DRY SEASON FIXED-WING AERIAL SURVEY OF LARGE MAMMALS IN THE NORTHERN TULI GAME RESERVE AND MAPUNGUBWE NATIONAL PARK AND OF ELEPHANTS IN THE GREATER MAPUNGUBWE TRANSFRONTIER CONSERVATION AREA, BOTSWANA, SOUTH AFRICA AND ZIMBABWE, AUGUST 2014

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ACKNOWLEDGEMENTS

The Botswana Department of Wildlife and National Parks, the Zimbabwe National Parks and Wildlife Authority, Botswana DCA, Zimbabwean Defence Force, and the landowners within the study area are thanked for permission to conduct the survey. The following organisations sponsored the 2014 elephant count – Elephants without Borders, Bateleurs, Northern Tuli Game Farmers Association, SANBI and South African National Parks. The van Rensburg provided accommodation, support preparing meals and transport. The survey dependent critically on their support and we are extremely grateful for their generosity. A word of thanks to Pete le Roux who assisted with sourcing and collecting AVGAS for the aerial count, Alec Dangare for their assistance on the Zimbabwean side, and Dennis Summers and his airfield team for always being ready and waiting to help with the refuelling of the planes. A special word of thanks to Raymond Steyn, Tim Webster and Chase Wells for their superb flying, all the counters and data capturers for their assistance and time, Eco-training for assisting with counters and Hamish Gilfillan for all the arrangements and logistical support. Hamish spent considerable time organising logistical support and purchasing supplies for the count and we are extremely grateful.

EXECUTIVE SUMMARY

During the 2014 dry season, a fixed-wing aerial survey of elephants in the Greater Mapungubwe Transfrontier Conservation Area (GMTFCA), Botswana, South Africa and Zimbabwe and of large mammals in the Northern Tuli Game Reserve (NTGR) and Mapungubwe National Park (MNP), Botswana and South Africa were conducted. The aerial survey was commissioned by the Central Limpopo River Valley Elephant Research Project and the Northern Tuli Game Farmers Association (Notugre). Three fixed-wing planes were used to fly a total count of the elephant population, with parallel transects across the GMTFCA study area, while one fixed-wing plane was used to fly a total count of large mammals in the NTGR and MNP. The study area totalled 2905km^2. The principle objective of the survey was to provide relative accurate estimates of the numbers of elephant and other large mammals in the survey area, using methodology similar to previous counts, to ensure repeatability and monitor trends in numbers and distributions of elephants and other large mammals within the study area. This report provides the results of this survey. Maps and tables illustrating the distribution, numbers, density and trends of large mammal species in the study area are provided.

The elephant aerial survey was undertaken on the 15th – 16th August 2014. The objective of the survey was to determine the distribution of the CLRV population, group size distribution, and total numbers and is the 8th survey conducted since 2000.

A total of 1449 elephants were counted during the 2014 survey. This is slightly higher than any of the previous counts. Distributions have however changed dramatically since the 2007 count but also substantially since 2012 count. Over the past decade, increasing numbers of elephants have moved into Mapungubwe National Park and onto game ranches in South Africa, while numbers in the Northern Tuli Game Reserve seem to be declining slightly. Elephants are now observed regularly on several properties on the South African side and fence breakages between properties occur frequently. The distributions in 2014 were different to those encountered in 2012 with a large number of elephants moving from South Africa into the lower Tuli Block.

Data from the counts further indicate that group size is strongly correlated to rainfall with a higher number of small groups within years with low rainfall and fewer but larger groups in

years with high rainfall. The study area received above average rainfall prior to the 2014 count (434 mm between September 2013 and August 2014), but was preceded by two years of below average rainfall, resulting in an average herd size of 22 similar to the average herd size (21) for all count years combined.

As a result of the shift in elephant distribution and higher numbers moving along the Limpopo River, human-elephant conflict is increasing in the area. Information on the shifts in range as well as on total numbers and the distribution in the range is required to avoid human-elephant conflict. Control hunting in response to conflict combined with legal trophy hunting and as well as poaching also influences movements and numbers. Information on the numbers and distribution are thus important to determine the effects of hunting.

The large mammal total aerial survey was undertaken on the 16th August 2014. This is the 17th survey within the NTGR but only the 3rd survey for the NTGR and MNP combined.

The population estimates for wildebeest, giraffe, eland, zebra and warthog have significantly increased over the period 1984 – 2014. However there have been significant declines in impala and ostrich numbers from 1997 to 2014. Kudu numbers have also declined significantly from 631 in 1984 to 141 in 2014. Both eland and wildebeest show a decline in numbers from 1997 – 2014, but these declines are not statically significant. Giraffe numbers have continued to increase from the original introduction of 22 animals to 407 animals in 2014. It is however impossible to determine the cause or causes of the recent declines in several species because surveys were only conducted within the NTGR and MNP (only in certain years) and did not include the entire distribution range of the various species that move in and out of the NTGR for example eland, giraffe, blue wildebeest and zebra. Counts conducted in the TSA can at best be considered minimum estimates for species due to the flight height and strip width used.

An analysis of the rainfall conditions over the period of the large mammal counts (1984 – 2014) indicate that rainfall in the region has been extremely variable with two extended periods of below average rainfall recorded (88/89 – 93/94 and 00/01 – 06/07) .

Various ecological and climatic factors may influence population estimates. Rainfall as a proxy for primary productivity influences the distribution and group sizes of elephant in the

CLRV. While we could not show any correlation between the population estimates of game species and rainfall, others have demonstrated the influence of rainfall on population densities. Natural predation further may influence population estimates within protected areas with healthy or increasing predator populations. Management activities within the different management units allow for the harvesting of species through hunting which includes offtakes as part of staff rations, trophy hunting and biltong hunting.

In light of the complexity of factors influencing population trends, the observed decline in several species and to understand the consequences of management activities such as hunting the effective monitoring of a variety of parameters are essential. Long term monitoring of population numbers and offtakes are further essential for the implementation of an adaptive quota system based on population trends and where populations span across administrative and/or international boundaries, cooperation between managing authorities allowing for the management of these species on a population level is imperative to their persistence.

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INTRODUCTION

No form of wildlife management whether it is the establishment of hunting or cropping quotas, the development of tourism or the demarcation of boundaries is possible without reliable information on the numbers, population dynamics and movements of the animals concerned (Selier and Di Minin 2015). Reliable game counts that are repeatable and capable of detecting trends in population increases or declines are one of the cornerstones of effective wildlife management. Several methods of game counting exist and the method of choice is determined by the size of the area, terrain, vegetation type, game species to be counted, manpower and cost.

For large mammal species total aerial counts in which the total area of interest is flown in transect sufficiently narrow to easily locate, identify and count the species of interest have proved reliable in many different localities . The objective of a total game count is to locate and count every animal in the census zone. Because it is a single sample, a statistical sample error cannot therefore be calculated and attached to the final estimate of numbers. There are however other sources of error and bias when conducting a total aerial count. These are (i) failing to search the whole area in which the animals of interest might move; (ii) failing to locate all the herds or individual animals and (iii) failing to count herds accurately. The above errors can be minimized by using sufficiently narrow strip widths, by controlling the height and speed of the aircraft and by using skilled and experienced counters.

Within the Northern Tuli Game Reserve 15 total fixed-wing aerial counts of large and intermediate sized mammal species have been conducted since 1984 primarily during the dry season. Data from these counts are invaluable to the reserve as they provide an indication of the variability in population numbers in the NTGR which has extremely variable rainfall. It also provides an indication of poaching and harvesting effects, and the effects of predation on herbivores. The longer a database is running, the more valuable and useful the data.

Elephants are one of the charismatic species of the Central Limpopo River Valley (CLRV) that roam freely between Botswana, South Africa and Zimbabwe and the main draw for tourism to the area. The first estimate of the elephant population in the region in the late 1970's was 1200 (Feely 1975, Nchunga 1978). The first aerial survey of the NTGR was conducted in June 1976, which counted 498 elephant in the Northern Tuli game Reserve (Walker 1977). The civil war in Zimbabwe (then Rhodesia) at this time prevented a count in the entire region. Regular aerial censuses of the NTGR area were undertaken until 1998. In 1999 the range of the elephant population was determined from a literature survey, questionnaires, interviews and by recording signs of the presence of elephants in the region surrounding the NTGR (Selier 2007). From the initial survey the region bounded by latitudes 21º 00' and 22º 40' south and longitudes 27º 30' and 30º 00' east, an area of some 185 km x 260 km, was defined as the potential range (Selier 2007) (Fig. 1). Seven total aerial counts were conducted between 2000 and 2014 within subsections of the previously identified potential range where elephants where known to have occurred in the years preceding the count.

Due to the cross border distribution of elephant and several other large mammal species including lion, giraffe and eland the different agencies in each country manage these cross-border species differently. In particular licences for control hunting in response to conflict and trophy hunting are issued independently and without cognisance of movement of animals between the three countries (see Selier *et al*. (2014) for a discussion on elephant). It is thus imperative that the populations of each species are surveyed in the entire range in order to facilitate management that ensures persistence of the species.

Large and intermediate size mammals, including giraffe, eland, kudu, wildebeest, zebra, impala, waterbuck, and warthog but excluding elephants were counted in the Northern Tuli Game Reserve (NTGR) and Mapungubwe National Park (MNP) on the 16th August 2014. Elephant were counted separately in a regional survey of the Central Limpopo River Valley on the 15th and 16th August 2014. Smaller and more cryptic species such as the predators that cannot be counted from the air were not included in this survey. Separate studies are in place to assess these numbers.

This report presents the results of the two surveys together and compares the results with previous aerial surveys conducted within the region.

STUDY AREA

The Central Limpopo River Valley (CLRV) elephant population's current distribution span three southern African countries namely Botswana, South Africa and Zimbabwe an includes an area of some 180 km along the Limpopo River between about Zanzibar in the west and Beit Bridge in the east, in a belt of about 20 km on either side of the river (Fig. 1). Historically elephants roamed freely across the entire Central Limpopo River Valley until approximately the start of the twentieth century during which hunting and increased human densities and agricultural activities led to the near extinction of elephants in the Limpopo Valley (Forssman, Page et al. 2014). With the establishment of the NTGR in the early 70s and its presidential declaration as a private game reserve under the Wildlife and National Parks Act, sec. 13, elephants started increasing within the region and slowly expanded their range moving east across the Shashe River into Zimbabwe and further west along the Tuli Block in Botswana. In 2006 the Greater Mapungubwe Transfrontier Conservation Area (GMTFCA) was established with the signing of the Memorandum of Understanding (MOU) by the Governments of the three partner countries. The GMTFCA is a transboundary park between Botswana, South Africa and Zimbabwe with the present core area covering 2572.98 km^2 centred on the confluence of the Shashe and Limpopo rivers and has the potential to double to 5638.23 km^2 (GMTFCA TTC 2011). The GMTFCA includes several properties within Botswana, South Africa and Zimbabwe (Fig. 1).

The area is low lying, hot and arid with much of its surface taken up by rocky hills and escarpments. The climate of the region is semi-arid sub-tropical. Rainfall is low (mean annual rainfall is 361 mm and median 348 mm) and unpredictable (range 136 to 917 mm) (Harrison 1984). Permanent natural surface water is confined to a few small pools in the channels of the major rivers, although elephants both obtain and provide water by digging in the sandy beds of the rivers. Droughts are frequent.

