Aerial Survey of Elephants and other Large Herbivores in Chewore Safari Area, Zambezi Valley: 2010

P.T. Kuvawoga & E. Gandiwa

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Cnr. Borrowdale Rd/ Sandringham Drive
P. O. Box CY 140 Causeway
Harare
Zimbabwe

CITES MIKE Program
MIKE Sub regional Office
Johannesburg
South Africa

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Monitoring the illegal killing of elephants

SUMMARY

The Monitoring of the Illegal Killing of Elephants (MIKE) programme, in partnership with the Zimbabwe Parks and Wildlife Management Authority, carried out an aerial survey of elephants and other large herbivores in Chewore Safari Area, Zimbabwe, from 26-29 July 2010 (block counts) and 25-26 August 2010 (transect survey). The area surveyed totaled 3401 km^2 and included Chewore North and South. The overall search effort for block and transect counts was 1.24 minutes/km^2 and sampling intensity was 17.35%.

The primary objective of the survey was to estimate elephant numbers. Other large herbivores are not easily visible from the air and their numbers were probably underestimated. However, population estimates are given for such species, since they provide a useful measure of abundance that can be used to map spatial distribution and temporal trends in population number.

The estimated populations of elephants are 5048 (95% confidence interval (CI) 22%, with Lower Confidence Limit (CL) of 3928 and Upper CL of 6168), buffalo 2275 (CI 94%), zebra 158 (CI 80%), impala 1097 (CI 61%), kudu 75 (CI 75%), warthog 165 (CI 66%), bushbuck 66 (CI 86%) and waterbuck 83 (CI 116%).

The estimated number of elephant carcasses of all age categories was 117, giving a carcass "ratio" of 2.3%. This is slightly greater than the carcass ratio of 1.14% (66 carcasses) during 2001.

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INTRODUCTION

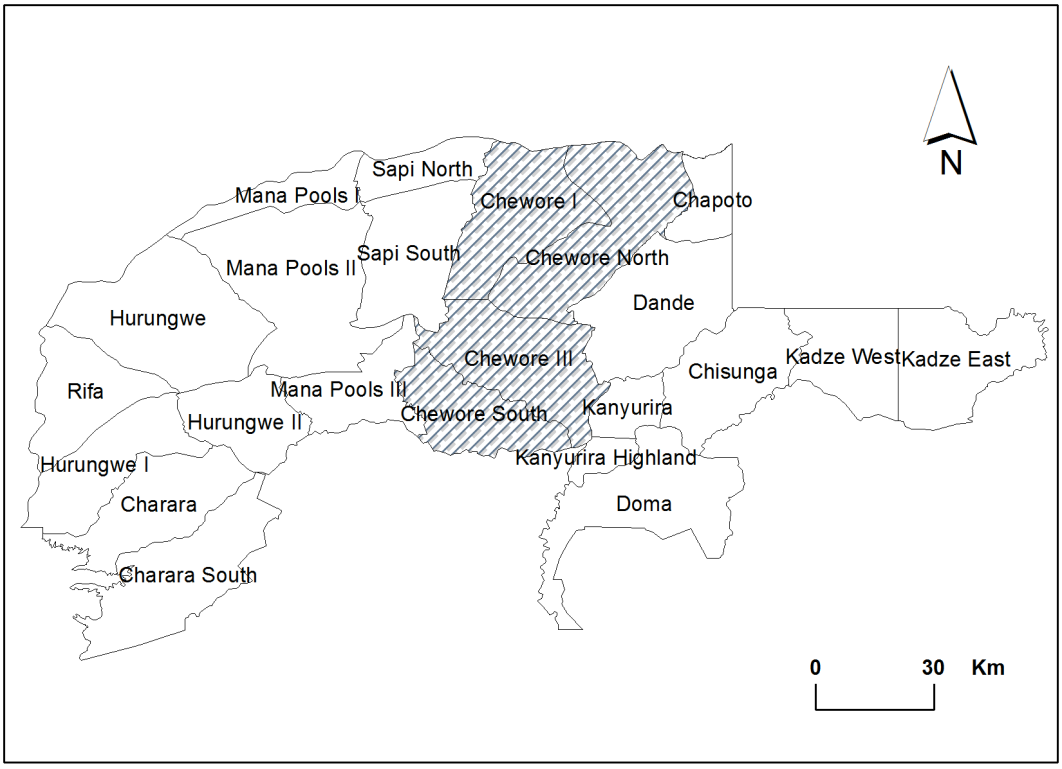
The Chewore Safari Area, Zimbabwe, aerial surveys were done in pursuit of MIKE support to parties that do not have the capacity to conduct surveys on their own for MIKE sites and to build capacity of resident ecologists. Aerial surveys are used to determine trends, spatial distribution and social organization of large herbivore populations (Joubert, 1983). The survey used MIKE standards and made reference to previous survey standards which conform to MIKE standards. This method and standards has been in practice since the mid-1970s and has been successfully applied in extensive conservation areas throughout southern Africa. Aerial surveys of the large herbivores in the Chewore Safari Area have been conducted since the 1980s.

The purpose of the current survey was to estimate the numbers of large herbivores, particularly elephants, in Chewore Safari Area at the end of the 2010 dry season. The methods used during this survey were similar to those used during previous surveys of the wildlife populations of the Chewore Safari Area. The principal objective of the survey was to provide relatively precise and accurate estimates of the number of elephants and other large herbivores in the survey area as a whole, using a technique that could be executed within a reasonable time and at a reasonable cost. Secondary objectives included determination of the spatial distributions of elephants and other large herbivores; and estimation of the number and spatial distribution of elephant carcasses. The methods used were suitable for meeting the survey objectives, repeatable and technically robust. The survey was conducted during July (block counts) and August (transects) in 2010. The escarpment was surveyed early in the dry season and the valley floor later. Many parts of the valley floor have *Colophospermum mopane* woodlands on clay soils, which hold their leaf well into the dry season and the major part of the region was therefore surveyed in August.

METHODS

Survey Area

The study covered 3401 km^2 within the Chewore Safari Area in the Zambezi Valley, Zimbabwe and was divided into four strata (Map 1, Table 1). The survey covered the same area as surveyed during 2003 (Dunham, 2004). The survey was done only for the MIKE site, to include strata Chewore 1 (I), Chewore 3 (III), Chewore II (North) and Chewore IV (South).



Map 1: Strata for the 2010 survey of Chewore Safari Area (MIKE site)

Survey Design

The procedures used followed those well established for aerial surveys of large African herbivores and livestock (Norton-Griffiths, 1978) and utilized during earlier surveys of large herbivores in Zimbabwe. Co-ordinates of previous survey boundaries were not changed and therefore strata boundaries are the same as those used during previous surveys. The survey area was divided into four strata, two for transect and two for block counts. Systematic transects were positioned across the valley-floor strata. Transects were arranged at right angles to the principal environmental feature within a stratum and transect orientation was similar to that used for previous surveys (Table 1 for transect orientation). The distance

between transects was calculated using Gibson's (1992) formula. Elephant density in each stratum was predicted from the results of the two preceding surveys in order to account for the sometimes large variations in density (see Table 1 for transect spacing).

Overall sampling intensity in this area was planned to be 15%, with a transect width (i.e. combined width of the two search strips) of 300 m. The planned sampling intensity in each stratum was determined by using the mean of the elephant densities in each stratum during previous surveys (Mackie, 2001; Dunham, 2004) as the predicted elephant densities in equation 1 of Gibson (1992). As a consequence, both strata were expected to contain high densities of elephants. In practice, the transect spacing was 2 km.

The survey was designed using WWF-SARPO's custom software (AIRDESW, version dated 29/05/97). Given a stratum boundary in the form of an ATLAS GIS bna format file, and the transect orientation and spacing, this software generates flight lines (the transects), with the first flight line offset from the end of the stratum by an entered random number. The start and end points for each transect (Appendices 1 and 2) were transferred as waypoints to a Global Positioning System (GPS) receiver in the plane prior to flying each stratum.

Block counts were used for the hilly strata of Chewore hills and Chewore Escarpment, where safe flying at low altitude was considered dangerous. Strata boundaries were the same as those used in the previous survey. The probability of a block being selected was proportional to its area; if selected twice, it was flown once, but included twice in the analysis.

Table 1: Sampling statistics for the 2010 aerial survey of large herbivores in Chewore Safari Area

Stratum name	Stratum area (km^2)	Transect spacing (km)	Transect orientation (degrees)	Number of transects per blocks (n)	Date and time sampled	Percent of stratum sampled	Flying time (hours)	Search effort (minutes per km^2)
Chewore 1	840	2	90	20	Am 25 & 26 Aug	15.5	1.55	1.3
Chewore 3	897	2	90	18	Am 26 Aug	13.7	1.37	0.89
Chewore North	1054			17	Am & pm 26&27 July	22	5.77	1.49
Chewore South	610			13	Am & pm 28 & 29 July	18.2	2.35	1.27

