: 9.3 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	32	3	0	485.2733	151.8	3 - 81	0.0348
ElephantBull			3				
Hartebeest	32	3	0	947.6851	212.2	3 - 101	0.0348
Kudu	151	14	2	3719.228	90.1	16 - 287	0.1622
Oryx	151	14	2	5367.012	108.2	16 - 314	0.1622
Roan	151	14	14	5604.493	110.6	28 - 318	0.1622
Steenbok	11	1	0	105.3325	212.2	1 - 34	0.0116
Warthog	86	8	0	1420.559	97.4	8 - 170	0.0927
Wildebeest	11	1	45	105.2109	212.1	46 - 34	0.0116
Hyeana Br			1				
Ostrich	43	4	0	990.2484	162.7	4 - 113	0.0463
Horse	22	2	3	420.8436	212.1	5 - 67	0.0232
Cattle			25				
Village/Hut			3				

Stratum Nyae Nyae 4 Area: 1395 km² Sampling intensity: 4.3 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	47	2	0	789.09	166	2 - 125	0.0337
ElephantBull	282	12	2	29972.76	170.5	14 - 763	0.2021
ElephantFamily			6				
All Elephants	282	12	8	29972.76	170.5	20 - 763	0.2021
Hartebeest	329	14	8	103928.5	272.2	22 - 1224	0.2358
Kudu	399	17	0	84238.74	201.8	17 - 1205	0.2863
Roan	23	1	1	528.05	271.6	2 - 87	0.0168
Steenbok	47	2	0	795.7	166.7	2 - 125	0.0337
Warthog	141	6	0	18917.86	270.9	6 - 523	0.1011
Wildebeest	423	18	85	40552.54	132.2	103 - 982	0.3032
Ostrich	47	2	1	2114.1	271.7	3 - 175	0.0337
Horse	94	4	0	8456.4	271.7	4 - 349	0.0674
Cattle	0	0	51	0	0	51 - 0	0
Village/Hut	0	0	4	0	0	4 - 0	0

Stratum Nyae Nyae 5 Area: 1315 km² Sampling intensity: 4.5 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Duiker	45	2	0	792.79	154.2	2 - 114	0.034
EleCarcass 4	22	1	0	476	239	1 - 76	0.017
All E carcasses	22	1	0	476	239	1 - 76	0.017
ElephantBull	0	0	5	0	0	5 - 0	0
All Elephants	0	0	5	0	0	5 - 0	0
Kudu	89	4	0	4292.33	179.4	4 - 250	0.068
Steenbok	45	2	0	798.51	154.8	2 - 114	0.034
Ostrich	112	5	3	5215.84	158.2	8 - 288	0.085
Horse	313	14	9	10120.5	78.7	67 - 559	0.2379
Donkey	22	1	5	475.25	238.8	6 - 76	0.017
Cattle	3708	166	87	754811.2	57.3	1582 - 5834	2.8204
Sheep/goats	313	14	5	93149.59	238.8	19 - 1060	0.2379
Fenceline	0	0	5	0	0	5 - 0	0
Village/Hut	89	4	1	4274.54	179	5 - 249	0.068

Stratum Nyae Nyae 6 Area: 2084 km² Sampling intensity: 4.7 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
Buffalo	63	3	1	3726.43	210	4 - 196	0.0304
Duiker	85	4	0	2151.17	119.5	4 - 186	0.0406
ElephantBull	169	8	23	8079.98	115.8	31 - 365	0.0812
ElephantFamily			33				
All Elephants	169	8	56	8079.98	115.8	64 - 365	0.0812
Giraffe			3				
Hartebeest	21	1	0	430.57	213.8	1 - 66	0.0101
Kudu	254	12	8	15163.39	105.8	20 - 522	0.1218
Roan	867	41	9	374725.9	153.9	50 - 2201	0.416
Warthog	63	3	0	3806.31	211.9	3 - 198	0.0304
Wildebeest	63	3	0	3875.17	213.8	3 - 199	0.0304
Ostrich	169	8	0	3786.98	79.3	35 - 303	0.0812
Horse	148	7	0	20950.03	213.1	7 - 463	0.071
Cattle	846	40	10	375444.1	157.9	50 - 2181	0.4059
Sheep/goats	211	10	0	40665.34	207.8	10 - 651	0.1015
Waterpoint			1				
Field/Cult			1				
Village/Hut	127	6	6	3866.46	106.8	12 - 262	0.0609