A bank of Karoo sandstone cuts through the centre of the area, straddling the Limpopo and lower Shashe channels. This provides a spectacularly rugged landscape (Alexander 1984). A second wide band of rocky basalt ridges occupies most of the northern part of the area (Le Baron, Grab et al. 2011). The southern part is made up of mixed geology forming a series of

steeply undulating rocky hills and scarps (CESVI 2001). The vegetation is broadly classified as Mopane Veld (Mucina and Rutherford 2006). Four broad vegetation types make up most of the area. These are (i) *Acacia/Faidherbia* riparian woodland, (ii) Cultivation on alluvium with scattered *Acacia* woodland (iii) *Colophospermum/Terminalia* Woodland to shrubland and (iv) *Albizia/Combretaceae* clumped open woodland to shrubland on sandstone (Timberlake, Mapaure et al. 1999). In the *Colophospermum/Terminalia* Woodland on shallow, rocky, basalt derived soils on hilltops *Combretum apiculatum* dominates, while on the deeper, less rocky soils at the foot of the slopes *Colophospermum mopane* dominates. *Terminalia pruniodes* is a sub-dominant, with *Commiphora tenuipetiolata*, *C. glandulosa* and *C. merkerii* occurring at lower densities (Nchunga 1978). On the Sandstone outcrops *Colophospermum*, *Combretum* and *Terminalia* occur at densities and *Commiphora* species are more abundant. In the Riparian Woodland *Acacia tortilis* and *Croton megalobotrys* dominate. Along the larger rivers, riverine forests occur in which large individuals of *Xanthocercis zambeziaca*, *Philenoptera violacea* and groves of *Acacia xanthophloea* and *Hyphaene benguelensis* occur. Aquatic grasslands dominated by *Sporobolus consimilis* occur adjacent to the larger rivers.

Land use in the CLRV varies across the elephant range. In Botswana the area along the Limpopo consists of a number of adjoining farms, which form an area known as the Tuli Block (Fig. 1). The core of the study area is the NTGR. This is an area of 77 000 ha that lies north of the Limpopo River and west of the Shashe River to just west of the Motloutse River (Fig. 1). It consists of a number of privately owned farms bounded by the Limpopo, Motloutse and Shashe Rivers are privately owned and used for commercial tourism. To the southwest of the NTGR, farms that lie between the Baines' Drift / Platjan border post to Talana, an agricultural development just west of the Motloutse River, are referred to as the Baines' Drift – Motloutse River Farms (BDMRF). South of the BDMRF between the Zanzibar and Baines' Drift border posts the farms are referred to as the Zanzibar – Baines' Drift farms (ZBDF). These farms are used for game ranching, hunting and cattle farming. Movement by game (including elephants) between the NTGR and the BDMRF is relatively unrestricted. There is a 2 m electrified game fence on the eastern border of Terrafo Ranch, which separates the BDMRF and the ZBDF. This fence is broken through occasionally by elephants, but movement along the Limpopo River is unrestricted. West of the NTGR is the communal land of the Batswana that is mainly used for subsistence crop and cattle farming. The number of people varies from around 3000 in towns like Mathathane and Selebi-Phikwe

to as few as 10 people in the cattle posts spread out over a large section of the area (Selier 2007). Movement of game between the NTGR and the communal land and between the BDMRF and the communal areas are partially restricted by a 2 m high electrified game fence. A double 3 m high electrified military fence runs along the Limpopo on the South African bank opposite Botswana and Zimbabwe. Opposite the confluence of the Shashe and Limpopo Rivers where the MNP is situated, an area known as the Vhembe Gap was unfenced until 2002 when a 1.5 m high electrified cattle fence was erected. North of the NTGR is the Tuli Safari Area (TSA). This is a 41 600 ha controlled hunting area that is managed by the Zimbabwean National Parks and Wildlife Authority. The border between the TSA and NTGR is unfenced. To the north of the communal areas within Botswana a 2 m high game fence runs along the southern bank of the Shashe River, and joins with the western boundary fence of the NTGR. On the eastern side of the Shashe River is a 6 km strip of communal land called Maramani. The area of Maramani covers about 49 000 ha and is inhabited by about 5 200 people and an unknown number of livestock (CESVI 2001). Sentinel Ranch (30 000 ha) is situated east of Maramani. Nottingham Estate comprising some 25 000 ha is situated east of Sentinel Ranch (CESVI 2001). The main commercial activity on this ranch is citrus farming. Hunting (including elephants) occurs on both farms and within the communal areas to the east, west and north through the CAMPFIRE (Communal Areas Management Programme For Indigenous Resources) program (Selier, Page et al. 2014). The northern borders of both Sentinel Ranch and Nottingham Estate are fenced with a 1.5m high cattle fence. River Ranch occurs to the east of Nottingham Estate. This is a resettled farm of about 17 000 ha. About 60 families have settled within the southern part of the ranch and use it for livestock grazing (CESVI 2001). The three ranches together are referred to as the Sentinel - Nottingham - River Ranch Complex (SNRC).

The NTGR, TSA and MNP form the core of the GMTFCA. Several wildlife based tourist operations occur in the Tuli area and depend on the presence of elephants for their success while along the Limpopo and Shashe rivers several citrus and crop irrigation farms are often in conflict with the expanding elephant population.

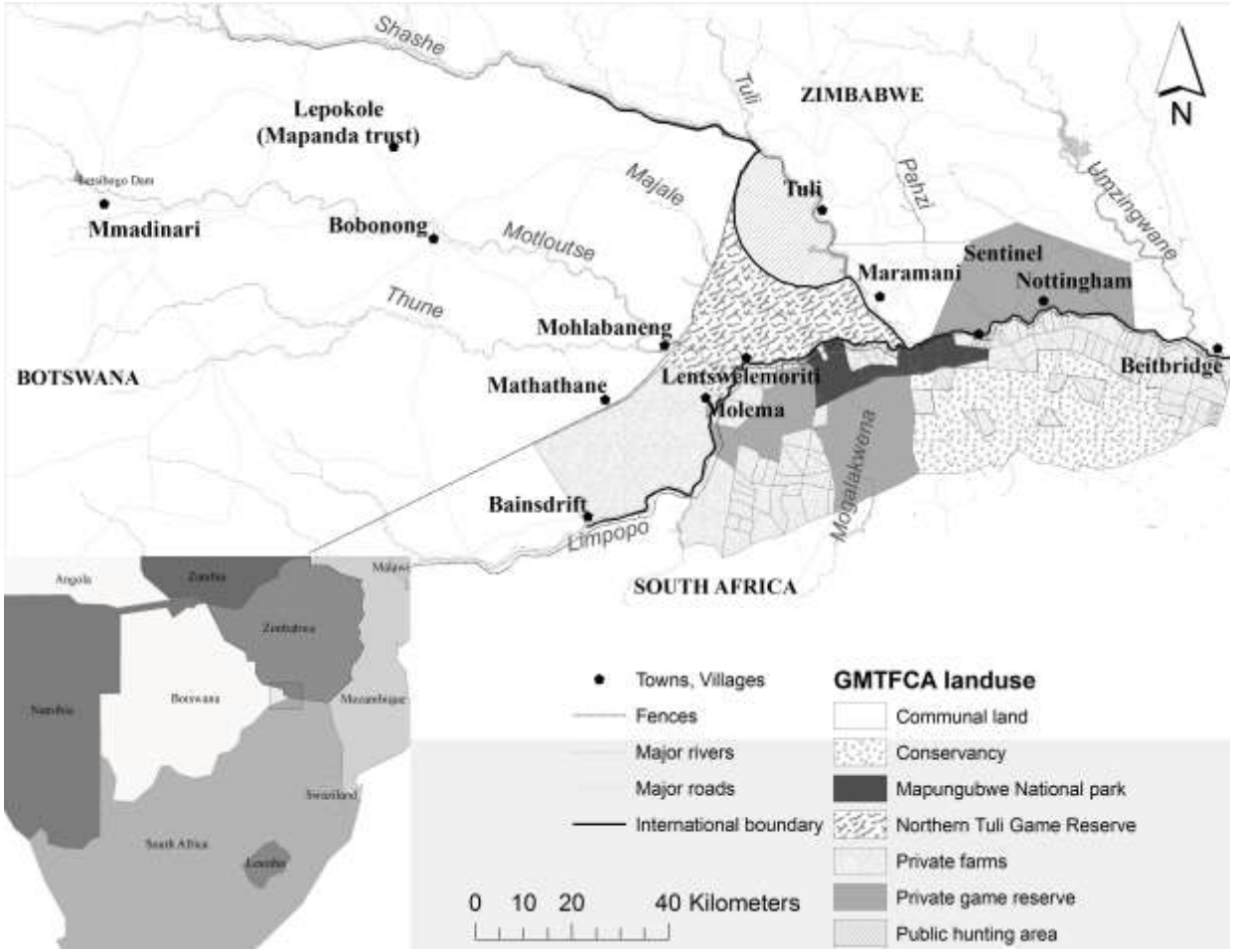

Fig. 1: The Central Limpopo River Valley between 21° 15' and 22° 40' South and 27° 30' and 30° 00' East, showing the major rivers, roads towns and villages and land use types.

METHODS

FIXED WING AERIAL SURVEY DESIGN

The elephant and general game counts were conducted separately. Authorization from all landowners and relevant Government departments in all three countries were obtained prior to the count.

CLRV ELEPHANT COUNT

A total aerial count of the CLRV elephant population was conducted over a two-day period (15 -16 August 2014). The methodology was similar to those of previous years. Three fixed-wing aircraft (Cessna 206 and two C182Ts) were used on day 1 and two fixed wing aircrafts on day 2 to count the study area simultaneously. A team consisting of a pilot, navigator and two observers were used. The two observers, one positioned on each side of the aircraft counted elephants on either side of the aircraft and relayed the information via an intercom to the navigator, who also recorded the position of the aircraft. Data and flight paths for the study area were recorded on a Cybertracker and combined with photographs taken of the various elephant groups encountered. All herds detected were circled to get an accurate count and photos are taken to verify numbers and to determine rough age structures. The central areas in which the majority of the elephants occurred (NTGR and Mapungubwe) were counted on the first day and the more outlying areas are left for the next day.

Because of reports of changes in the distribution an additional area, Mapungubwe Private Reserve (Vhembe), was added to the survey in 2012. Further because no elephants were encountered in the vicinity of Letsibogo Dam and along the northern reaches of the Shashe and Motloutse rivers, this river survey was omitted from the census for the 2012 and 2014 counts.

Flight lines ran roughly parallel to the Shashe River and were therefore aligned in a roughly NW-SE direction for the entire study area. Transects were 1 km wide (500m each side of the aeroplane) and flying height 100 m to 150 m with a flight speed of 90-100 knots. The transect width was set at 1 km due to the openness of the area (Figs. 2 and 3).

Fig. 2: Elephants from the air showing the openness of the terrain.

Transects were allocated to different aircraft such that the start and end of transects flown by different aircraft and on successive flights by the same aircraft would ensure that double counting did not occur.

On day one the Tuli circle (TSA) was flown by aircraft one (Tim Webster) (Fig. 3A), the Tuli Block from the Motloutse River to Zanzibar (LLMRF) including the south bank of the Limpopo to about 1km away from the river and Mapungubwe Private Game Reserve in South Africa (MPRS) by a second aircraft (Chase Wells) (Fig 3C), the Northern Tuli Game Reserve (NTGR), and the western section of Mapungubwe National Park (MNP) by a third aircraft (Raymond Steyn) (Fig 3D & E). On day two the first aircraft counted the eastern section of MNP and Sentinel Ranch in Zimbabwe (Fig. 3B), while the second aircraft counted Nottingham Estate and River Ranch in Zimbabwe (SNRC) (Fig. 3C). The third aircraft conducted a general game count within the NTGR and MNP.

NORTHERN TULI GAME RESERVE AND MAPUNGUBWE NATIONAL PARK LARGE MAMMAL SURVEY

The area surveyed in the general game count included MNP in the south and bordered the Shashe River in the east, the Tuli Circle in the north the Tuli Back-line veterinary fence in the west and the farm Oerwoud (Redshields) in the south west (Fig. 1). The latter farm has only been included in the counts since 2001.