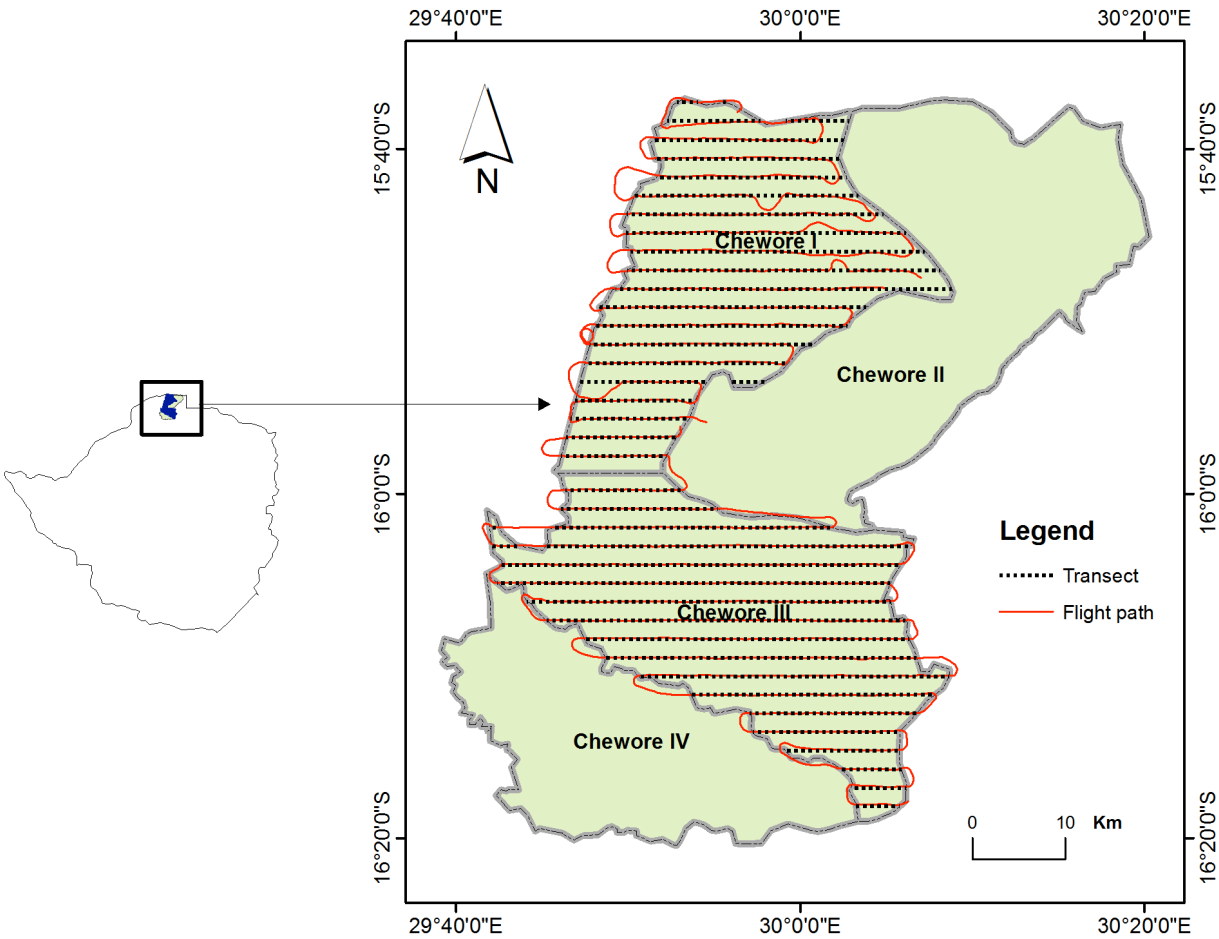
Flight Procedure

Transect counts

All strata were surveyed during the period 25 to 26 August 2010 (Table 1; Map 2). The aircraft used was a Cessna 206 registration number N206CE, the same aircraft used during other surveys of the region. It was fitted with a radar altimeter and a GPS navigator. During surveys, the aircraft was flown at an average speed of 187.82 km per hour at about 300 feet above ground level. The actual height was recorded from the radar altimeter every 30 seconds while flying along flight paths or transects. Navigation along transects was undertaken by the pilot, using a GPS navigator and a course deviation indicator mounted in the aircraft's instrument panel. The aircraft crew included a pilot Conrad, a recorder Greg Nyaguse seated next to the pilot, and two observers David Chipesi and Charles Gava who sat behind the pilot and recorder. The crew could talk to one another through headsets and an intercom. All animals seen by the observers within the search strips (see section *Strip Width and Calibration* below) were called to the recorder, who wrote down the species, the number of individuals of the group that were within the strip, and the GPS location against the time (to the nearest 30 seconds) after the start of the transect. Locations were recorded as waypoints using a Garmin Etrex GPS receiver. During the survey, the actual height of the plane above ground level (agl) was recorded by the recorder, from the radar altimeter, every 30 seconds (of time) while flying along the transects. Later the mean height above ground level for each transect was calculated. The recorder used a cell phone to record time.

Survey crew

Name	Designation	Previous Experience	Year
Conrad	Pilot	Survey: Niassa Mozambique	2010
Chipesi David	Observer	Observer for all surveys in Zimbabwe and Mozambique	1993, 2001, 2006, 2007
Gava Charles	Observer	Aerial survey training: By Kevin Dunham, Kariba, 2008	2008
Nyaguse Gregory	Recorder and Observer	Observer for most survey	2007



Map 2: Survey transects and flight paths for the 2010 survey of Chewore Safari Area (MIKE site)

Block counts

The block count strata were flown between the dates 27 to 30 July 2010. For the block counts, a different technique was used. Blocks for census were defined on 1:50,000 scale maps using features which were navigable from the air. Blocks to be counted were drawn by using random numbers as map co-ordinates. Consequently, the probability of a block being selected for survey was proportional to its area (Caughley 1977). After navigating directly to a grid reference point, which marked a distinctive point in the block, pilot Collin Taylor and one observer David Chipesi in a Piper Super Cub aircraft searched the block until all animals within it were seen or they had spent approximately 1 minute/km^2 searching the block.

Observations

As during previous surveys of this region, the observers were instructed to search for elephants but to count also other wild large herbivores and domestic livestock (cattle, goats, sheep and donkeys). Sheep and goats are not readily distinguished during aerial surveys and so both were recorded as 'shoats'. If any animal group was too large for all the individuals within it to be counted, group size was estimated by the observer. Groups of elephant bulls were differentiated from elephant cow herds (i.e. herds containing calves), although the latter may have included some bulls. The observers were instructed to note any carcasses seen. All elephant carcasses noted were classified using four age categories as follows:

Carcass Category	Definition
1	**Fresh** Carcass still had flesh, giving the body a rounded appearance. Vultures were probably present and the ground was still moist from body fluids. (Likely to have died within the past month).
2	**Recent** Rot patch and skin still present. Skeleton not scattered. (Likely to have died within the past year).
3	**Old** Clean bones; skin usually absent; vegetation regrown in rot patch. (Likely to have died more than 1 year ago).
4	**Very Old** Bones scattered and turning grey. (Likely to have died within the last 10 years).

These carcass categories are those used by Douglas-Hamilton & Hillman (1981) and now recommended by MIKE for elephant surveys (Craig undated). MIKE is a CITES programme that uses aerial and ground surveys of elephant populations, and data collected by law-enforcement patrols, to monitor the illegal killing of elephants at representative sites across Africa and Asia. Carcasses that could not be identified as elephant carcasses were recorded as 'unknown carcasses'. Ground hornbills are large and conspicuous birds and any seen were counted. This species has been counted since 1997, at the request of the then Department of National Parks and Wildlife Management (DNPWLM) (now Zimbabwe Parks and Wildlife Management Authority), as a possible indicator of environmental change (Mackie, 1998). Poachers' camps were identified by the presence of a relatively large and rectangular pattern of fire ash (suggesting that the fire was used to dry meat or fish and that it was not simply a camp fire). Human activities and infrastructure in the study area were also recorded.

Hippos and crocodiles were counted but because their whole habitat was not surveyed, the "estimates" of these species serve only as indices of abundance rather than estimates of population size.

Strip width and calibration

Two fishing rods were attached with custom brackets to each wing strut of the aircraft, so that the rods pointed backwards and parallel to the ground during level flight. The distance between the rods on each strut was arranged so that, when the aircraft was flying at 300 feet a.g.l., this distance represented a strip about 150 m wide on the ground (Dunham *et al*., 2010). Each outer rod was marked with a small piece of tape to provide the observers with a "decision point" (it was at this point that the observer decided whether an animal was inside his search strip). When deciding whether animals were inside or outside the strip, the observer moved his eye so as to align the tape on the outer rod with a small piece of tape on his window, thereby ensuring that all his decisions were made at the same viewing angle. Prior to the survey, the strip widths were calibrated by flying the aircraft at right angles across an airstrip that had two sets of large-sized numbers (from 0 to 35) arranged at 10-meter intervals along the side of the airstrip. The numbers were arranged as 35 34 33….2 1 0 1 2…..33 34 35, with 0 near the centre of the airstrip. Each observer noted the largest and smallest number within his strip and the recorder noted the aircraft's height above ground level, as recorded by the radar altimeter. For each flight passing over the calibration numbers, the combined strip width (in meters) was adjusted to 300 feet above ground level as follows:

$$\text{Combined strip width at 300 feet} = \frac{\text{Actual combined strip width x 300}}{\text{Actual flying height}}$$

The combined strip widths, after adjustment to 300 feet above ground level, were then averaged to give the nominal (calibrated) combined strip width at 300 feet. This was 270 m (Appendix 6).

Data Validation

Data validation was done to check for errors, and outliers before data analysis. The following parameters were looked at: flying height above ground (m), strip width, ground speed, and search intensity and observer performance. The statistical analysis showed that both heights above ground (agl) and strip width was well controlled (ref Annex 11 and 12). Map overlay showing transects lines and actual fly paths indicate that the pilot navigated along the transects, however the cross track error was not recorded or calculated for this survey (Ref Map 2). A detailed analysis of observer performance was done (Ref Annex 10).

Data Analysis

Population estimates and confidence intervals for individual strata were calculated with WWF's custom software (AIRSURVW, version dated 22/05/97), which uses Jolly's (1969) method 2 for unequal-sized sample units. Given the combined strip width when the plane was flying at 300 feet, and the mean height for each transect, the software determined the actual combined strip width for each transect. The area of each transect was calculated as the product of the actual combined strip width and the transect length (provided by AIRDESW). Search intensity (in minutes km^{-2}) for a stratum was defined as the total time spent flying all transects within that stratum, divided by the total area of those same transects. The greater the search intensity, the less the probability that observers will not observe animals that are within the strips.

Transects near the boundary of a stratum were often broken into two or more sections, with land outside the stratum between the sections. For the purposes of this analysis, data for all sections of the same transect were combined and entered into the program as one transect. This represents the most realistic approach to the calculation of *n* (the number of sampling

units) and the confidence interval. The value of Student's *t* entered in the program to calculate the confidence interval was t_{n-1} for $P = 0.05$ (Rohlf & Sokal 1981).

Block counts were analyzed using Jolly's method 3 in which the probability of block selection was proportional to size, with large blocks have a greater chance of selection than smaller ones (Caughley 1977).

Population estimates for the entire study area were calculated as the sum of the estimates for all strata. The confidence interval for the population estimate for the entire study area was calculated as:

$$t_v . \sqrt{(\text{Sum of Variances})}$$

Where: v = the degrees of freedom estimated by Satterthwaite's rule (Gasaway *et al*. 1986).

No corrections have been applied to the estimates to compensate for any undercounting or missed animals.

RESULTS

Table 2a provides a summary of population estimates of large herbivores in Chewore Safari Area in July/August 2010. The population estimates and statistics for elephants, elephant bulls, elephant cows, elephant carcasses for category 1 to 4 and unknown carcass are shown in Tables 2b to 9. Population estimates and statistics for the following species buffalo, zebra, kudu, impala, warthog, waterbuck, crocodile, duiker, eland, ground hornbill, hippopotamus, lion, roan antelope, bushbuck and hyena are shown in Tables 10 to 24. Confidence intervals (CI) and confidence limits (CL) are confidence intervals and limits at the 95% level of probability. The estimates are shown for each stratum, for both transect and block counts.

DISCUSSION

Search effort and sampling intensity

Sampling statistics are given in Table 1. The survey covered 38 transects in 1737 km^2 and 30 blocks in 1664 km^2. The mean search effort in the block counts was 1.38 minutes/km^2 and 1.10 minutes/km^2 for transects. Sampling intensity for transect counts was 14.6% and block counts was 20.1%, resulting in an overall sampling intensity of 17.35%. Sampling intensity was higher than the previous survey in Chewore Safari Area (Dunham, 2004).

Elephants

The primary objective of the survey was to estimate elephant numbers. The estimated population of elephants was 5048 (Table 2b). The estimated population is lower than the population estimate of 2001, which stood at 5741 (Mackie, 2001).