Stratum Nyae Nyae 7 Area: 129 km²

Mean Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
ElephantBull	15	4	6	59.36	116.2	10 - 32	0.1145
ElephantFamily			42				
All Elephants	15	4	48	59.36	116.2	52 - 52	0.1145
Hartebeest	88	22	7	2041.06	114.5	29 - 189	0.681
Kudu	39	11	4	627.13	142.3	15 - 95	0.3038
Oryx	95	29	4	8163.03	211.5	33 - 296	0.7374
Springbok	44	12	24	913.43	151.9	36 - 112	0.3435
Steenbok	4	1	0	15.55	213.9	1 - 13	0.0318
Warthog	12	3	0	136.93	211.6	3 - 38	0.0955
Wildebeest	368	94	30	64967.77	154.4	124 - 936	2.8508
Ostrich	7	2	10	24.81	151.5	12 - 18	0.0568
Waterpoint			5				

The above result for Nyae Nyae 7 is the mean of the following three samples (7A, 7B, and 7C):

Nyae Nyae 7A Area: 129 km² Sampling intensity: 10.2 %

Estimates:

SPECIES	*Pop. est.*	*No. seen*	*No. out*	*Variance*	*PRP %*	*95%Range*	*Dens: No./km²*
ElephantBull	*20*	*2*	*3*	*345.12*	*261.9*	*5 - 71*	*0.1526*
ElephantFamily			*42*				
All Elephants	*20*	*2*	*45*	*345.12*	*261.9*	*47 - 71*	*0.1526*
Hartebeest	*30*	*3*	*5*	*355.83*	*177.3*	*8 - 82*	*0.2289*
Kudu	*69*	*7*	*2*	*4280.5*	*263.6*	*9 - 251*	*0.534*
Oryx	*286*	*29*	*2*	*73467.31*	*263.6*	*31 - 1038*	*2.2122*
Springbok	*59*	*6*	*0*	*3181.1*	*265.1*	*6 - 216*	*0.4577*
Wildebeest	*217*	*22*	*11*	*29800.53*	*221.3*	*33 - 696*	*1.6782*
Ostrich	*10*	*1*	*7*	*87.36*	*263.6*	*8 - 36*	*0.0763*
Waterpoint			*2*				

Nyae Nyae 7B Area: 129 km² Sampling intensity: 8.2 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
ElephantBull			3				
Hartebeest			2				
Kudu	36	3	2	1223.71	305.9	5 - 148	0.2819
Springbok			20				
Ostrich	12	1	0	135.97	305.9	1 - 49	0.094
Waterpoint			2				

Stratum Tsum7C Area: 129 km² Sampling intensity: 8.1 %

Estimates:

SPECIES	Pop. est.	No. seen	No. out	Variance	PRP %	95%Range	Dens: No./km²
ElephantBull	25	2	0	189.11	177.6	2 - 68	0.191
Hartebeest	234	19	0	18013.71	182.4	19 - 661	1.814
Kudu	12	1	0	139.99	305.6	1 - 50	0.0955
Oryx			2				
Springbok	74	6	4	5039.78	305.6	10 - 300	0.5729
Steenbok	12	1	0	139.99	305.6	1 - 50	0.0955
Warthog	37	3	0	1232.37	302.2	3 - 149	0.2864
Wildebeest	887	72	19	554909.5	267.2	91 - 3258	6.8743
Ostrich			3				
Waterpoint			1				