A Cessna 206 fixed wing, six-seater aircraft was used as the counting platform. An average height of 250 ft AGL was maintained at an average airspeed of 80-100 knots. Aircraft flight lines over NTGR were predetermined and followed those of previous years. GPS coordinates of the end points of each transect were programmed into the GPS. Transects run across the full width of NTGR and surrounding areas (if applicable) in a North/South direction. To achieve 100% coverage, transects were placed on every 28 Seconds of latitude (± 800M apart). The survey was conducted on 16th August.

The entire area was covered in three flights of approximately three, three and two and half hours respectively; flying parallel transects 800 m apart (Fig. 4). Counting therefore occurred in census strips of 400 m either side of the aircraft. A pilot, navigator / recorder and four counters were used. The pilot, navigator and two counters had extensive experience and proven skill in counting game, while the other two counters had moderate previous experience but had high skills levels. Skill and experience are the major factors influencing the accuracy of aerial censuses. A cybertracker supplied by South African National Parks (SANParks) was used and accurately recorded the numbers and the distribution of the animals as they were encountered and entered. This gave an accurate location of the aircraft at each sighting (Fig. 3 & Fig. 4). It also had an added benefit of recording the exact track that the aircraft flew so that one could verify that the transect widths were correct and flown accurately.

Whilst conducting the elephant survey in the Tuli Circle general game was also counted but at 500 ft AGL with a strip width of 1000 m. The figures are thus not an accurate reflection of total numbers of game within the Circle but a rough indication of numbers in the Tuli Circle.

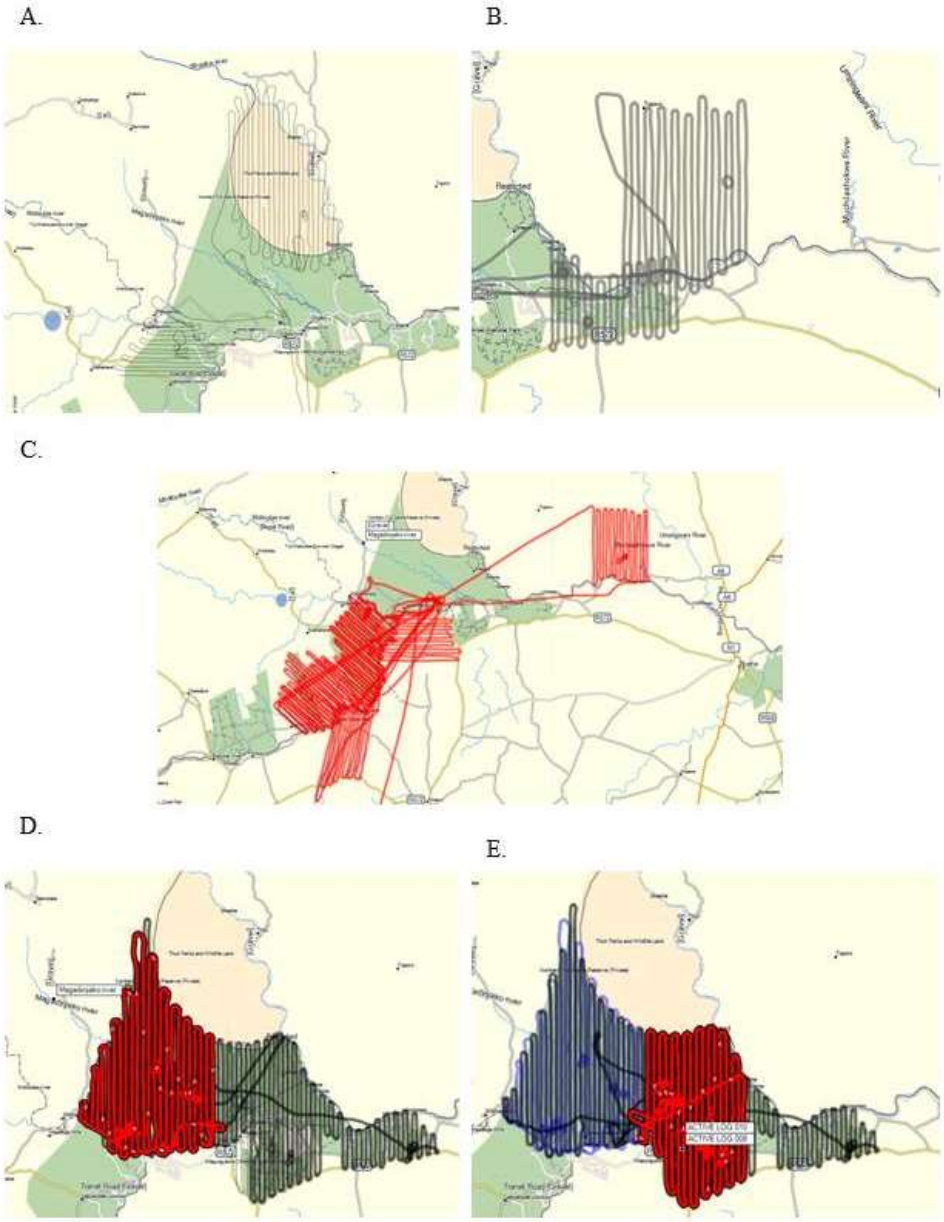

Fig. 3: Flight lines for different areas counted during the elephant survey. A) Flight paths for the Tuli Circle, B) eastern section of Mapungubwe National Park in South Africa and Sentinel Ranch in Zimbabwe, C) Tuli Block in Botswana, Mapungubwe Private Game Reserve in South Africa and Nottingham Ranch, Zimbabwe, D) western section of the Northern Tuli Game Reserve and E) the eastern section of the Northern Tuli Game Reserve.

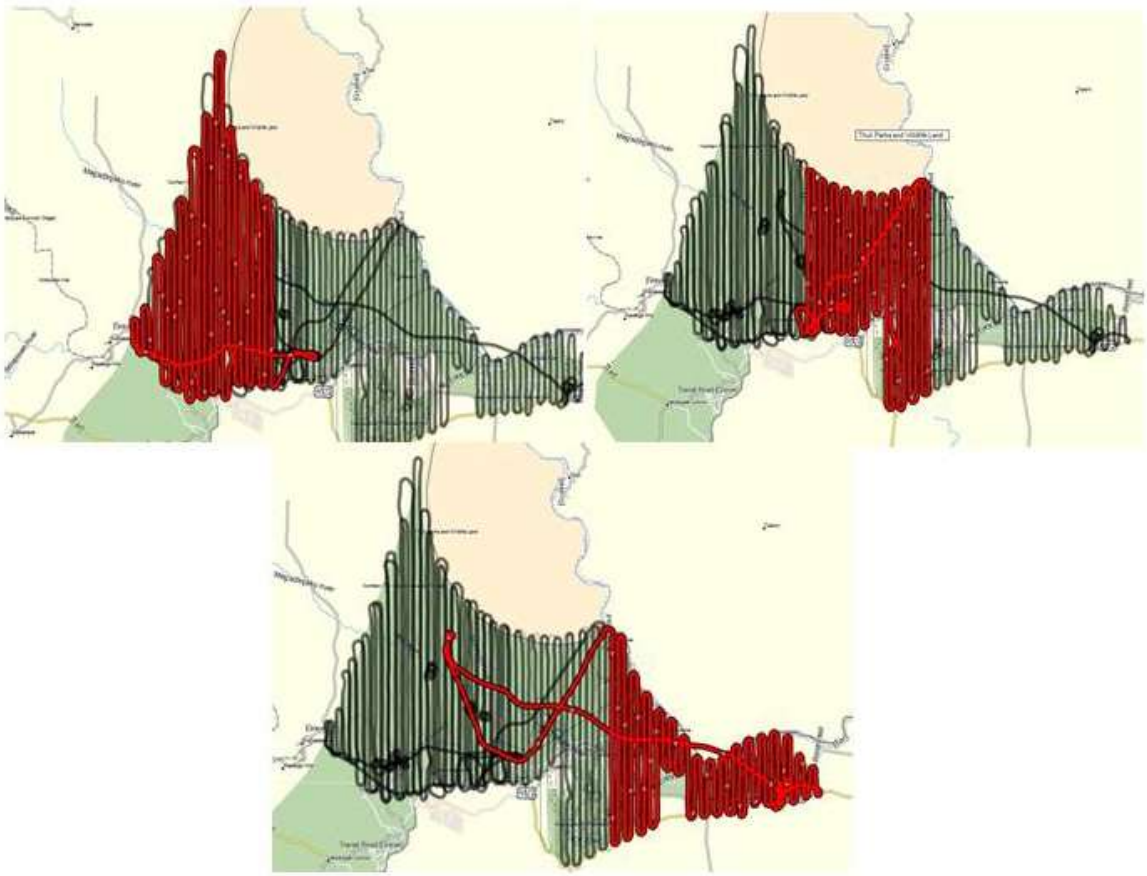

Fig. 4: Flight lines and area covered in the three flights during the general game count within the Northern Tuli Game Reserve and Mapungubwe National Park.

RESULTS

CLIMATIC CONDITIONS AND VISIBILITY

On the morning of the 15th the conditions were ideal for counting. The wind started picking up from the east towards the afternoon with resulted bumpy conditions. On the morning of the 16th we woke up to a howling wind. Due to time constraints we had to fly in less than ideal conditions as the cross wind component on the north-south transects was between 20 and 27 knots or 37km/h to 50km/hr. The two 182's only had to fly in the morning to complete the elephant count and had the advantage of being able to fly a bit higher.

The count followed an above average rainfall year of 434 mm (July 2013 – June 2014) to a mean of 350 mm (46 year period) measured at Pontdrift weather station (Fig. 5). Surface water was still well distributed with all of the rivers, containing pools at regular intervals and most dams still with water.

Rainfall in the region is variable and two extended periods of below average rainfall have been recorded (88/89 – 93/94 (one year (90/91) of above average rainfall) and 00/01 – 06/07) (Fig. 5).

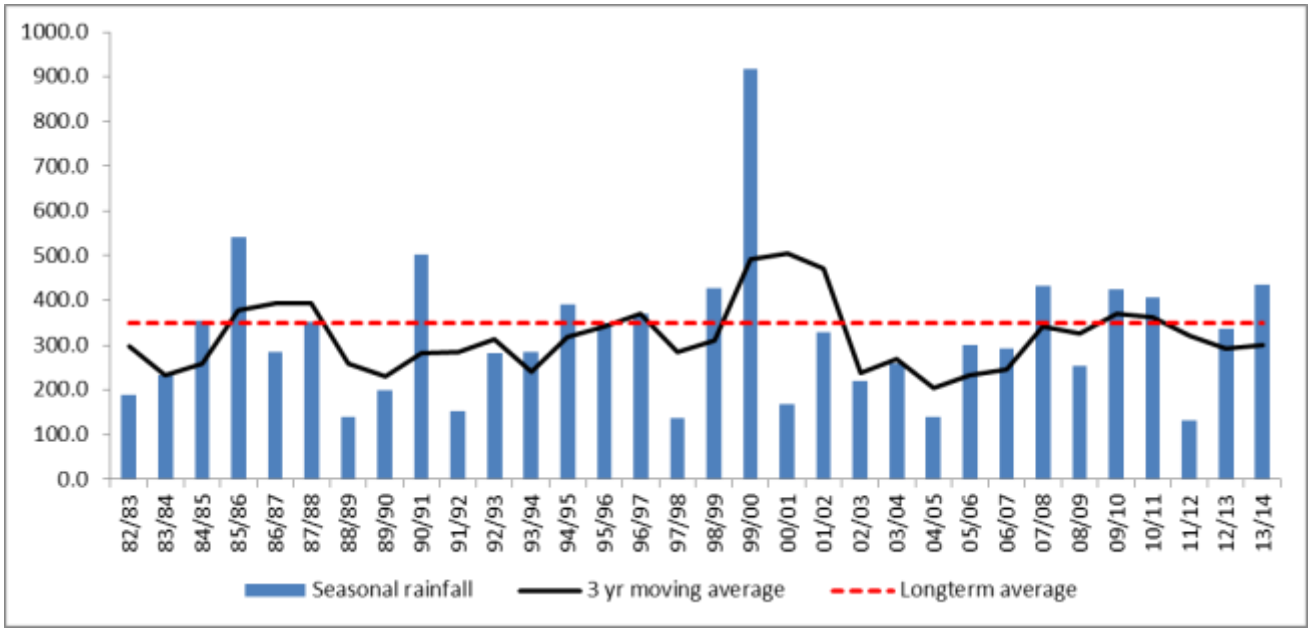

Fig. 5: Seasonal rainfall (blue) as measured at Pontdrift weather station from July to June of the following year for the period (July 1982 – June 2014). Bars indicate annual seasonal

records (July – June) and solid line indicates three year moving average. The horizontal dotted line represents the long term average (July 1966 - June 2014).