Table 2a. Population estimates and statistics for major wildlife species and elephant carcasses in Chewore Safari Area during July/August 2010

Species	Population Estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Elephants	5048	901	313612	22	3928	6168	1.509
Elephant males	457	85	3677	27	336	579	0.14
Elephant females	4590	816	301870	24	3492	5689	1.373
Elephant carcass (Category 1)	20	3	119	113	3	42	0.01
Elephant carcass (Category 3)	71	11	723	78	16	127	0.02
Elephant carcass (category 4)	20	3	113	107	3	42	0.01
Elephant carcass (category 2)	6	1	36	212	1	19	0.00
Unknown carcass	13	2	66	132	2	30	0.004
Buffalo	2275	581	1096174	94	581	4412	0.68
Zebra	158	23	3800	80	32	284	0.05
Kudu	75	11	776	75	19	131	0.022
Impala	1097	195	106267	61	425	1768	0.328
Warthog	165	31	2877	66	56	275	0.049
Waterbuck	83	13	2251	116	13	179	0.025
Crocodiles	18	3	100	133	1	42	0.01
Common duiker	21	3	115	104	1	43	0.01
Eland	16	3	116	141	3	38	0.005
Ground hornbill	15	2	187	198	2	43	0.004
Hippopotamus	187	31	15087	137	31	444	0.056
Lion	44	6	1749	202	6	132	0.013
Roan antelope	7	1	47	199	1	22	0.002
Bushbuck	66	10	761	86	10	122	0.020
Hyena	13	2	139	192	2	38	0.004

Other wildlife

Comparison of other population estimates for other herbivores species with the estimates for 2001 and 2003 shows a substantial decline for buffalo, zebra, kudu and impala. Predator species like lion and hyena were seen during the surveys, but aerial survey is not a suitable technique to estimate population numbers for predators. Population estimates of the ground hornbill are also shown in Table 17, the bird is an indicator of good ecosystem health.

Elephant Carcasses

There were estimated to be 20 category 1 (fresh) elephant carcasses, 71 category 3 carcasses, 6 category 2 carcasses, 20 category 4 carcasses and 13 unknown carcasses in Chewore Safari Area. The observation produced a carcass "ratio" of 2%. A carcass ration less than 8% is usually indicative of a stable or increasing population number (Douglas-Hamilton and Burril 1991). Generally the survey counted more fresh carcasses (category 1) than in the previous survey during which none were seen (Dunham, 2004).

Illegal Activities

There was a lot of gold panning in block 14, Chewore North and a poachers' base in block 94, Chewore South.

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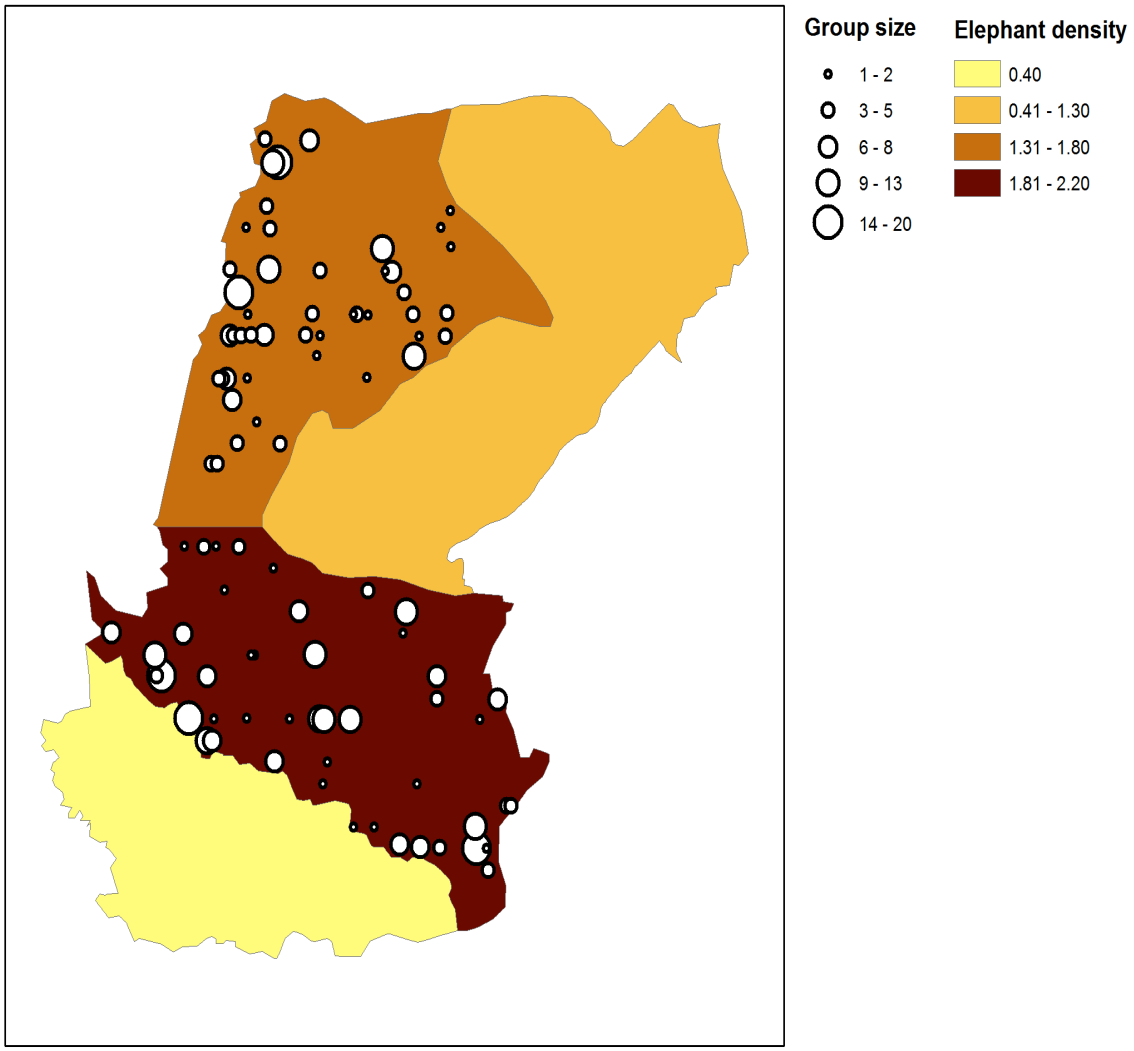
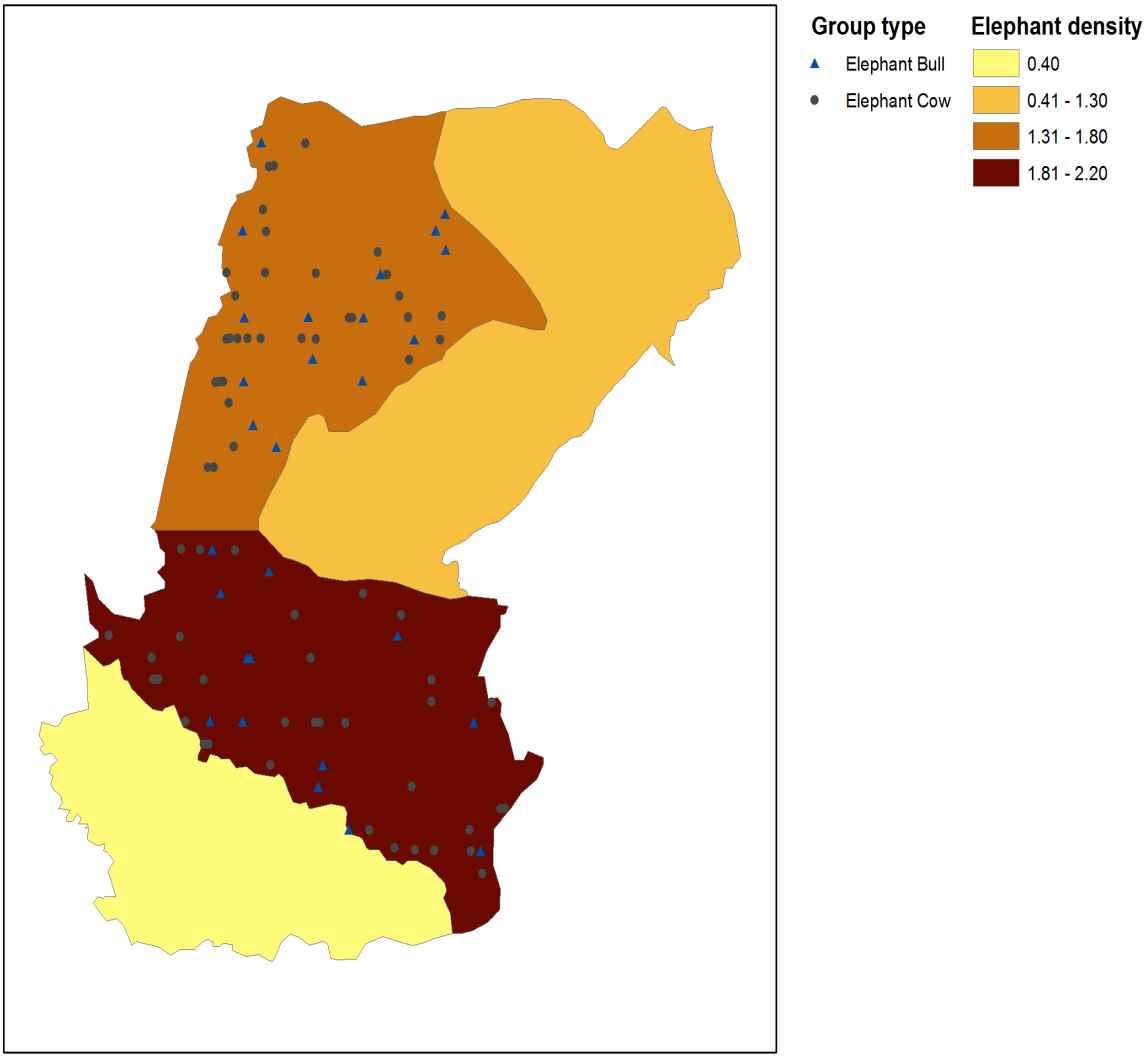
Table 2b: Population estimates and statistics for Elephants in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	1488	231	50060	31	1020	1956	1.8
Chewore 3	1974	271	125857	38	1225	2722	2.2
Chewore North	1360	346	115178	53	637	2084	1.3
Chewore South	226	53	22517	145	0	553	0.4
Totals	**5048**	**901**	**313612**	**22**	**3928**	**6168**	**1.509**



Map 3a: Spatial distribution of Elephants in Chewore Safari Area



Map 3b: Spatial distribution of Elephants in Chewore Safari Area. Red Represents cows and blue elephant bulls

Table 3: Population estimates and statistics for Elephant Males in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	167	26	1377	46	90	245	0.20
Chewore 3	138	19	1259	54	64	213	0.15
Chewore North	128	35	786	47	68	188	0.12
Chewore South	24	5	255	148	0	58	0.04
Totals	**457**	**85**	**3677**	**27**	**336**	**579**	**0.14**

Table 4: Population estimates and statistics for Elephant Females in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	1321	205	48682	35	859	1782	1.6
Chewore 3	1835	252	124599	41	1090	2580	2.0
Chewore North	1232	311	110132	57	525	1940	1.2
Chewore South	202	48	18457	146	0	498	0.3
Totals	**4590**	**816**	**301870**	**24**	**3492**	**5689**	**1.37**

Table 5: Population estimates and statistics for Elephant Carcass Category 1 in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	6	1	33	187	0	18	0.008
Chewore 3	7	1	50	206	0	22	0.008
Chewore North	6	1	36	213	0	19	0
Chewore South	0	0	0	0	0	0	0
Totals	**20**	**3**	**119**	**113**	**3**	**42**	**0.01**

Table 6: Population estimates and statistics for Elephant Carcass Category 3 in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	58	9	639	91	5	111	0.07
Chewore 3	7	1	49	202	0	22	0.01
Chewore North	6	1	36	213	0	19	0.01
Chewore South	0	0	0	0	0	0	0.00
Totals	**71**	**11**	**723**	**78**	**16**	**127**	**0.02**

Table 7: Population estimates and statistics for Elephant Carcass Category 4 in Chewore Safari Area

