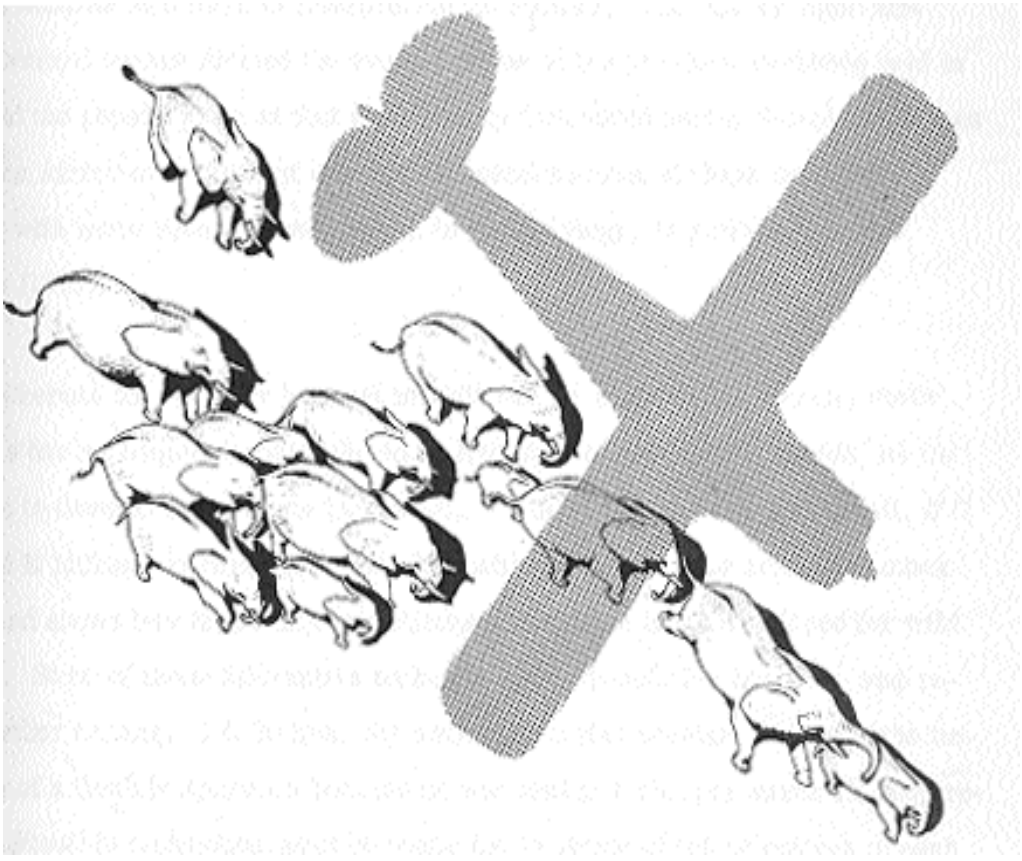
AERIAL TOTAL COUNT of ELEPHANT and BUFFALO in the SERENGETI ECOSYSTEM

Wet Season 2014



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CONSERVATION INFORMATION AND MONITORING UNIT

in collaboration with

WILDLIFE DIVISION

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CITATION

Tanzania Wildlife Research Institute (2014) Aerial Total Count of Elephant and Buffalo in the Serengeti Ecosystem, Dry Season, 2014. TAWIRI Aerial Survey Report

SUMMARY

A total count of elephants (*Loxodonta africana*) and buffaloes (*Syncerus caffer*) was conducted in the Serengeti ecosystem during the wet season from 19th May to 6th June 2014. The Serengeti Ecosystem includes Serengeti National Park, Maswa Game Reserve, Ngorongoro Conservation Area, Ikorongo-Gurument Game Reserve, IKONA Wildlife Management Area, Loliondo Game Controlled Area, and Makao Wildlife Management Area. The survey covered an area of 32,000 km², as part of the annual ecological monitoring censuses undertaken since 1957. The survey was conducted using three aircrafts (Cessna 182). The census was synchronized with Masai-Mara in Kenya. The Paul G. Allen Foundation provided financial support.