WILDLIFE ESTIMATES AND DISTRIBUTION

The numbers and densities of elephant and other large and medium-sized species counted within the NTGR are presented in Table 1.

Table 1: Densities, numbers observed, average herd sizes and the maximum and minimum herd sizes observed of counted species within the Northern Tuli Game Reserve during the 2014 dry season total aerial count. (Area of NTGR used to estimate density = 720km^2)

	Density (animals/ km^2)	No. individuals counted	No. of herds counted	Ave herd size	STDEV	Max. herd size	Min. herd size
Eland	0.52	400	96	4	4.18	25	1
Elephant*	0.54	388	30	13	13.47	48	1
Giraffe	0.43	329	94	4	3.00	14	1
Impala	5.27	4059	235	17	14.41	90	1
Kudu	0.13	102	28	4	2.31	9	1
Ostrich	0.05	39	26	2	0.91	5	1
Warthog	0.15	119	24	5	9.73	50	1
Waterbuck	0.06	46	4	12	14.39	32	1
Blue wildebeest	1.83	1409	159	9	9.49	40	1
Zebra	0.85	656	120	5	3.77	25	1

**Elephant count was conducted separately.*

Table 2: Game numbers in the Northern Tuli Game Reserve (NTGR), Mapungubwe National Park (MNP) and Tuli Safari Area (TSA) as counted during the 2014 dry season total aerial count.

Species	NTGR	MNP	TSA	Total
Impala	4059	426	284	4769
Blue wildebeest	1409	247	0	1656
Zebra	656	161	109	926
Eland	400	55	31	486
Giraffe	329	35	43	407
Kudu	102	14	25	141
Waterbuck	46	68	0	114
Warthog	119	0	0	119
Ostrich	39	2	14	55
Steenbok	1	0	0	1
Red hartebeest	0	3	0	3
Gemsbok	0	25	0	25
White rhino	0	3	0	3

Flight height and strip width used during the count in the TSA were different from that in the Northern Tuli Game Reserve and Mapungubwe National Park.

Elephant

A total of 1449 elephants were counted during the 2014 survey. The numbers and densities of elephants counted within each of the counting areas are presented in Figure 6. The highest number of elephants was counted within the Tuli Block between the Motloutse River and Baines Drift, while the highest density of elephants was observed within MNP. The TSA, Zimbabwe had the lowest number and density of elephants during the 2014 count.

Note that in the first three counts of 2000, 2001 and 2004 elephants were counted at Letsibogo Dam and along the northern reaches of the Shashe River. In the later counts of 2007, 2008 and 2010 no elephants were counted within these areas and as a result these areas were excluded from the 2012 and 2014 counts.

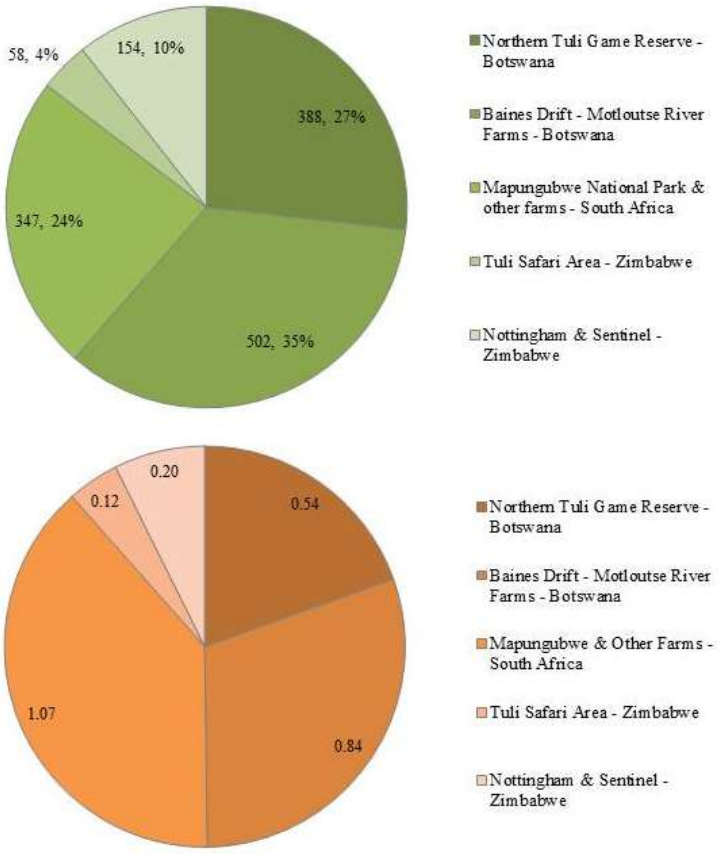

Fig. 6: The numbers and densities of elephant counted within each of the counting sections for the 2014 dry season aerial survey of the Central Limpopo River Valley.

The total number of elephants counted during the 2014 aerial count was slightly higher than any of the previous counts (Table 3).

Table 3: Comparison of the results of the eight total aerial counts of the Central Limpopo Valley elephant population. NTGR – Northern Tuli Game Reserve, MNP – Mapungubwe National Park, MPRS - Mapungubwe Private Reserve and Surrounding Farms, ZMPR - Zanzibar to Mapungubwe Private Reserve, MBB - Mapungubwe National Park to Beit Bridge, TSA – Tuli Safari Area, LLMRF - Limpopo Lipadi to Motloutse River Farms (BDMRF – Baines Drift to Motloutse River Farms in previous Counts), LL - Limpopo Lipadi, SNRC – Sentinel Ranch, Nottingham Estate, River Ranch Complex, LDNS – Letsibogo Dam and Northern Shashe Area, MTRR – Motloutse and Thune Riverine.

Management Area	Total Counted											
	Aug-00	Jul-01	Oct-04	Jun-07	Aug-08	Sep-10	Sep-12	Aug-14	Ave	Median	Max	Min
Botswana - NTGR	490	718	278	619	477	463	320	388	481	477	718	278
RSA - MNP	0	11	2	98	82	280	127	344	86	82	280	0
RSA - MPRS	5	5	5	0	0	0	123*	3	20	5	123	0
RSA - ZMPR	0	0	0	0	0	0	0	0	0	0	0	0
RSA - MBB	0	0	0	0	0	0	0	0	0	0	0	0
Zimbabwe - TSA	57	0	0	3	0	0	0	58	9	0	57	0
Botswana - LLMRF	395	446	535	244	636	190	367	502	402	395	636	190
Botswana - LL	0	0	0	0	0	0**	1	0	0	0	1	0
Zimbabwe - SNRC	170	104	20	116	34***	304	355	154	158	116	355	20
Zimbabwe _Zhove Dam	0	0	250[#]	0[$]	0	0	0	0	36	0	250	0
Botswana - LLDNS	145	10	150	0	0	0	0	0	44	0	150	0
Botswana - MTRR	0	0	0	0	0	0	0	0	0	0	0	0
	1262	**1294**	**1240**	**1080**	**1229**	**1237**	**1293**	**1449**				

** Mapungubwe Private Reserve was included in the count*

*** Count along Tuli Block was extended to the border of Limpopo-Lepadi*

**** Count along the Limpopo River, not a total count of area.*

[#] *Zhove Dam is an estimate from verbal reports.*

[$] *Umzingwane River to Zhove dam included in the count*

Numbers within SNRC for the 2014 count (154) were similar to the 2000 (170), 2001 (104), and 2007 (115) counts and much lower than the 2010 (304) and 2012 (353) counts. During 2004, only 20 elephants were counted within the SNRC, but local reports indicated that a group of approximately 250 elephants were seen near Zhove Dam, a section not included during that year. This number is an estimate and might be much lower than the suggested 250. During the 2008 count due to political unrest in Zimbabwe only a small strip along the Limpopo River were counted explaining the low number of elephants counted during that year.

Elephant numbers within the NTGR were slightly higher than the 2012 count, but lower than the 2010 count, while elephant numbers within the Tuli Block were much higher (502) than the previous count (368) (Table 3). Elephant numbers within MNP have steadily increased since the first count in 2000 (Fig. 7 & 8), while only three elephants were counted in MPRS. Collar data from a breeding herd within MPRS show regular movements of elephants between MPRS and the Tuli Block in Botswana and this could account for the higher total within the Tuli Block and the lower estimate for MPRS.

A total of 58 elephants were counted in the TSA (Table 3). This is the first count since 2007 (3 elephants counted) that elephants were counted within the TSA. Movement data from four

collared herds show short incursions of elephants from the NTGR into the TSA but mainly along the Shashe River.

Botswana had the highest densities of elephants (0.54 elephants/km^2) within the study area, while Mapungubwe National Park had the highest density of elephants (1.02 elephants/km^2) of all the management units (Table 4). Overall the highest concentrations of elephants were found in protected and semi protected areas (NTGR; MNP; LLMRF). These areas also have the highest number of water points in the region and human disturbances are low which may account for the higher densities of elephants within these areas. A lower elephant density was observed within Nottingham Estate and Sentinel Ranch this year compared to the previous count. During the 2011/2012 season low rainfall were recorded with subsequent food shortages for elephants. During the dry season Nottingham Estate where dumping excess oranges on the property, and this attracted large numbers of elephant (Selier 2012). The lower densities during the 2014 count within SNRC could be explained by the higher rainfall, no supplementary feeding of the elephants and the higher number of elephants observed within MNP.

The overall extent of the range has changed since 2000 with a substantial movement of elephants into South Africa since 2007 (Fig. 7). This initially was due to the removal of fencing, but more recently fence breakages have been observed especially along the borders of MNP and MPRS. Several landowners to the east and west of MNP have report elephants venturing onto their properties within the last few years (Selier, pers. comm.).