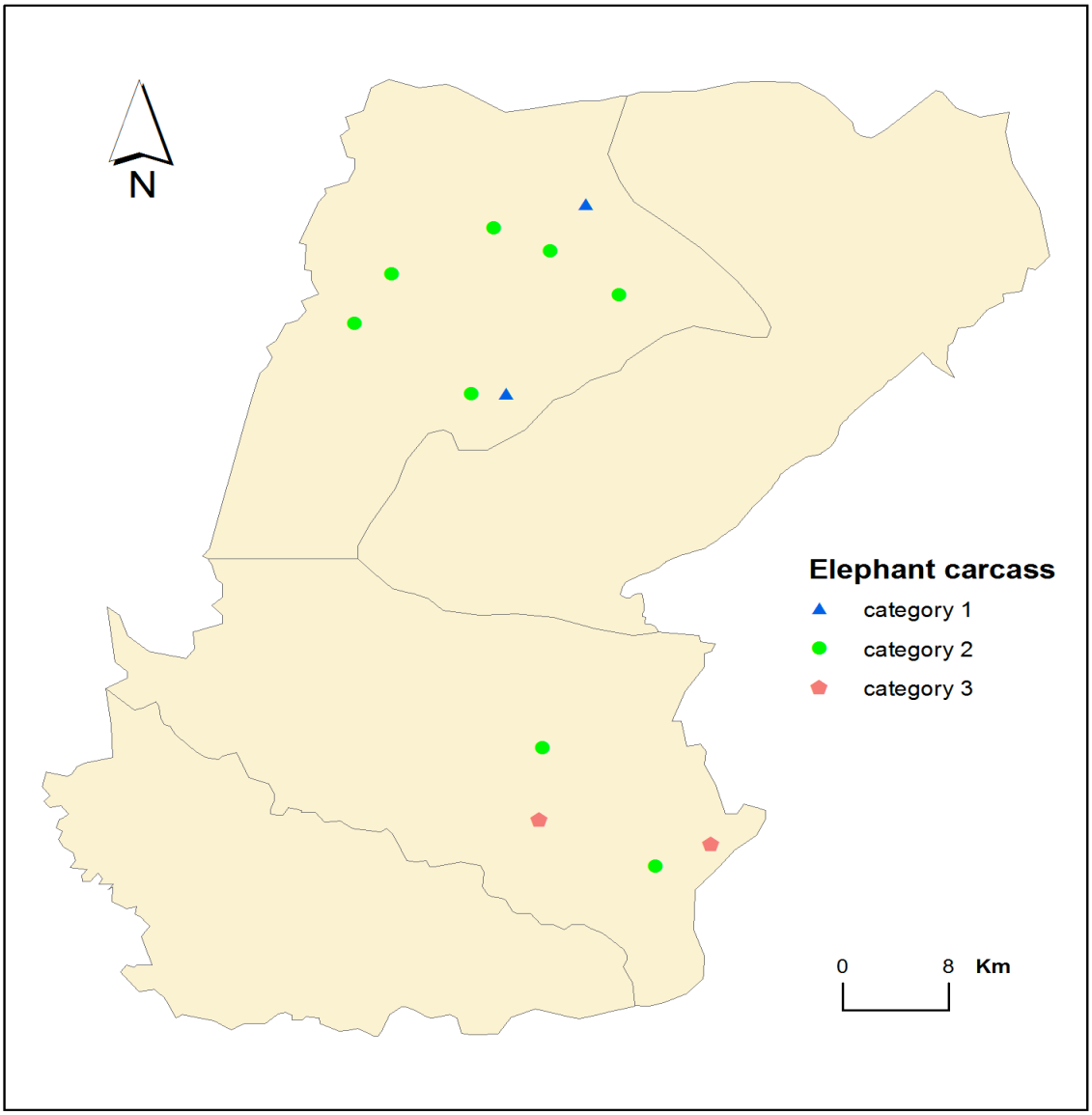
Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	13	2	67	132	0	30	0.0
Chewore 3	7	1	47	198	0	22	0.0
Chewore North	0	0	0	0	0	0	0.0
Chewore South	0	0	0	0	0	0	0.0
Totals	**20**	**3**	**113**	**107**	**3**	**42**	**0.01**

Table 8: Population estimates and statistics for Elephant Carcass Category 2 in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	0	0	0	0	0	0	0.0
Chewore 3	0	0	0	0	0	0	0.0
Chewore North	6	1	36	213	0	19	0.0
Chewore South	0	0	0	0	0	0	0.0
Totals	**6**	**1**	**36**	**212**	**1**	**19**	**0.00**

Table 9: Population estimates and statistics for Unknown Carcasses in Chewore Safari Area

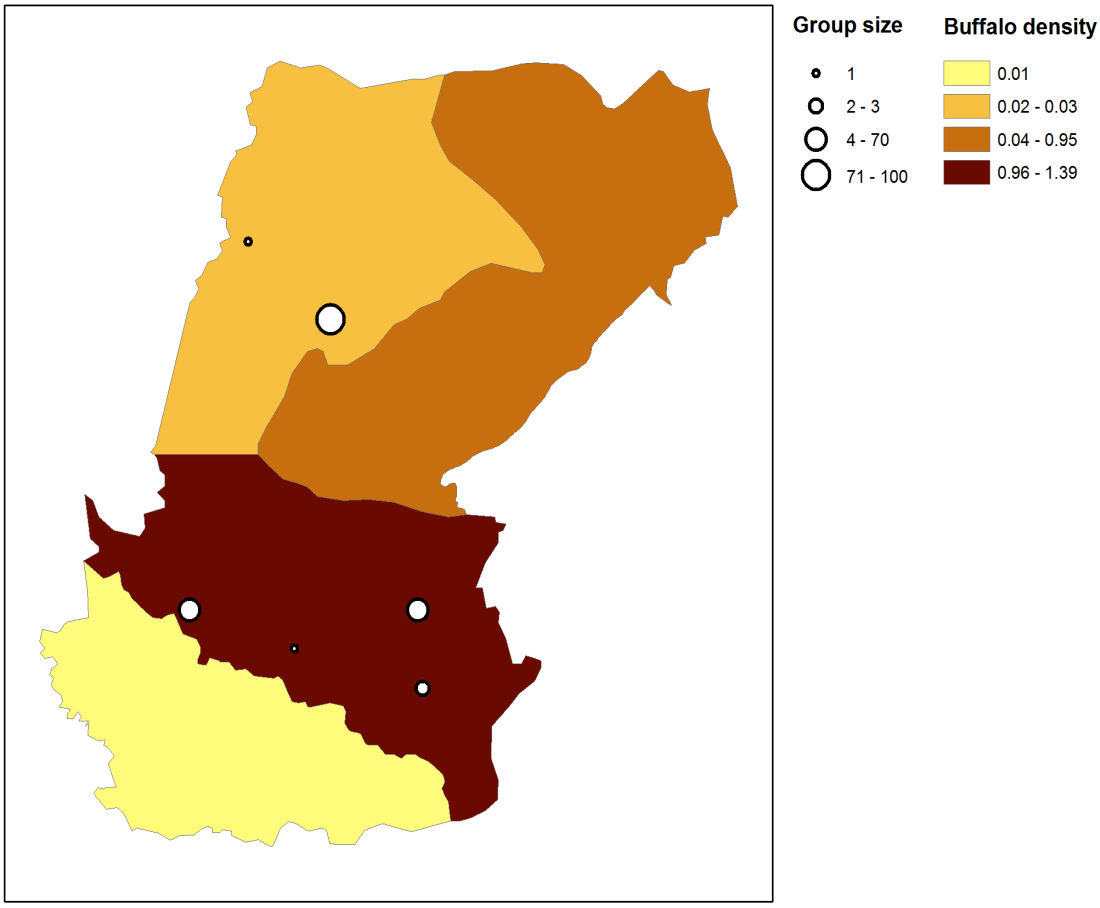
Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	13	2	66	131.515	0	29.83	0.02
Chewore 3	0	0	0	0	0	0	0.00
Chewore North	0	0	0	0	0	0	0.00
Chewore South	0	0	0	0	0	0	0.00
Totals	**13**	**2**	**66**	**132**	**2**	**30**	**0.004**



Map 4: Spatial distribution of Elephants carcass in Chewore Safari Area. Red represents category 3, blue category 1 and green category 2)

Table 10: Population estimates and statistics for Buffalo in Chewore Safari Area

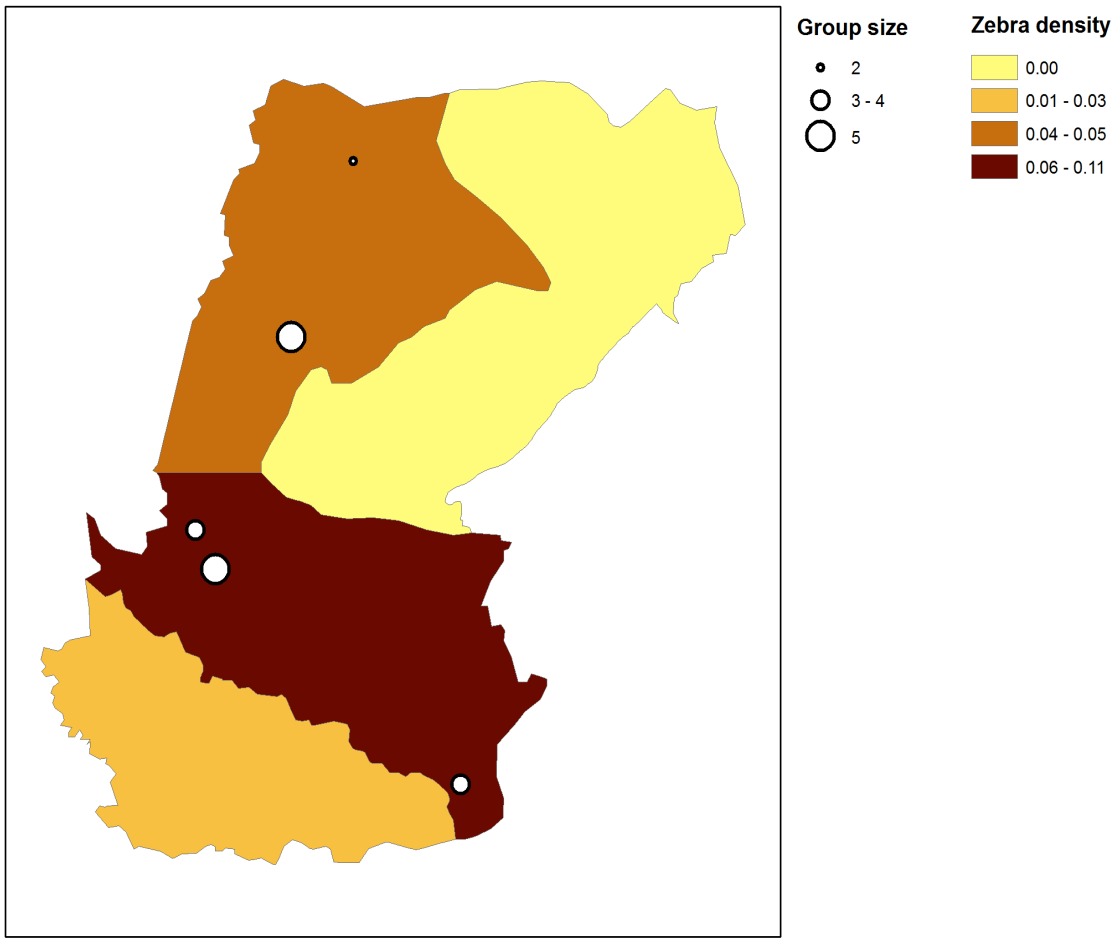
Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	26	4	344	151	0	65	0.03
Chewore 3	1245	171	648637	136	0	2945	1.39
Chewore North	999	405	447171	143	0	2424	0.95
Chewore South	5	1	21	218	0	15	0.01
Totals	**2275**	**581**	**1096174**	**94**	**581**	**4412**	**0.68**