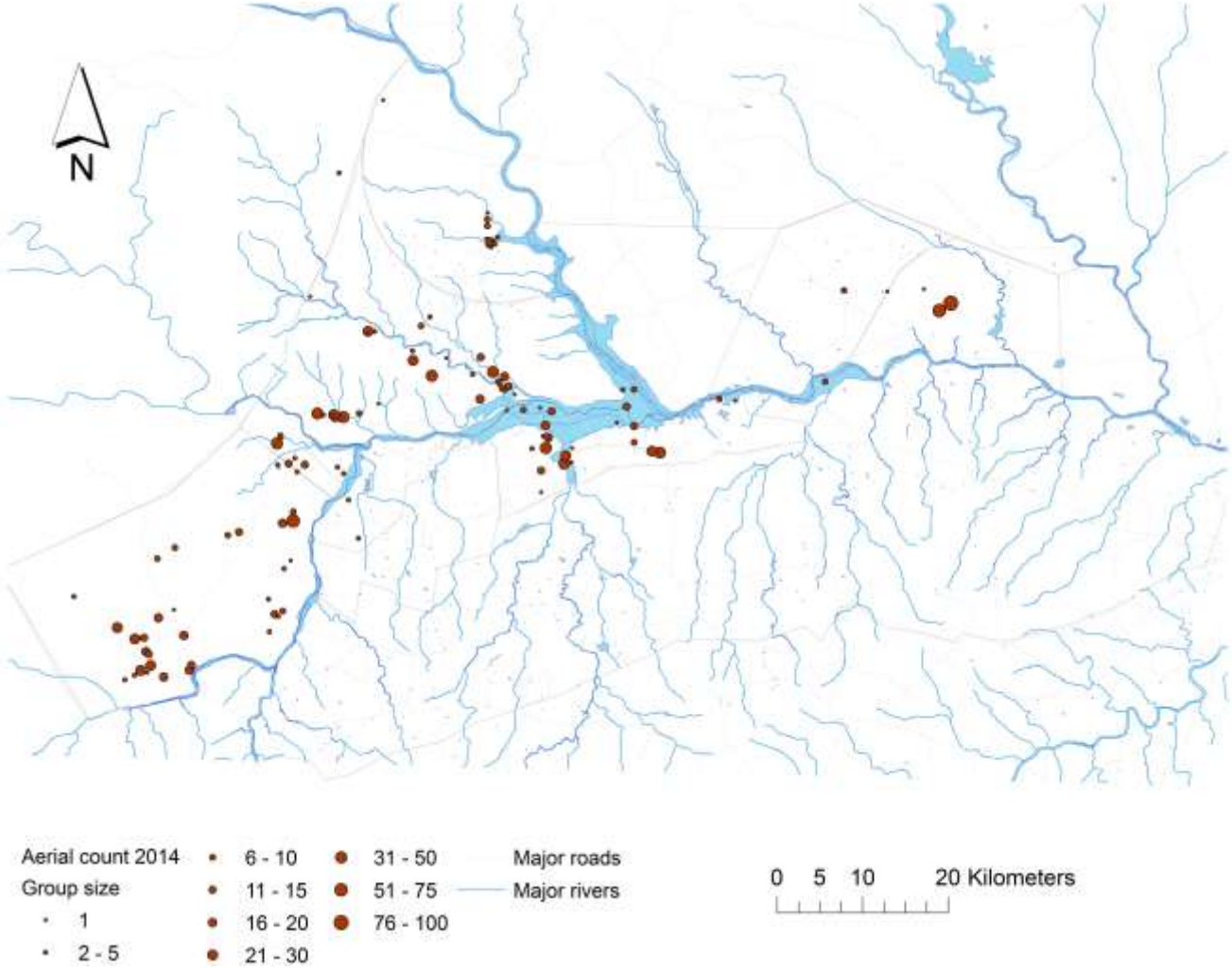

Fig. 7: Elephant distribution and group sizes during the September 2014 total aerial count conducted in the Central Limpopo River Valley.

Table 4: Elephant density distribution within the different regions of the study area

	2000	2001	2004	2007	2008	2010	2012	2014	Ave	Max	Area km2
Northern Tuli Game Reserve - Botswana	0.71	**1.22**	0.40	0.84	0.66	0.64	0.44	0.54	0.68	1.22	720
Tuli Safari Area - Zimbabwe	0.11	0.00	0.00	0.01	0.00	0.00	0.00	0.12	0.03	0.12	500
Baines Drift - Motloutse River Farms - Botswana	0.62	0.48	0.87	0.41	1.06	0.32	0.61	0.84	0.65	1.06	600
Mapungubwe & Other Farms - South Africa	0.02	0.05	0.02	0.35	0.26	0.87	0.77	1.07	0.43	1.07	325
Nottingham & Sentinel - Zimbabwe	0.22	0.14	0.36	0.15	0.04	0.40	0.47	0.20	0.25	0.47	760
	1.69	**1.88**	**1.65**	**1.76**	**2.03**	**2.22**	**2.29**	**2.76**	**2.04**	**3.93**	**2905**

**Due to the political situation at the time only elephants along the Limpopo River was counted. Thus not a total count for Nottingham and Sentinel.*

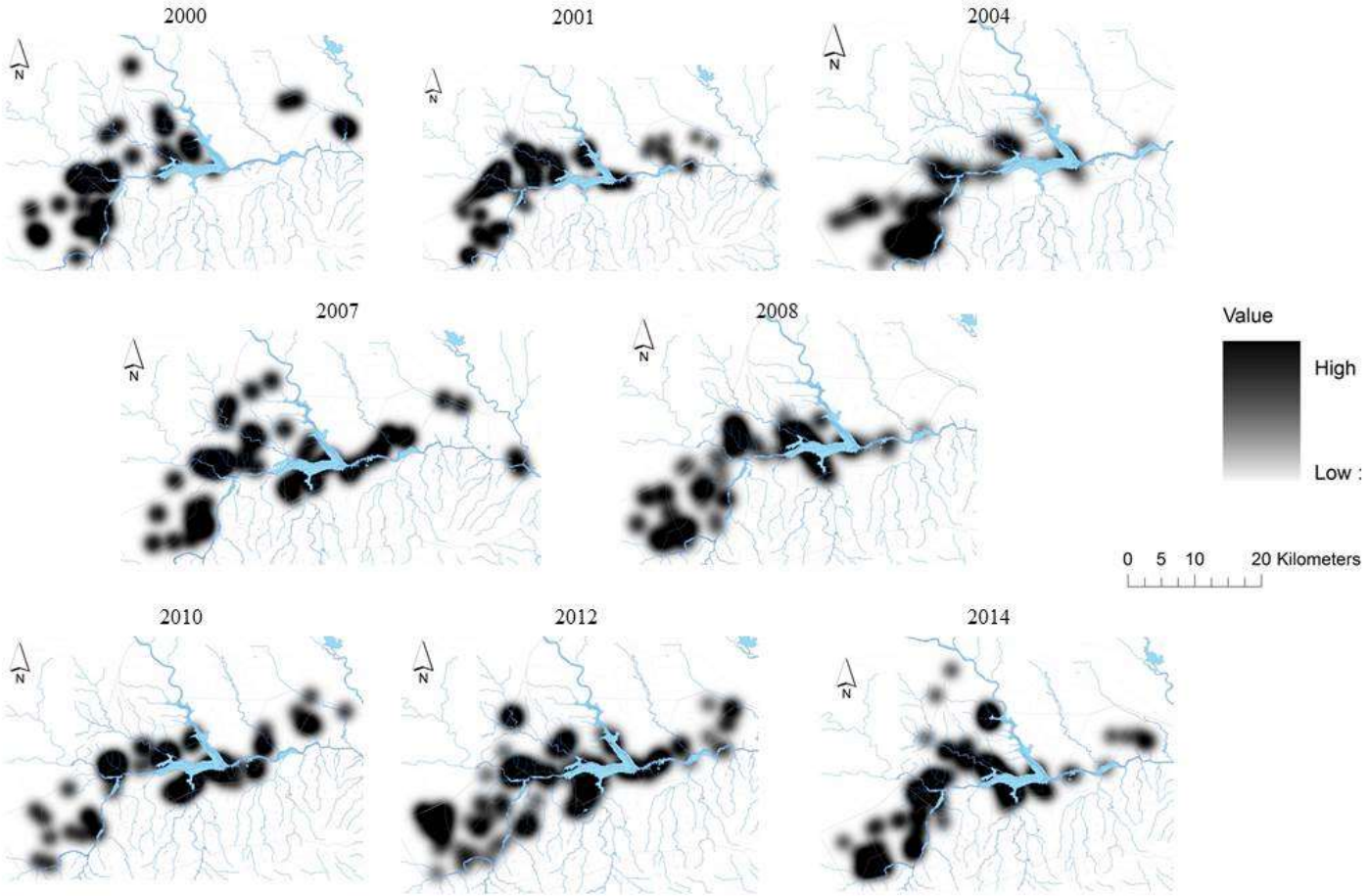

Fig. 8: Comparison of 95% kernel density distribution of elephants for each of the eight total aerial counts conducted in the Central Limpopo River Valley.

The number of elephant groups counted was 54, 105, 82, 61, 111, 76, 114 and 115 for the respective counts in 2000, 2001, 2004, 2007, 2008, 2010, 2012 and 2014 (Table 5).

The average group size for 2000 (35) was highest recorded (Fig. 9). Average group size recorded for 2014 (22) was very similar to the group sizes recorded in 2001 (19), 2004 (18), and 2008 (17), while the average group size recorded in 2010 were the same as recorded in 2007 (28) (Fig. 9). The 2012 average group size of 11 was the lowest recorded for all counts to date. During the 2014 count only three groups with more than 50 elephants were recorded. The two largest groups (72, 78) were counted in the Tuli Block and Nottingham Estate respectively.

The total seasonal rainfall for the 1999 / 2000 season was 916 mm (Fig. 5), and for the 2000 / 2001 season 168 mm. The 257 mm during the 2003 / 2004 season followed two years of below average rainfall, making this the worst of the three seasons, while the total annual rainfall for the 2006 / 2007 season was 293 mm and the 2007 / 2008 season was 433 mm (Fig. 5). The census in 2004 was later in the year (October compared to August in 2000 and July in 2001), while the 2007 census was earlier in the year (June) following a season of late rainfall. During the 2007 / 2008 rainfall year, rain was received early in the season, but little rain was received after March 2008. During the 2009/2010 season high rainfall was received during November and again late in the season during April with a total of 425 mm. For the season 2011/2012 the reserve received 131 mm of rain, the lowest rainfall recorded in the last 100 years. For the 2013/2014 season the reserve received 434 mm of rain following a season of 336 mm during the 2012/2013 rainfall season. However Mashatu main camp measured 606 mm of rain for the 2012/2013 rainfall season. These results suggest that group size is significantly correlated with rainfall ($r = 0.75$; $p = 0.03$) with fewer, larger merged herds occurring in early or wetter winters and more, smaller herds in late winter and in drier seasons (Fig. 9 & Fig. 10).

Table 5: Comparison of results on elephant numbers between the six total aerial counts conducted within the Central Limpopo Valley.

	Aug-00	Jul-01	Oct-04	Jun-07	Aug-08	Sep-10	Sep-12	Aug-14	Mean	STDEV
Total	1262	1294	990	1080	1229	1237	1293	1449	1198	116.909
10% Correction	126	129	99	108	123	123.7	129.3	144.9		
Corrected Total	1388	1423	1089	1188	1352	1361	1422.3	1593.9		
Number of Observations	54	105	82	61	111	76	146	115		
Number of Bulls	28	64	51	32	69	65	63	86		
Bulls as % of pop	2.22%	4.95%	5.15%	2.96%	5.61%	5.25%	4.87%	5.94%	4.43%	1.30%
Average Herd Size	35	19	18	28	17	28	11	19	22	8
Bull:Breeding herd ratio	0.023	0.052	0.054	0.031	0.059	0.055	0.05	0.06		
Median	21	12	10	17	13	18	5	8		
Variance	56.54	20.29	26.89	28.34	12.86	23.95	13.51	14.84		
Number of Breeding herds	35	65	53	38	69	42	114	72		
Number of Bull groups	19	40	29	23	42	34	44	46		

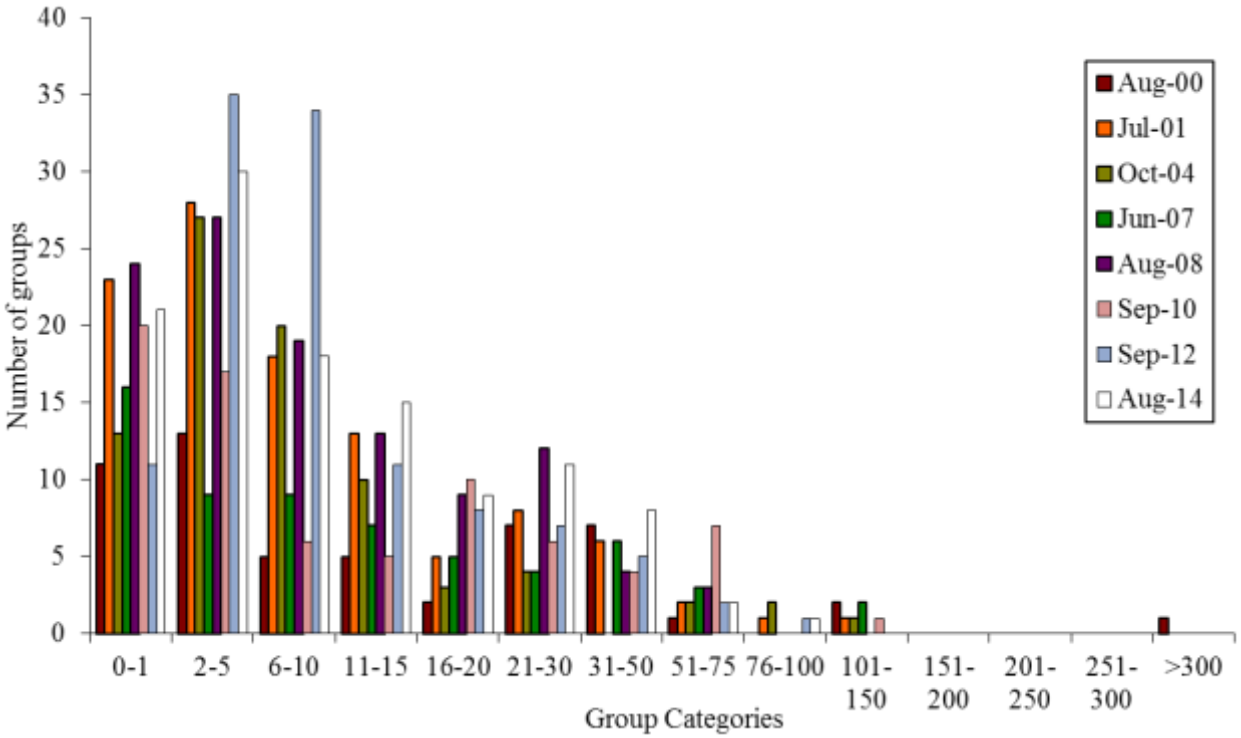

Fig. 9: Comparison of group size distribution for the eight total aerial counts of the Central Limpopo Valley Elephant population.

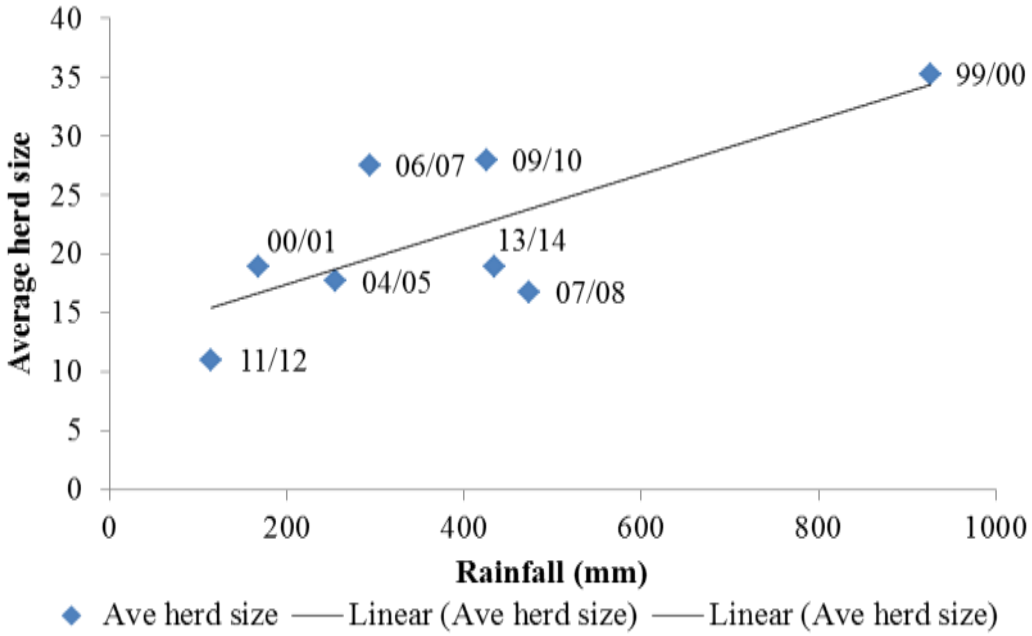

Fig. 10: The relationship between average herd size of elephants in study area and rainfall in the 12 months preceding the aerial count. Each point is labelled with the year of the count.

General game count

Figure 11 presents the distribution of several species within the core area of the GMTFCA (NTGR, MNP, TSA) during the 2014 dry season count. Waterbuck were mainly distributed along the Limpopo River with most of the animals occurring within MNP. Very few kudu were counted and the distribution of kudu seemed to be mainly along the major river systems and their tributaries (Fig. 11E). Tables 6, 7 and 8 present the species estimates for the NTGR (Table 6), MNP and the TSA (Table 7) and the collective totals per species per count year for all three localities were combined (Table 8) for the period 1983 – 2014. Figure 12 shows the trends in the population estimates of some of the utilized species within the area. Three white rhinos and the carcass of a single white rhino poached earlier in the year were observed during the count. Gemsbok and red hartebeest were only observed within MNP, while no warthog and only two ostrich were observed within MNP.

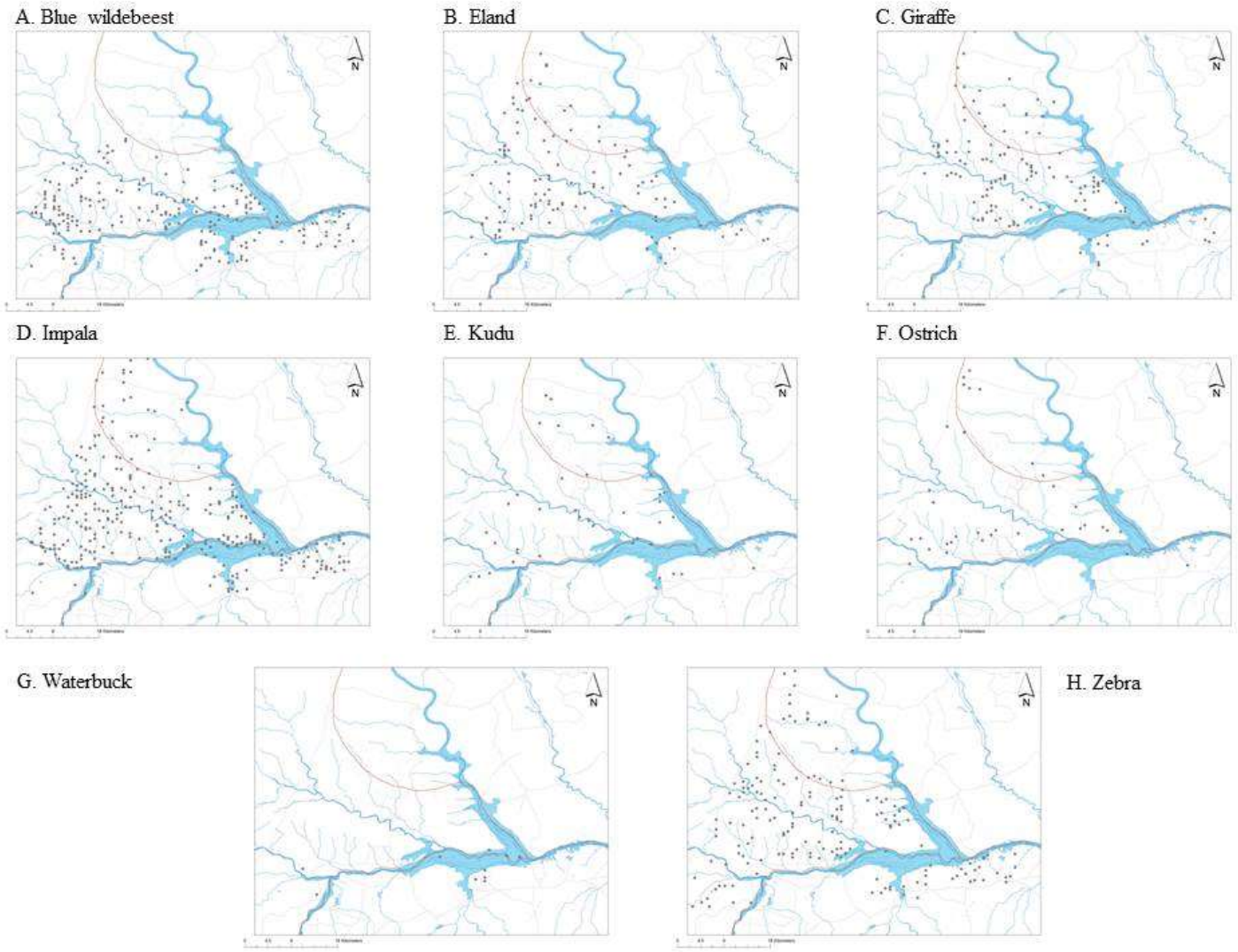

Fig. 11: Distribution of several species counted within the Northern Tuli Game Reserve, Mapungubwe National Park and the Tuli Safari Area during the 2014 dry season aerial survey.

Table 6: Game numbers counted within the Northern Tuli Game Reserve (NTGR) from 1983 – 2014.

	83	84	86	87	88	89	91	93	95	96	97	99	01	07	08	10	12	14
Impala	11000	4637	3832	3232	4871	4119	5748	7134	8012		9771	9124	10950	7452	5034	4605	1909	4059
Wildebeest	1200	102	200	218	272	212	467	582	921	849	1648	1809	1545	719	1361	647	200	1409
Zebra	2500	47	69	110	135	169	218	246	465		640	777	928	590	991	835	255	656
Eland	60	438	573	296	293	99	309	206	237		769	498	1039	493	533	393	373	400
Giraffe					16	26	35	32	63		51	55	218	181	207	150	192	329
Kudu	700	631	649	300	350	378	326	254	227		455	219	406	126	206	201	154	102
Waterbuck		17	40	42	28	6	44	49	22		17	14	55	40	18	2	1	46
Warthog		29	21	23	30	36	63	58	92		93	34	138	85	65	102	37	119
Elephant*	400	567	576	258	617	406	627	587	392	261	690	508	898	603	564	461	320	388
Ostrich	125	69	62	51	62	95	53	92	85		234	165	172	77	105	48	69	39
Steenbok		14	20	13	8	20	41	41	29		28	13	29	12	8	17	9	1
Duiker		3	7	7		3	1		2		2	1	1					
Bushbuck		3	3		1	1	5		3		4		6					
Ground h/b		9	11		3		6	9				1						
Baboon tp		34	24	19	8	6		19	12		11	22	9					80
Hyena		5		3	-	2	-	3	10					11			11	3
Jackal		17	12	14	5	23	19	19	7					5				
Lion		13						4						2				4
B/e fox														2				

Data for Redshields included from 2001 excluding 2010; the 2010 census was only a partial count. The section form Limpopo Valley airfield to the Shashe River and Redshields were not counted due to engine failure.

Table 7: Game numbers counted within Mapungubwe National Park (MNP) in 2007, 2010 and 2014 and the Tuli Circle in 2010, 2012 and 2014.