Map 5: Spatial distribution of Buffalo in Chewore Safari Area

Table 11: Population estimates and statistics for Zebra in Chewore Safari Area

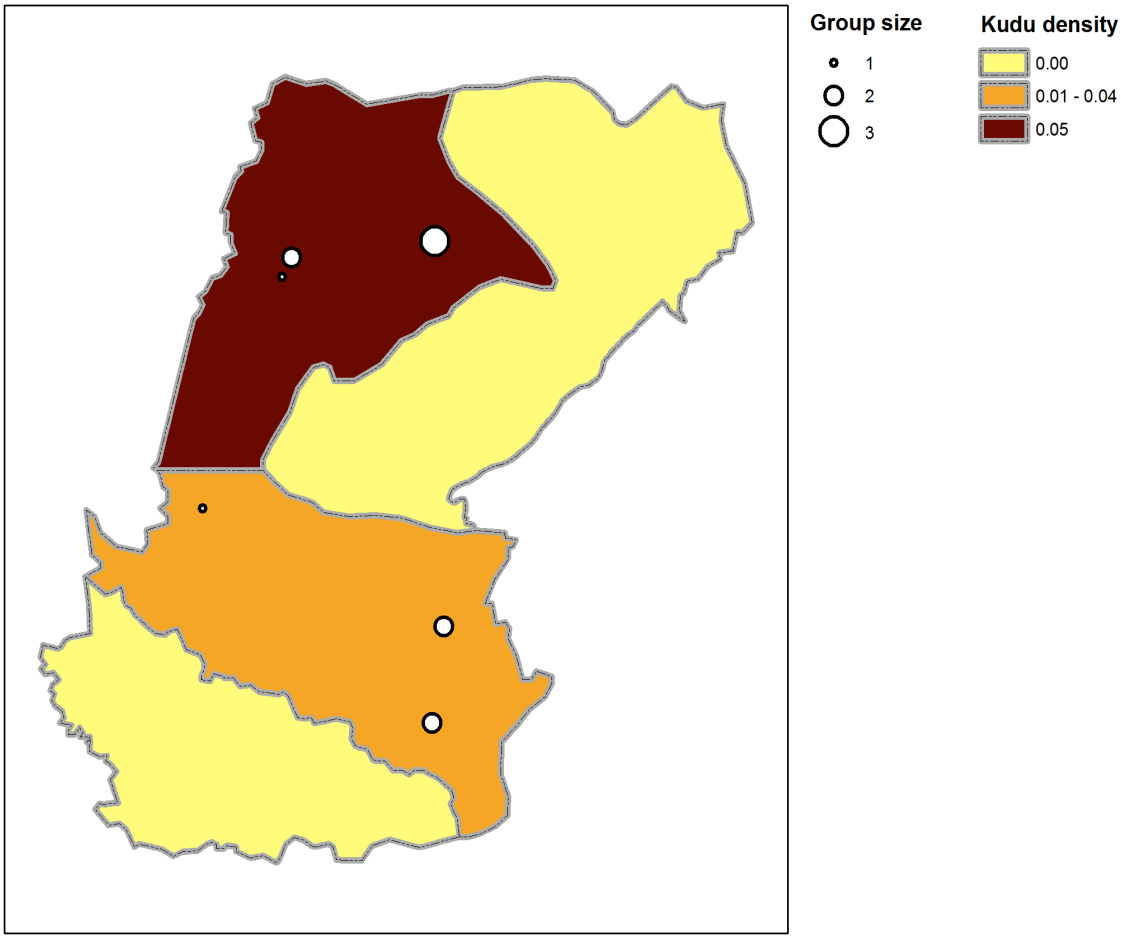
Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	45	7	1020	148	0	112	0.05
Chewore 3	95	13	2453	110	0	199	0.11
Chewore North	0	0	0	0	0	0	0.00
Chewore South	18	3	327	218	0	58	0.03
Totals	**158**	**23**	**3800**	**80**	**32**	**284**	**0.05**



Map 6: Spatial distribution of Zebra in Chewore Safari Area

Table 12: Population estimates and statistics for Kudu in Chewore Safari Area

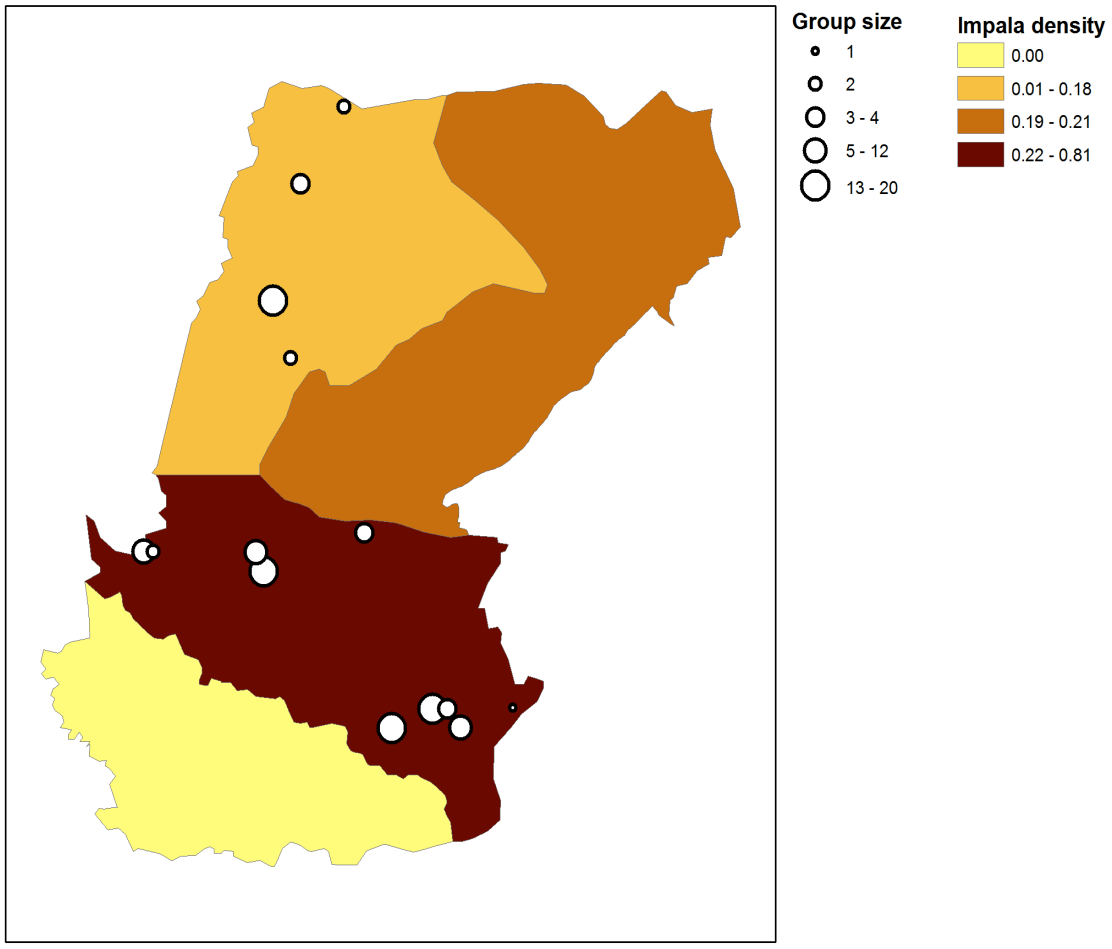
Stratum	Population estimate	No. Seen	Variance	% CI	Lower CI	Upper CI	Density (km^{-2})
Chewore 1	39	6	372	104	0	79	0.05
Chewore 3	36	5	404	117	0	79	0.04
Chewore North	0	0	0	0	0	0	0.00
Chewore South	0	0	0	0	0	0	0.00
Totals	**75**	**11**	**776**	**75**	**19**	**131**	**0.022**



Map 7: Spatial distribution of Kudu in Chewore Safari Area

Table 13: Population estimates and statistics for Impala in Chewore Safari Area

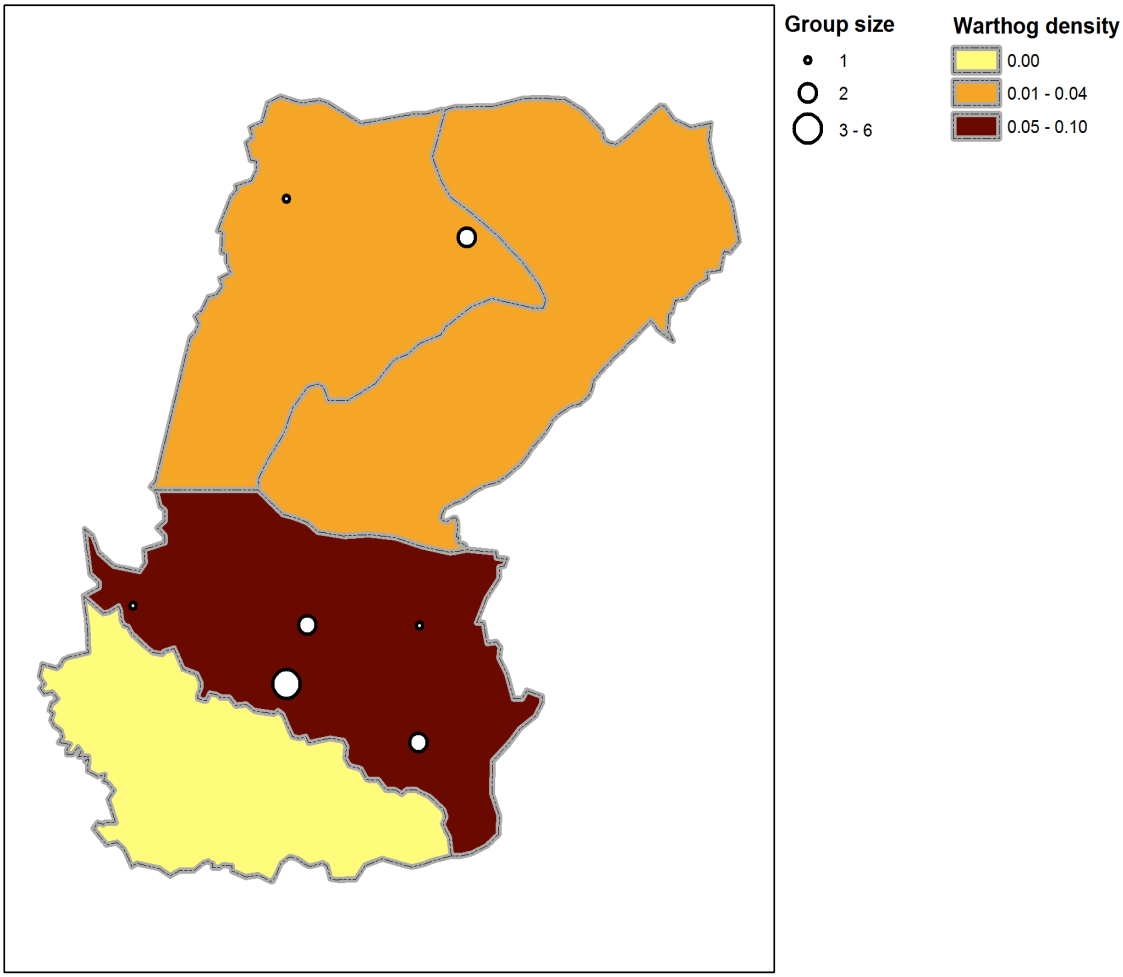
Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	148	23	9116	135	23	348	0.18
Chewore3	728	100	86457	85	108	1349	0.81
Chewore North	220	72	10694	100	72	440	0.21
Chewore South	0	0	0	0	0	0	0.00
Totals	**1097**	**195**	**106267**	**61**	**425**	**1768**	**0.328**



Map 8: Spatial distribution of Impala in Chewore Safari Area

Table 14: Population estimates and statistics for Warthog in Chewore Safari Area

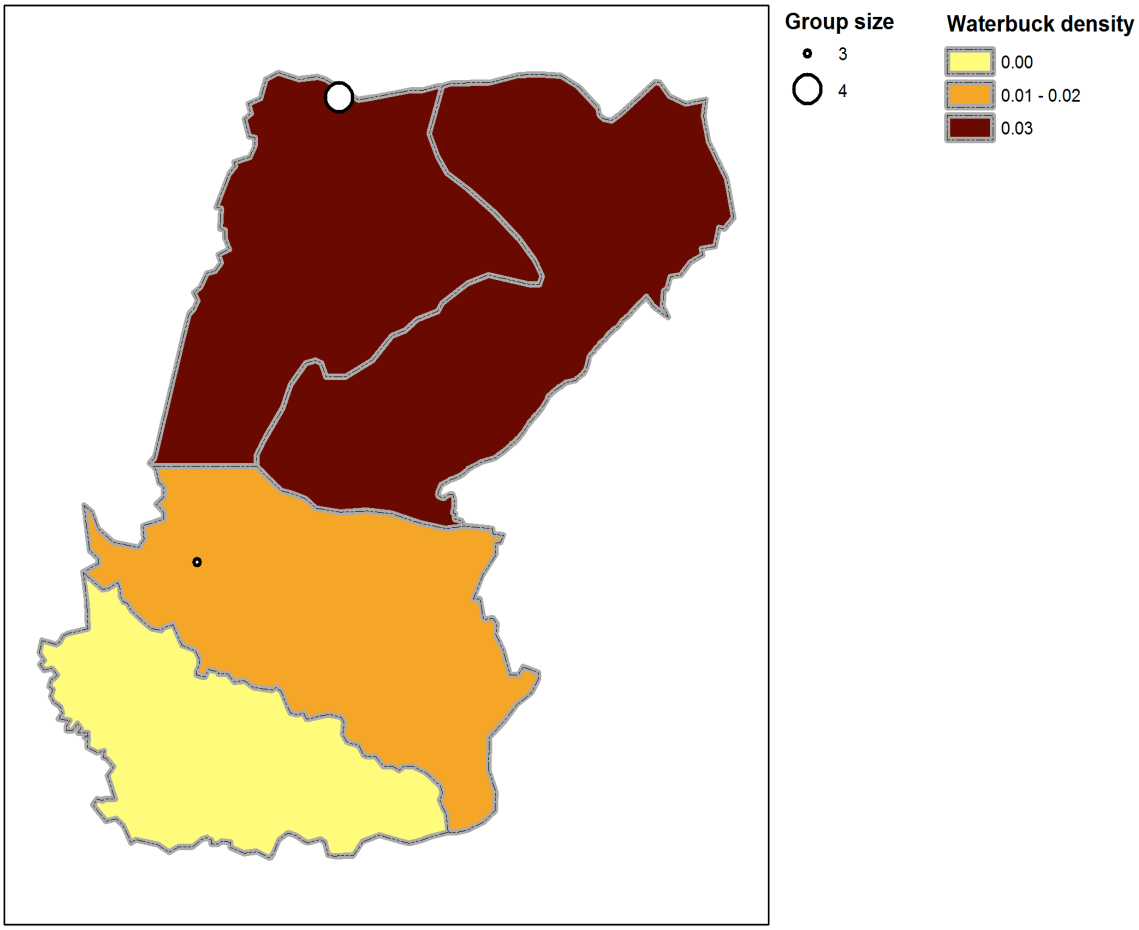
Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	32	5	305	113	0	69	0.04
Chewore 3	87	12	2007	108	0	182	0.10
Chewore North	46	14	565	110	0	97	0.04
Chewore South	0	0	0	0	0	0	0.00
Totals	**165**	**31**	**2877**	**66**	**56**	**275**	**0.049**



Map 9: Spatial distribution of Warthog in Chewore Safari Area

Table 15: Population estimates and statistics for Waterbuck in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	26	4	597	199	0	77	0.03
Chewore 3	22	3	406	195	0	64	0.02
Chewore North	35	6	1248	213	0	111	0.03
Chewore South	0	0	0	0	0	0	0.00
Totals	**83**	**13**	**2251**	**116**	**13**	**179**	**0.025**



Map 10: Spatial distribution of Waterbuck in Chewore Safari Area

Table 16: Population estimates and statistics for Crocodile in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	0	0	0	0	0	0	0.000
Chewore 3	7	1	47	199	0	22	0.008
Chewore North	11	2	53	147	0	26	0.010
Chewore South	0	0	0	0	0	0	0.000
Totals	**18**	**3**	**100**	**133**	**1**	**42**	**0.01**

Table 17: Population estimates and statistics for Duiker in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	6	1	35	192	0	19	0.008
Chewore 3	15	2	80	130	0	33	0.016
Chewore North	0	0	0	0	0	0	0
Chewore South	0	0	0	0	0	0	0
Totals	**21**	**3**	**115**	**104**	**1**	**43**	**0.01**

Table 18: Population estimates and statistics for Eland in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	0	0	0	0	0	0	0.00
Chewore3	7	1	47	198	0	22	0.01
Chewore North	8	2	69	213	0	26	0.01
Chewore South	0	0	0	0	0	0	0.00
Totals	**16**	**3**	**116**	**141**	**3**	**38**	**0.005**

Table 19: Population estimates and statistics for Ground Hornbill in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	0	0	0	0	0	0	0.00
Chewore 3	15	2	187	198	0	43	0.02
Chewore North	0	0	0	0	0	0	0.00
Chewore South	0	0	0	0	0	0	0.00
Totals	**15**	**2**	**187**	**198**	**2**	**43**	**0.004**

Table 20: Population estimates and statistics for Hippo in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	110	17	11405	204	0	333	0.13
chewore3	0	0	0	0	0	0	0.00
Chewore North	78	14	3682	166	0	207	0.07
Chewore South	0	0	0	0	0	0	0.00
Totals	**187**	**31**	**15087**	**137**	**31**	**444**	**0.056**

Table 21: Population estimates and statistics for Lion in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CI	Upper CI	Density (km^{-2})
Chewore 1	0	0	0	0	0	0	0.00
Chewore 3	44	6	1749	202	0	132	0.05
Chewore North	0	0	0	0	0	0	0.00
Chewore South	0	0	0	0	0	0	0.00
Totals	**44**	**6**	**1749**	**202**	**6**	**132**	**0.013**

Table 22: Population estimates and statistics for Roan Antelope in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	0	0	0	0	0	0	0.00
Chewore3	7	1	47	199	0	22	0.01
Chewore North	0	0	0	0	0	0	0.00
Chewore South	0	0	0	0	0	0	0.00
Totals	**7**	**1**	**47**	**199**	**1**	**22**	**0.002**

Table 23: Population estimates and statistics for Bushbuck in Chewore Safari Area

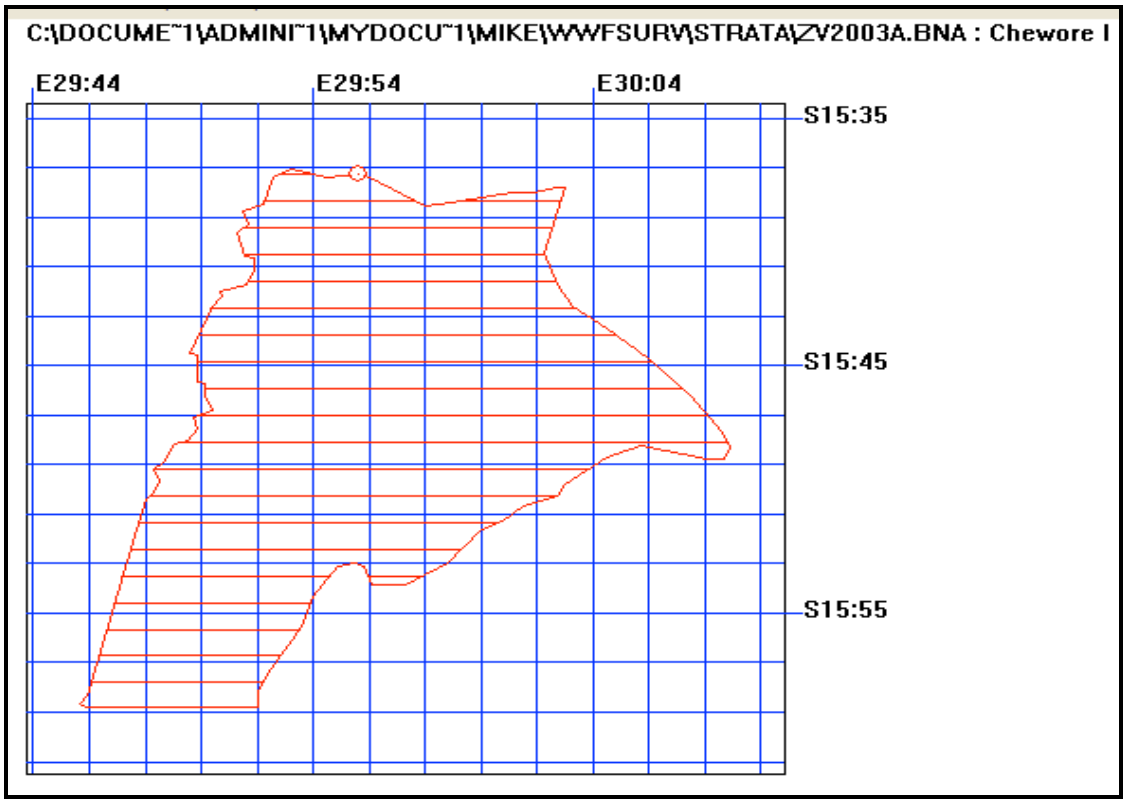
Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	0	0	0	0	0	0	0.00
Chewore 3	36	5	388	114	0	78	0.04
Chewore North	5	1	30	213	0	17	0.01
Chewore South	24	4	343	169	0	64	0.04
Totals	**66**	**10**	**761**	**86**	**10**	**122**	**0.020**

Table 24: Population estimates and statistics for Hyena in Chewore Safari Area

Stratum	Population estimate	No. Seen	Variance	% CI	Lower CL	Upper CL	Density (km^{-2})
Chewore 1	13	2	139	192	0	38	0.02
chewore3	0	0	0	0	0	0	0.00
Chewore North	0	0	0	0	0	0	0.00
Chewore South	0	0	0	0	0	0	0.00
Totals	**13**	**2**	**139**	**192**	**2**	**38**	**0.004**