	07 MNP	10 MNP	14 MNP	10 Tuli Circle	12 Tuli Circle	14 Tuli Circle
Impala	872	1490	426	868	299	284
Blue wildebeest	307	519	247	92	275	0
Zebra	235	277	161	351	472	109
Eland	286	326	55	69	52	31
Giraffe	36	60	35	43	42	43
Kudu	110	114	14	36	8	25
Waterbuck	66	44	68	0	1	0
Warthog	30	193	0	6	0	0
Ostrich	1	2	2	12	11	14
Steenbok	2	16	0	0	1	0
Duiker	5	2	0			
Bushbuck	7	10	0			
Baboons	152	171	0			
Black-back Jackal	5	11	0			
Gemsbok	121	125	25			
Red hartebeest	18	14	3			
Tsessebe	6	1	0			
White rhino	3	4	3			

Table 8: Game numbers within the core area of the GMTFCA when combining the data from the Northern Tuli Game Reserve (NTGR), Mapungubwe National Park and the Tuli Circle where these areas have been counted.

	83	**84**	**86**	**87**	**88**	**89**	**91**	**93**	**95**	**96**	**97**	**99**	**01**	**07**	**08**	**10**	**12**	**14**
	NTGR	NTGR	NTGR	NTGR	NTGR	NTGR	NTGR	NTGR	NTGR	NTGR	NTGR	NTGR	NTGR	Total	NTGR	Total	Total	Total
Impala	11000	4637	3832	3232	4871	4119	5748	7134	8012		9771	9124	10950	8324	5034	6963	2208	4769
Blue wildebeest	1200	102	200	218	272	212	467	582	921	849	1648	1809	1545	1026	1361	1258	475	1656
Zebra	2500	47	69	110	135	169	218	246	465		640	777	928	825	991	1463	727	926
Eland	60	438	573	296	293	99	309	206	237		769	498	1039	779	533	788	425	486
Giraffe					16	26	35	32	63		51	55	218	217	207	253	234	407
Kudu	700	631	649	300	350	378	326	254	227		455	219	406	236	206	351	162	141
Waterbuck		17	40	42	28	6	44	49	22		17	14	55	106	18	46	2	114
Warthog		29	21	23	30	36	63	58	92		93	34	138	115	65	301	37	119
Ostrich	125	69	62	51	62	95	53	92	85		234	165	172	78	105	62	80	55
Steenbok		14	20	13	8	20	41	41	29		28	13	29	14	8	33	10	1
Duiker		3	7	7		3	1		2		2	1	1	5		2	0	0
Bushbuck		3	3		1	1	5		3		4		6	7		10	0	0
Ground h/b		9	11		3		6	9			-	1		0		0	0	0
Baboon tp		34	24	19	8	6		19	12		11	22	9	152		171	0	80
Hyena		5		3		2		3	10					13		4	11	9
Jackal		17	12	14	5	23	19	19	7					10		11	0	0
Lion		13						4						3		0	0	4
B/e fox														3		0	0	0
Gemsbok														121		125		25
Red hartebeest														18		14		3
Tsessebe														6		1		0
White rhino														3		4		3

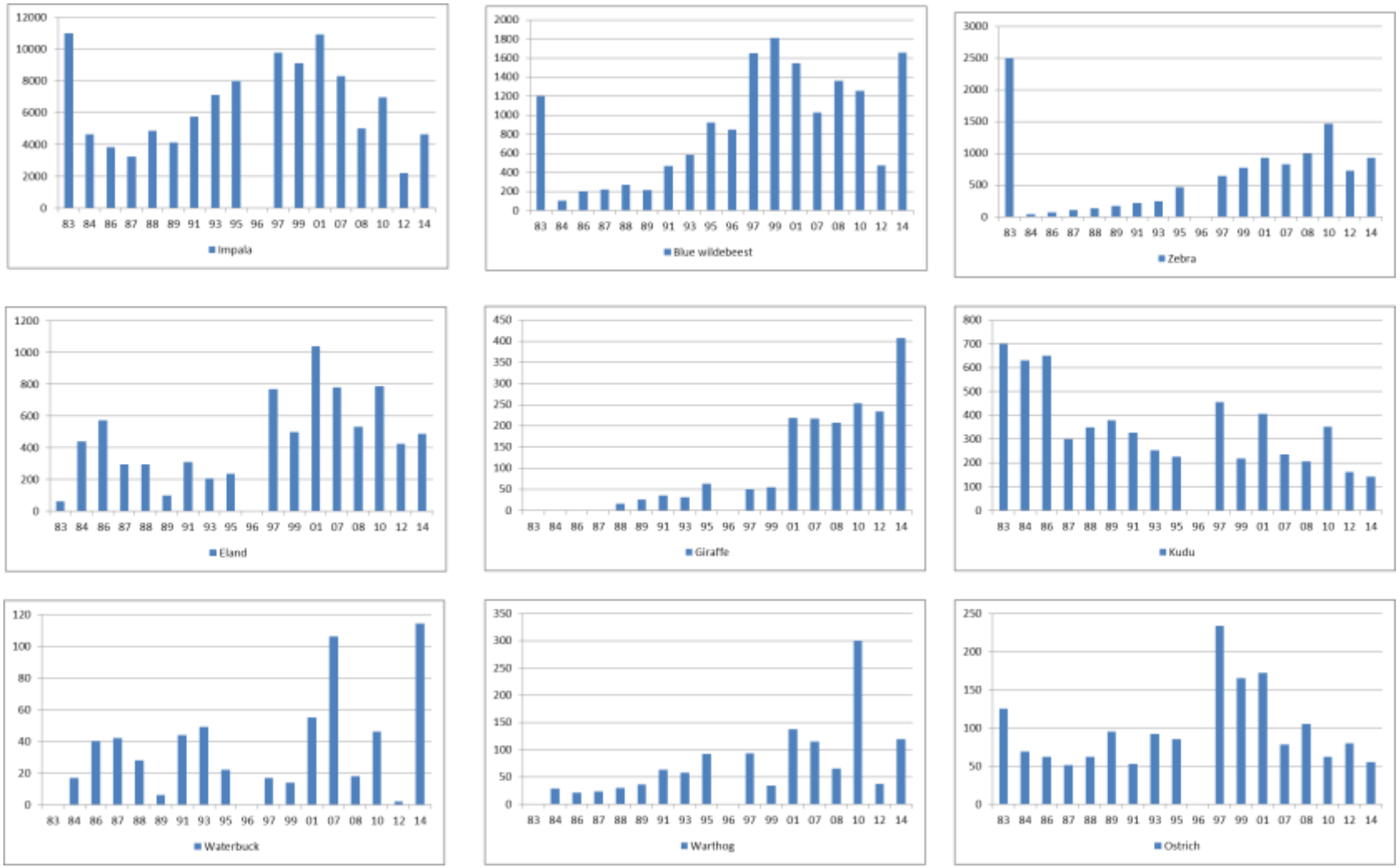

Fig. 12: Trends in specific species numbers when using the combined data from the Northern Tuli Game Reserve, Mapungubwe National Park and the Tuli Circle where these areas where counted for the period 1983 – 2014. Mapungubwe National Park was counted in 2007, 2010 and 2014 while the Tuli Circle was counted in 2010 and 2012. No data available for Redshields during 2010 count.

Table 9: The total number of animals counted per species, the average group sizes and the number of groups per group size category for the large and medium sized species counted within the Northern Tuli Game Reserve during the 2014 and 2012 dry season total aerial surveys.

	Total	No.	Ave.		Group Size distribution									
2014	**counted**	**observations**	**goup size**	**STDEV**	**1-3**	**4-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-50**	**51-70**	**70-100**	**101+**
Blue wildebeest	1409	159	9	9.49	76	10	17	23	8	17	8			
Eland	400	96	4	4.18	55	18	15	5	2	1				
Giraffe	329	94	4	3.00	61	14	15	4						
Impala	4059	235	17	14.41	44	17	50	20	33	22	46	2	1	
Kudu	102	28	4	2.31	16	5	7							
Warthog	119	24	5	9.73	13	8	2				1			
Waterbuck	46	4	12	14.39	2			1			1			
Zebra	656	120	5	3.77	43	31	36	7	2	1				

	Total	No.	Ave.		Group Size distribution									
2012	**counted**	**observations**	**group**	**STDEV**	**1-3**	**4-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-50**	**51-70**	**70-100**	**101+**
Blue wildebeest	200	31	6	4.91	13	2	10	5	1	0				
Eland	373	150	2	1.75	112	29	9							
Giraffe	192	105	2	1.42	93	9	3							
Impala	1909	346	6	5.29	170	62	67	32	6	8	30			
Kudu	154	65	2	1.64	51	10	4							
Warthog	37	18	2	2.62	16	1								
Waterbuck	1	1			1									
Zebra	255	85	3	1.96	76	9								

DISCUSSION

ELEPHANT

Elephant numbers counted within the Central Limpopo Valley during the eight total aerial counts fluctuate between about 1200 and 1450 elephants. No estimate of the accuracy of these counts is possible. Other than two counts since 2000 (Table 3) the population has been counted at between about 1200 and 1300 elephants. In 2007 the estimate was lower at about 1100 and this year significantly higher at 1450. The population in the range surveyed appears to be relatively stable but may fluctuate slightly depending on factors that influence birth and death such as rainfall, predation and hunting, as well as emigration and immigration. The increase in numbers of elephants between the last count in 2012 (1293) and 2014 (1449) is greater than can be accounted for by birth and reduced death rates alone. If the figure is accurate i.e. there were no double counts of herds, the increase might be explained by immigration from areas not included in the CLRV survey. Resource supply is currently high, so it is possible that immigration plus increased survival and birth rates accounts for the higher numbers.

According to age structure data from Amboseli National Park, Kenya, the percent of males >25 years within the population should be approximately 9.5% of the total population (Moss 2001). Within the CLRV the percentage adult bulls >25 years vary between 2.2 – 5.9% of the total elephant population which is much lower than what was observed within Amboseli National Park. The likely cause is the historical and continued offtake of large bulls as either DCAs or hunting trophies from this population. However the number of bulls counted annually combined with the high numbers of bulls hunted each year (Selier, Page et al. 2014) suggests that replacement of bulls is possibly occurring from outside of the CLRV population. The closest resident populations to the CLRV are in Gonarezhou National Park and northern Kruger National Park some 250 km to the east, and Hwange National Park some 400 km to the northeast. Patterson (1999) and other reports indicate that elephants are seen reasonably often between Gonarezhou National Park and the CLRV as well as tributaries of the Shashe to the north of the CLRV. If the exchange of bulls between these populations is occurring it is probable that small groups of females might also move between these areas.

The distribution of the elephant population is mainly determined by the presence of humans and human activity, fences and large river systems, but legal and illegal hunting also appears to have an effect (Selier, Slotow et al. 2015). The data presented above suggests regular movements between the three countries and the different management units such as Sentinel – Nottingham area in Zimbabwe, Mapungubwe National Park (MNP), and the NTGR. However the high density of people in the Maramani area suggests that the movement of elephants are probably along the Limpopo River. There are elephant pathways that enter the communal areas of Machuchuta, Masera, Maramani and River Ranch from the Sentinel-Nottingham Estate area, and residents reported crop raiding by elephants at night and return to the safety of the game farms in the early mornings. There appears also to be some movement to the northeast and east as in 2004 elephants were also observed moving back towards Nottingham Estate from the Zhove Dam (Ambler-Smith, pers. comm.)[2], and Patterson (1999) reported some 30 elephant recorded at Beitbridge. During the 2007 count no elephants were observed in the vicinity of Zhove Dam but elephant utilisation in the area was noted.