APPENDICES

Appendix 1: Start and end points for Transects in Chewore I stratum in Chewore 2010



Chewore I

Number of transects : 23
Transect Bearing : 90.00 Degrees
Transect Spacing : 2.00 km

Transect # : 1
Start Lat : S 15 : 37.287 Start Lon : E 29 : 55.646
Finish Lat : S 15 : 37.287 Finish Lon : E 29 : 55.522
Length : 0.22 km

Transect # : 2
Start Lat : S 15 : 37.287 Start Lon : E 29 : 54.050
Finish Lat : S 15 : 37.287 Finish Lon : E 29 : 52.821
Length : 2.19 km

Transect # : 3
Start Lat : S 15 : 38.367 Start Lon : E 29 : 52.257
Finish Lat : S 15 : 38.367 Finish Lon : E 29 : 57.684
Length : 9.68 km

Transect # : 4
Start Lat : S 15 : 38.367 Start Lon : E 29 : 59.136
Finish Lat : S 15 : 38.367 Finish Lon : E 30 : 2.832
Length : 6.59 km

Transect # : 5
Start Lat : S 15 : 39.447 Start Lon : E 30 : 2.512
Finish Lat : S 15 : 39.447 Finish Lon : E 29 : 51.476
Length : 19.69 km

Transect # : 6
Start Lat : S 15 : 40.527 Start Lon : E 29 : 51.542
Finish Lat : S 15 : 40.527 Finish Lon : E 30 : 2.262
Length : 19.12 km

Transect # : 7
Start Lat : S 15 : 41.607 Start Lon : E 30 : 2.686
Finish Lat : S 15 : 41.607 Finish Lon : E 29 : 51.654
Length : 19.68 km

Transect # : 8
Start Lat : S 15 : 42.687 Start Lon : E 29 : 50.353
Finish Lat : S 15 : 42.687 Finish Lon : E 30 : 3.396
Length : 23.27 km

Transect # : 9
Start Lat : S 15 : 43.767 Start Lon : E 30 : 4.834
Finish Lat : S 15 : 43.767 Finish Lon : E 29 : 49.905
Length : 26.63 km

Transect # : 10
Start Lat : S 15 : 44.847 Start Lon : E 29 : 49.874
Finish Lat : S 15 : 44.847 Finish Lon : E 30 : 6.147
Length : 29.03 km

Transect # : 11
Start Lat : S 15 : 45.927 Start Lon : E 30 : 7.227
Finish Lat : S 15 : 45.927 Finish Lon : E 29 : 50.111
Length : 30.53 km

Transect # : 12
Start Lat : S 15 : 47.007 Start Lon : E 29 : 49.929
Finish Lat : S 15 : 47.007 Finish Lon : E 30 : 8.135
Length : 32.48 km

Transect # : 13
Start Lat : S 15 : 48.087 Start Lon : E 30 : 8.790
Finish Lat : S 15 : 48.087 Finish Lon : E 29 : 49.266
Length : 34.83 km

Transect # : 14
Start Lat : S 15 : 49.167 Start Lon : E 29 : 48.321
Finish Lat : S 15 : 49.167 Finish Lon : E 30 : 3.844
Length : 27.69 km

Transect # : 15
Start Lat : S 15 : 50.247 Start Lon : E 30 : 2.724
Finish Lat : S 15 : 50.247 Finish Lon : E 29 : 48.142
Length : 26.01 km

Transect # : 16
Start Lat : S 15 : 51.327 Start Lon : E 29 : 47.743
Finish Lat : S 15 : 51.327 Finish Lon : E 30 : 0.708
Length : 23.13 km

Transect # : 17
Start Lat : S 15 : 52.407 Start Lon : E 29 : 59.303
Finish Lat : S 15 : 52.407 Finish Lon : E 29 : 47.461
Length : 21.12 km

Transect # : 18
Start Lat : S 15 : 53.487 Start Lon : E 29 : 47.185
Finish Lat : S 15 : 53.487 Finish Lon : E 29 : 54.602
Length : 13.23 km

Transect # : 19
Start Lat : S 15 : 53.487 Start Lon : E 29 : 55.977
Finish Lat : S 15 : 53.487 Finish Lon : E 29 : 57.905
Length : 3.44 km

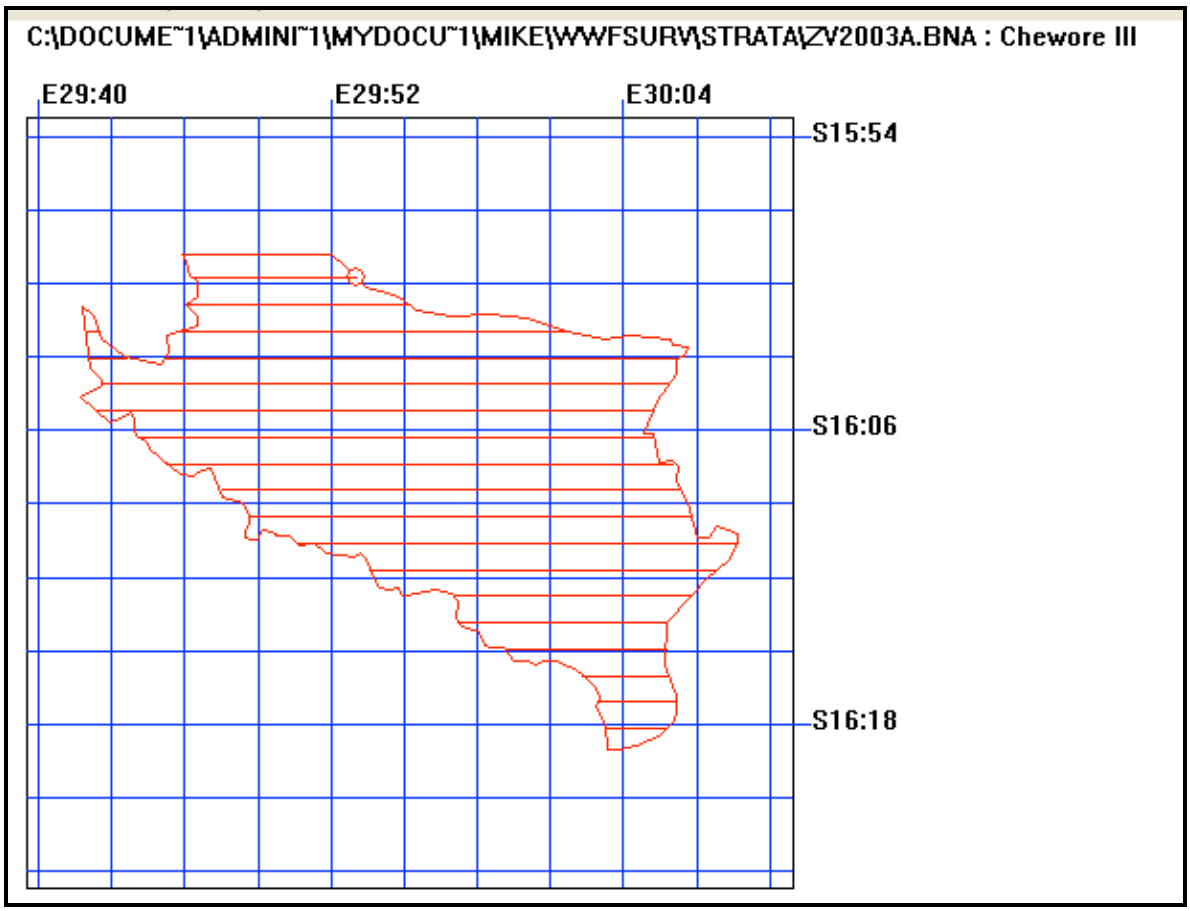
Transect # : 20
Start Lat : S 15 : 54.567 Start Lon : E 29 : 53.907
Finish Lat : S 15 : 54.567 Finish Lon : E 29 : 46.910
Length : 12.48 km

Transect # : 21
Start Lat : S 15 : 55.647 Start Lon : E 29 : 46.634
Finish Lat : S 15 : 55.647 Finish Lon : E 29 : 53.509
Length : 12.26 km

Transect # : 22
Start Lat : S 15 : 56.727 Start Lon : E 29 : 52.818
Finish Lat : S 15 : 56.727 Finish Lon : E 29 : 46.359
Length : 11.52 km

Transect # : 23
Start Lat : S 15 : 57.807 Start Lon : E 29 : 46.083
Finish Lat : S 15 : 57.807 Finish Lon : E 29 : 52.202
Length : 10.91 km

Appendix 2: Start and end points for Transects in Chewore III stratum in Chewore: 2010



Chewore III

Number of transects : 18
Transect Bearing : 90.00 Degrees
Transect Spacing : 2.00 km

Transect # : 1
Start Lat : S 15 : 59.799 Start Lon : E 29 : 53.054
Finish Lat : S 15 : 59.799 Finish Lon : E 29 : 46.344
Length : 11.95 km

Transect # : 2
Start Lat : S 16 : 0.879 Start Lon : E 29 : 46.080
Finish Lat : S 16 : 0.879 Finish Lon : E 29 : 55.214
Length : 16.27 km

Transect # : 3A
Start Lat : S 16 : 1.959 Start Lon : E 30 : 1.713
Finish Lat : S 16 : 1.959 Finish Lon : E 29 : 45.737
Length : 28.46 km

Transect # : 3B
Start Lat : S 16 : 1.959 Start Lon : E 29 : 42.503
Finish Lat : S 16 : 1.959 Finish Lon : E 29 : 41.910
Length : 1.06 km

Transect # : 4A
Start Lat : S 16 : 3.039 Start Lon : E 29 : 42.056
Finish Lat : S 16 : 3.039 Finish Lon : E 29 : 43.695
Length : 2.92 km

Transect # : 4B
Start Lat : S 16 : 3.039 Start Lon : E 29 : 45.194
Finish Lat : S 16 : 3.039 Finish Lon : E 30 : 6.300
Length : 37.59 km

Transect # : 5
Start Lat : S 16 : 4.119 Start Lon : E 30 : 5.860
Finish Lat : S 16 : 4.119 Finish Lon : E 29 : 42.611
Length : 41.41 km

Transect # : 6
Start Lat : S 16 : 5.199 Start Lon : E 29 : 42.377
Finish Lat : S 16 : 5.199 Finish Lon : E 30 : 5.225
Length : 40.70 km

Transect # : 7
Start Lat : S 16 : 6.279 Start Lon : E 30 : 5.248
Finish Lat : S 16 : 6.279 Finish Lon : E 29 : 44.100
Length : 37.67 km

Transect # : 8
Start Lat : S 16 : 7.359 Start Lon : E 29 : 45.232
Finish Lat : S 16 : 7.359 Finish Lon : E 30 : 6.118
Length : 37.20 km

Transect # : 9
Start Lat : S 16 : 8.439 Start Lon : E 30 : 6.334
Finish Lat : S 16 : 8.439 Finish Lon : E 29 : 47.439
Length : 33.65 km

Transect # : 10
Start Lat : S 16 : 9.519 Start Lon : E 29 : 48.611
Finish Lat : S 16 : 9.519 Finish Lon : E 30 : 6.761
Length : 32.33 km

Transect # : 11
Start Lat : S 16 : 10.599 Start Lon : E 30 : 8.654
Finish Lat : S 16 : 10.599 Finish Lon : E 29 : 50.558
Length : 32.23 km