Even though several reports of elephants within MNP have been received all counts prior to 2007 only recorded bulls within MNP. During the 2007, 2008, 2010, 2012 and 2014 counts several herds were recorded within MNP and mainly on Little Muck. Elephant numbers within MNP increased significantly from 2000 – 2014 ($r = 0.933$; $p = 0.001$). A fenced population of about 110 elephants also occurs on the Venetia Reserve in South Africa. There are reports of bulls breaking into and out of this reserve, as well a small female herd of some 35 animals that broke into the reserve in 2008 and is now resident there. The absence of elephants from the Tuli Circle Safari Area (TSA) during the 2001, 2004, 2007, 2008, 2010 and 2012 counts can probably be explained by disturbance from extensive hunting. During the 2014 count several bull groups and one herd of 30 elephants were observed within the TSA.

Movement of elephants from the NTGR and BDMRF into the communal areas of the Bobirwa in Botswana has been regularly reported. Elephants make use of the dry riverbeds as well as road crossings to gain access to the communal areas. Recently several reports on the presence of elephants have been received from as far as Zanzibar along the Tuli Block. From

[2] Ambler-Smith, C. November 2004. Manager Nottingham Estate, Zimbabwe. Personal communication.

the 2010 count onwards this area was included in the counts. No elephants were observed within this section of the Tuli Block during the 2010 count and a single bull was observed during the 2012 count. Signs of the presence of elephants however were noted.

During May 2008 a large herd of elephants were reported near Bobonong. During the 2007, 2008 and 2010 aerial counts no elephants were observed along any of the rivers within the communal area. Signs of the presence of elephants were however recorded along the Motloutse and Thune rivers. These areas were not counted during the 2012 and 2014 counts.
During the 2004 aerial count a total 165 elephants were counted at Letsibogo dam. Since 2006, 15 elephants have been placed on the hunting quota for the Mmadinari Trust, 15 for the Mapunda (Lepokole) Trust and three bulls for the Molema Trust (Sechele, pers. comm.)[3]. This could have an effect on the number of elephants counted in the area since the 2004 count. Botswana has however placed a moratorium on the killing of elephants which took effect in January 2014.

It is suggested that the elephants move from Letsibogo dam to the confluence of the Shashe and Ramokgwabane rivers and further north along the Ramokgwabane River. Little sign of elephants were recorded along the Shashe River during previous counts. For most part large herds of cattle and several new cattle posts along the Zimbabwean side of the Shashe River were observed during the 2010 count. Patterson (1999) recorded elephant movement along the Shoshani, Simukwe and Tuli rivers. The high density of people and livestock along this area makes the movement of elephants from the NTGR and TSA along the Shashe River to the Ramokgwabane River unlikely. During May 2008 a large herd of elephants were reported near Bobonong. Signs of the presence of elephants were recorded along the Motloutse and Thune rivers during the 2007, 2008 and 2010 aerial counts. A high number of elephant conflict reports have also been received by the Botswana Department of Wildlife and National Parks for villages Mmadinari, Bobonong and Mathathane for the years 2006 – 2009. It therefore seems likely that there may be movement between the Letsibogo Dam area and the NTGR region along the Motloutse River.

Critique of the census method

[3] Sechele, M. August 2007. Department of Wildlife and National Parks, Botswana. Personal communication.

Counting animals in wild populations is problematic wherever it is undertaken. There are always statistical issues that have to be addressed. The census conducted here suffers from the drawback that no estimates of the counting error can be made. There are always counting errors. Considering that it is also expensive and very time consuming particularly from an organisational perspective in obtaining permission to overfly three different countries, several agencies have suggested that a sample count be undertaken to replace the total count. Such an undertaking is however not straightforward. As the analysis presented above shows, the distribution of herds is strongly contagious in that elephants are associated with rivers. A sample survey would therefore require stratification of the sampling in areas away from and associated with rivers. Location of the boundaries of these areas strongly influences the results, and it is not possible to accurately define were they should be, so the sample size would need to be quite large to take account of this problem. In addition, given the small population and relatively few groups, a large proportion of the population would need to be sampled in order to stabilize the sample variance, and a large sample size would be required to achieve this. To account for both of these problems a large sample covering nearly all of the area currently sampled would be required. This would provide no financial gain or for that matter much improvement in the estimate.

In theory, a total count repeated at least twice, preferably three times in succession would provide estimates of the accuracy of the counts. This would of course cost two or three times as much.

Large areas of Zimbabwe were not sampled in 2008, and the expectation was that more elephants might be found in this area. However the numbers in the Tuli Block west of NTGR increased dramatically from the 2008 distribution, suggesting that elephants may have moved there from the rest of the range. Because flight paths are mapped, double counts are easy to detect when similar numbers are counted on adjacent flight paths, so double counting is not likely.

During the 2012 count group sizes were very small and in some cases family units consisting of a mother and calf were observed. Small groups of elephant are often more difficult to spot and it is possible that during the 2012 count some small groups might have been missed as a result.

GENERAL GAME COUNT

The population estimates for wildebeest ($r = 0.75$; $P = 0.001$), giraffe ($r = 0.91$; $P < 0.0001$), eland ($r = 0.44$; $P = 0.08$), zebra ($r = 0.90$; $P < 0.0001$) and warthog ($r = 0.58$; $P = 0.02$) have significantly increased over the period 1984 – 2014. However there have been a significant declines in impala ($r = -0.84$; $P = 0.01$) and ostrich ($r = -0.90$; $P = 0.002$) numbers from 1997 to 2014. Kudu numbers have declined significantly from 631 in 1984 to 141 in 2014 ($r = -0.70$; $P = 0.003$). Both eland and wildebeest show a decline in numbers from 1997 – 2014, but these declines are not statically significant. Giraffe numbers have continued to increase from the original introduction of 22 animals to 407 animals in 2014. It is however impossible to determine the cause or causes of the recent declines in several species because surveys were only conducted within the NTGR and MNP (only in certain years) and did not include the entire distribution range of the various species. Counts conducted in the TSA can at best be considered minimum estimates for species due to the flight height and strip width used. One or more of the following could possibly explain the recent declines observed in some species:

1. The declines seen could be as a result of actual population declines due to changes in the available resources. In African savannahs, rainfall is a proxy of primary productivity that may determine population numbers of large herbivores and annual changes in densities. During the study period annual rainfall declined over the last 46 years. The 3-year moving average of annual rainfall linearly decreased from 2000 to 2014 (Fig. 5; $F_{1,44} = 6.47$; $P = 0.01$), while only 10 years over the study period had above average rainfall. Several drought years occurred over the study period and the period 2000/2001 to 2006/2007 had seven consecutive years of below average rainfall. Droughts can be detrimental to large herbivores and particularly to selective grazers such as waterbuck. Browse production is more constant over time than grass production making browsers (eland, giraffe, kudu) and mixed feeders (impala) potentially more resistant to droughts than grazers (blue wildebeest, zebra) and particularly selective grazers (Crosmary, Côte et al. 2014).
2. Possible increase in natural predation within specifically the NTGR and MNP. Predators can negatively impact on large herbivore populations. The introduction of wild dogs, improved population status of lions and the healthy leopard and hyena populations could contribute to declines in certain large herbivore species.

3. Dispersal of animals to areas outside of the NTGR. In recent years there has been an increase in the number of wildlife areas within all three countries and it is possible that animals are dispersing into these new areas such as MNP, Mapungubwe Private Nature Reserve, properties within the Tuli Block and into the TSA. Because these areas are not included in the general game count or counted independently by the various management authorities no estimates exist for mammal populations on these properties. This once again highlights the need to monitor species on a population level rather than within administrative boundaries.
4. Increased offtake of animals through trophy hunting, biltong hunting and poaching in several of the management units. Hunting is allowed within the TSA, Mapungubwe Private Nature Reserve and several properties along the Limpopo River within South Africa and properties within the Tuli Block, Botswana. Animals are also removed within the NTGR as part of staff rations. No harvest or illegal offtake data are available for any of the management units and therefore the impact of the harvesting on herbivore populations cannot be calculated.
5. Failing to count all animals accurately. Kudu is one of the more difficult species to count accurately from the air and the low numbers might partially be explained by a failure to spot this species from the air especially where less experienced counters are used or counting conditions are not optimal.

CONCLUSIONS

While protected areas are fundamental for biodiversity persistence in increasingly human-dominated landscapes, they are often too small to sustain viable populations of large mammals. In addition, conservation areas are imbedded within a mosaic of different land uses such as agriculture, cattle grazing, commercial forestry and mining as well as falling under a range of management strategies. Incorporating land uses and management practises that are compatible with biodiversity conservation, not only helps protecting critical habitats for a variety of species, but also contributes to maintaining landscape connectivity. The establishment of the GMTFCA and the inclusion of various land uses have increased the conservation estate within the region significantly and allows for the cross border movements of species between Botswana, South Africa and Zimbabwe. This however has resulted in several administrative, legal and political challenges in the management of these species. At

present species are managed independently within different management units and quotas for offtake (where applicable) are set per management unit based on limited or no data.

Even though photographic tourism is a powerful tool for the conservation of species and can generate economic benefits for landowners and local communities and as for example the NTGR, it is restricted to those areas that are easily accessible and where charismatics species are present (Di Minin, Fraser et al. 2013). The inclusion of consumptive utilisation such as trophy hunting and biltong hunting can be an important generator of revenue in remote areas where charismatic species are absent or occur in low densities and can thus be used as an effective strategy for the expansion of the conservation estate and for generating important economic benefits for landowners and local communities (Selier and Di Minin 2015). All three countries subscribe to a sustainable use policy and allow for the trophy hunting and the consumptive use of species. In 2014 Botswana placed a moratorium on the trophy hunting of several species including elephant and lion but hunting and lethal damage causing animal (DCA) control is allowed in both South Africa and Zimbabwe.

Where consumptive utilisation is unmanaged and/or solely driven by economic gain and not by conservation objectives, excessive hunting can lead to the extirpation of targeted species or selective harvesting may have negative evolutionary consequences. Selier et al. (2014) have shown that the current levels of trophy hunting within the GMTFCA are unsustainable and far exceeds the mean sustainable yield (MSY) of 10 trophy bulls per annum. Harvesting may also be contributing to the decline in some species within the GMTFCA. It is thus important that the goals of hunting and conservation are compatible and that an adaptive framework is used to ensure sustainability. This can only be achieved through long-term monitoring of offtakes and population numbers (Crosmary, Côte et al. 2014, Selier and Di Minin 2015) at a population level.

Various ecological and climatic factors may influence population estimates. Rainfall as a proxy for primary productivity influences the distribution and group sizes of elephant in the CLRV. While we could not show any correlation between the population estimates of game species and rainfall, Crossmary *et al*. (2014) and others have demonstrated the influence of rainfall on population densities. Natural predation further may influence population estimates within protected areas with healthy or increasing predator populations. Management activities

within the different management units allow for the harvesting of species through hunting which includes offtakes as part of staff rations, trophy hunting and biltong hunting.

In light of the complexity of factors influencing population trends, the observed decline in several species and to understand the consequences of management activities such as hunting the effective monitoring of a variety of parameters are essential. Long term monitoring of population numbers and offtakes are further essential for the implementation of an adaptive quota system based on population trends (Selier and Di Minin 2015) and where populations span across administrative and/or international boundaries, cooperation between managing authorities allowing for the management of these species on a population level is imperative to their persistence.

The NTGR has been monitoring population numbers since the early 80s. With the increase in the conservation estate through the establishment of the GMTFCA and the dispersal and free movement of species between different management units outside of the NTGR it is essential that monitoring takes place at a population level and include all management units that form part of the core area of the proposed GMTFCA. To improve interpretation of data and ensure accuracy of count data it is important that counts are repeatable, the entire area is counted and that animals are counted accurately. This can only be achieved through proper planning, using experienced and preferably the same counters for biennial counts and counting the entire core area or at the very least use a similar counting method and counting at more or a less the same time to prevent double counting of species. Good recording keeping of offtakes including the sex and age of the animals removed will further improve the quality of the data and is important for establishing sustainable offtake quotas and determining the impact of hunting and/or ecological factors on population estimates.

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