Transect # : 12
Start Lat : S 16 : 11.679 Start Lon : E 29 : 53.635
Finish Lat : S 16 : 11.679 Finish Lon : E 30 : 7.812
Length : 25.25 km

Transect # : 13
Start Lat : S 16 : 12.759 Start Lon : E 30 : 6.769
Finish Lat : S 16 : 12.759 Finish Lon : E 29 : 57.047
Length : 17.32 km

Transect # : 14
Start Lat : S 16 : 13.839 Start Lon : E 29 : 57.223
Finish Lat : S 16 : 13.839 Finish Lon : E 30 : 5.777
Length : 15.24 km

Transect # : 15
Start Lat : S 16 : 14.919 Start Lon : E 30 : 5.743
Finish Lat : S 16 : 14.919 Finish Lon : E 29 : 59.114
Length : 11.81 km

Transect # : 16
Start Lat : S 16 : 15.999 Start Lon : E 30 : 2.322
Finish Lat : S 16 : 15.999 Finish Lon : E 30 : 5.870
Length : 6.32 km

Transect # : 17
Start Lat : S 16 : 17.079 Start Lon : E 30 : 6.151
Finish Lat : S 16 : 17.079 Finish Lon : E 30 : 2.928
Length : 5.74 km

Transect # : 18
Start Lat : S 16 : 18.159 Start Lon : E 30 : 3.239
Finish Lat : S 16 : 18.159 Finish Lon : E 30 : 5.772
Length : 4.51 km

Appendix 3: Transect summaries of sightings for Chewore 1: 2010

Species codes:

Code	Species
BBk	Bushbuck
Buff	Buffalo
Croc	Crocodile
Drk	Common or Bush Duiker
ElC1	Elephant carcass, age category 1
ElC3	Elephant carcass, age category 3
ElC4	Elephant carcass, age category 4
Eld	Eland
EleF	Elephant cow
EleM	Elephant bull
Ghbl	Ground hornbill
Grf	Giraffe
Hipo	Hippopotamus
Hye	Hyaena
Imp	Impala
Kudu	Kudu
Lion	Lion
Nyl	Nyala
Unca	Unclassified carcass
Rlop	Roan antelope
Wart	Warthog
Wbck	Waterbuck
Whog	Warthog
Zeb	Zebra

Abbreviation	Meaning
n	number of transects sampled
N	possible number of transects in stratum
t	Student's *t* value, $P = 0.05$
T	# transect number
-	no animals were seen in search strips

The following tables list, for each stratum, the number of individuals of each species that were seen inside the search strips on each transects.

Date of Survey : 25/08/10 — Stratum Name : Chewore 1
Stratum Locality : Mid-Zambezi Valley — Base Line Length : 40.3 km
Stratum Area : 840 km^2 — Calibrated Strip Width at 300ft : 270 m
N : 130 n : 20 — t : 2.093
Pilot : Conrad — Observer : Chipesi D, Gava C
Map overlay file : None

Transect summary table :

T #	EleM	EleF	Buff	Zeb	Wbck	Imp	Kudu	Hipo	EIC1	EIC3	EIC4	UnCa	hye	Drk	Wart
1	-	-	-	-	-	-	-	17	-	-	-	-	-	-	-
2	-	-	-	-	4	2	-	-	-	-	-	-	-	-	-
3	4	6	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	25	-	-	-	-	-	-	-	4	-	1	-	-	-
5	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
6	1	4	-	-	-	3	-	-	-	1	-	-	-	-	1
7	2	4	-	-	-	-	-	-	-	1	-	-	-	-	-
8	2	12	-	-	-	-	-	-	-	1	-	-	2	-	2
9	1	25	-	-	-	-	3	-	1	-	-	-	-	-	-
10	-	19	1	-	-	-	2	-	-	1	-	1	-	-	-
11	5	14	-	-	-	-	1	-	-	-	1	-	-	-	-
12	2	26	-	-	-	16	-	-	-	-	-	-	-	1	-
13	2	17	-	-	-	-	-	-	-	-	-	-	-	-	-
14	3	13	3	5	-	-	-	-	-	1	-	-	-	-	-
15	-	7	-	-	-	2	-	-	-	-	-	-	-	-	-
16	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-
19	-	23	-	-	-	-	-	-	-	-	1	-	-	-	2
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sighting Totals

	EleM	EleF	Buff	Zeb	Wbck	Imp	Kudu	Hipo	EIC1	EIC3	EIC4	UnCa	hye	Drk	Wart
	26	205	4	7	4	23	6	17	1	9	2	2	2	1	5

Appendix 4: Transect data for Chewore III: 2010

Date of Survey : 26/08/10 — Stratum Name : chewore3
Stratum Locality : Mid-Zambezi Valley — Base Line Length : 37.8 km
Stratum Area : 897 km^2 — Calibrated Strip Width at 300ft : 270 m
N : 134 n : 18 — t : 2.11
Pilot : Conrad — Observer : Chipesi D, Gava C
Map overlay file : None

Transect summary table :

T #	EleM	EleF	Buff	Zeb	Imp	Kudu	EIC1	EIC3	EIC4	bbk	Eld	Wbck	Rlop	Croc	lion	Ghbl	Drk	Wart
1	1	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
3	2	7	-	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-
4	-	18	-	-	23	-	-	-	-	-	-	-	-	-	-	-	-	-
5	1	16	-	5	20	-	-	-	-	-	-	3	-	-	-	-	1	-
6	2	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
7	-	37	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	3
8	-	11	100	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
9	4	49	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-
10	-	16	1	-	-	-	-	-	-	-	-	-	1	1	-	-	-	6
11	2	8	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-
12	3	2	70	-	25	-	-	1	-	-	-	-	-	-	6	-	-	-
13	-	7	-	-	28	2	1	-	-	2	-	-	-	-	-	-	-	2
14	2	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	1	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	-	4	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sighting Totals

	EleM	EleF	Buff	Zeb	Imp	Kudu	EIC1	EIC3	EIC4	bbk	Eld	Wbck	Rlop	Croc	lion	Ghbl	Drk	Wart
	19	252	171	13	100	5	1	1	1	5	1	3	1	1	6	2	2	12

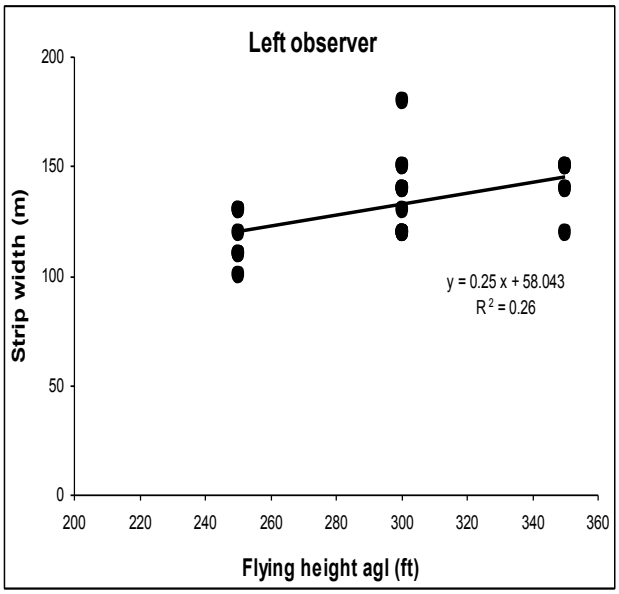
Appendix 5: Calibration done at Mana Pools: Chewore survey: 2010

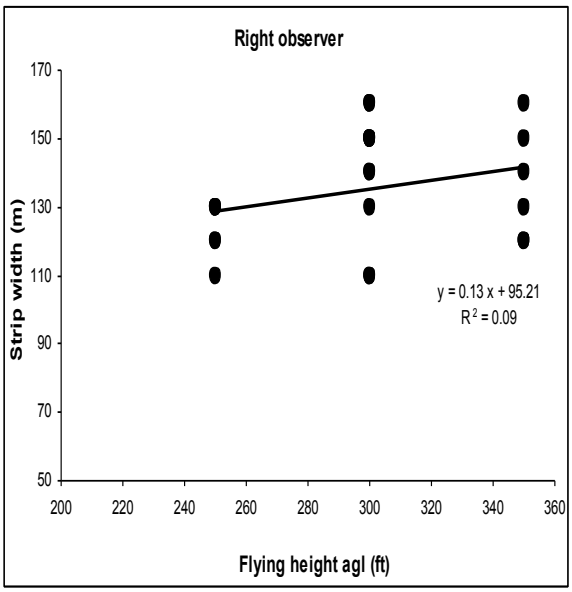
Run number	Left observer			Right observer		
	Outer marker	Inner marker	Strip width (m)	Outer marker	Inner marker	Strip width (m)
1	18	4	150	26	11	160
2	22	10	130	23	8	160
3	16	3	140	28	14	150
4	21	10	120	21	8	140
5	18	1	180	30	16	150
6	18	7	120	23	9	150
7	19	6	140	21	9	130
8	14	1	140	22	12	110
9	19	8	120	23	9	150
10	20	6	150	20	7	140
11	17	6	120	18	8	110
12	16	6	110	15	5	110
13	18	7	120	22	11	120
14	16	4	130	21	9	130
15	18	4	150	23	9	150
16	22	9	140	16	4	130
17	22	8	150	19	6	140
18	22	12	110	23	11	130
19	21	8	140	30	15	160
20	17	8	100	25	14	120
21	18	7	120	18	7	120
22	16	4	130	17	5	130
23	21	7	150	18	7	120

Appendix 6: Calibrated strip width for Chewore Survey: 2010

Combined strip width (m) at flying height	Flying height agl (ft)	Combined strip width (m) when flying at 300ft
310	300	310
290	300	290
290	300	290
260	300	260
330	300	330
270	300	270
270	300	270
250	300	250
270	300	270
290	300	290
230	300	230
220	250	264
240	250	288
260	250	312
300	350	257
270	350	231
290	350	249
240	250	288
300	350	257
220	250	264
240	350	206
260	250	312
270	350	231
	Mean	**270**
	Standard deviation	**30**
	Standard error (SE)	**6.4**
	SE as % of mean	**2.4**

Strip calibration – left and right observers





Appendix 7: Aerial Survey of Elephants and other Herbivores in Chewore S.A, Zimbabwe, 2010

BLOCK COUNT STRATUM:CHIWORE SOUTH

Date:	**27/07/2010**	Pilot:	**Taylor C**
Stratum name:	**Chewore South**	Observer:	**Chipesi D**
Total flying time:		Aircraft:	**Super cub**
Counting time:		n:	**13**
Stratum area Z:	**610**	t(df =n-1):	**2.179**

	Block Number	Time (mins)	Block area Sqkm	EleF	Bk	Zeb	Buf	EleM	GP
1	7	16	9.10	0	0	0	0	0	0
2	9	8	13.86	7	0	0	0	0	0
3	15	14	10.13	0	0	0	1	0	0
4	17	9	8.37	0	0	0	0	0	1
5	22	12	11.71	33	0	0	0	3	1
6	25	13	7.76	0	0	0	0	0	0
7	29	9	10.32	0	0	0	0	0	0
8	33	8	4.62	0	0	0	0	0	0
9	40	10	5.04	0	0	0	0	0	0
10	41	10	8.13	8	1	0	0	2	0
11	44	9	7.78	0	3	3	0	0	0
12	51	10	6.06	0	0	0	0	0	0
13	55	13	8.20	0	0	0	0	0	0
			Total	**48**	**4**	**3**	**1**	**5**	**1**