A total of 6,087 elephants were counted in the Serengeti ecosystem, suggesting a tremendous increase of 98.4% (3,019 elephants) compared to 3,068 elephants that were counted in a similar survey carried out in 2009. Of the 6,087 recorded individuals, 5,774 elephants (95%) were recorded within the boundaries of the ecosystem's protected areas, while only 313 (5%) were recorded in open areas (Makao and Ikona). A total of 75 carcasses were recorded in the entire ecosystem. Majority (n=70) were stage III and IV (old and very old) and stage I & II (new and recent) were five.

Similarly, the buffalo population in the ecosystem has nearly doubled from 32,041 in 2009 to 55,411, an increase of 73%. Of this total, Serengeti National Park recorded the highest percentage of buffalo, at 62.25%, followed by Maswa Game Reserve (22.4%), and Ngorongoro Conservation Area (4.84%), while the Ikorongo-Grumeti GR has 2.92%. No buffaloes were counted in the Loliondo Game Controlled Area. Ninety-seven percent (n=53,626) of the 55,411 buffaloes counted in the ecosystem were found inside protected areas and 3% (n=1,785) in open areas (Makao and Ikona).

RECOMMENDATION

The results of this census show that elephant and buffalo populations in the Serengeti Ecosystem have increased. The increase is a complimentary to Wildlife Conservation Authorities and wakeup call for increased protection of elephant in the ecosystem. With the low numbers of animals observed in open areas surrounding the ecosystem, the establishment of Wildlife Management Areas should be encouraged to assist in the protection in these vulnerable areas.

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ABBREVIATIONS

APS	Aerial Point Survey
CA	Conservation Area
CIMU	Conservation Information and Monitoring Unit
EAC	East African Community
FSO	Front Seat Observer
FZS	Frankfurt Zoological Society
GCA	Game Controlled Area
GPS	Global Positioning System
GR	Game Reserve
GGR	Grumeti Game Reserve
GSD	Global Systems Division
IGR	Ikorongo Game Reserve
IKONA	Ikoma and Nata Wildlife Management Area
ITCZ	Inter-tropical Convergence Zone
LGCA	Loliondo Game Controlled Area
NCA	Ngorongoro Conservation Area
NCAA	Ngorongoro Conservation Area Authority
NP	National Park
PA	Protected Area
RSO	Rear Seat Observer
SENAPA	Serengeti National Park
SRF	Systematic Reconnaissance Flight
TANAPA	Tanzania National Parks
TAWIRI	Tanzania Wildlife Research Institute
TC	Total Count
TWCM	Tanzania Wildlife Conservation Monitoring
WD	Wildlife Division
WMA	Wildlife Management Area

INTRODUCTION

The Serengeti ecosystem is one of the six key ecosystems for wildlife conservation in Tanzania. The ecosystem is approximately 33,185 km^2 (Sinclair and Arcese, 1995) and comprises seven administrative areas. The areas include Serengeti National Park (SENAPA), Ngorongoro Conservation Area (NCA), Maswa Game Reserve, Ikorongo Game Reserves, Grumeti Game Reserves, IKONA WMA and Loliondo Game Controlled Area (Figure 1). Systematic wildlife censuses have been carried out in the ecosystem since 1957, using various methods including Systematic Reconnaissance Flight (SRF), Total Counts (TC) and Aerial Point Survey (APS).

1.1 Survey objective

The objectives of the Aerial Total Count Survey in the Serengeti Ecosystem were: (i) to determine the population size of elephant and buffalo numbers; (ii) to map their density and distribution patterns; and, (iii) to derive their population trends.

1.2 Survey rationale

The survey provides an update on the population status of elephants and buffaloes as a comparison to previous surveys conducted in the same ecosystem (Table 1).

Table 1: Previous total count surveys in the Serengeti ecosystem

Census code	SEASON	**Year**	**Area (km^2)**	**Source**
SE 05		1986	13,763	(TWCM 1986)
SE 19		1992	21,184	(TWCM 1992)
SE 22		1994	17,258	(TWCM 1994)
SE 26		1998	24,156	(TWCM 1998)
SE 31	WET	2000	21,916	(TAWIRI 2002)
SE 38	WET	2003	21,641	(TAWIRI 2003)
SE 42	DRY	2006	23,660	(TAWIRI 2007)
SE 43	WET	2008	21,379	(TAWIRI 2008)
SE 45	DRY	2009	26,931	(TAWIRI 2010)
SE 47	WET	2014	33,193	This report

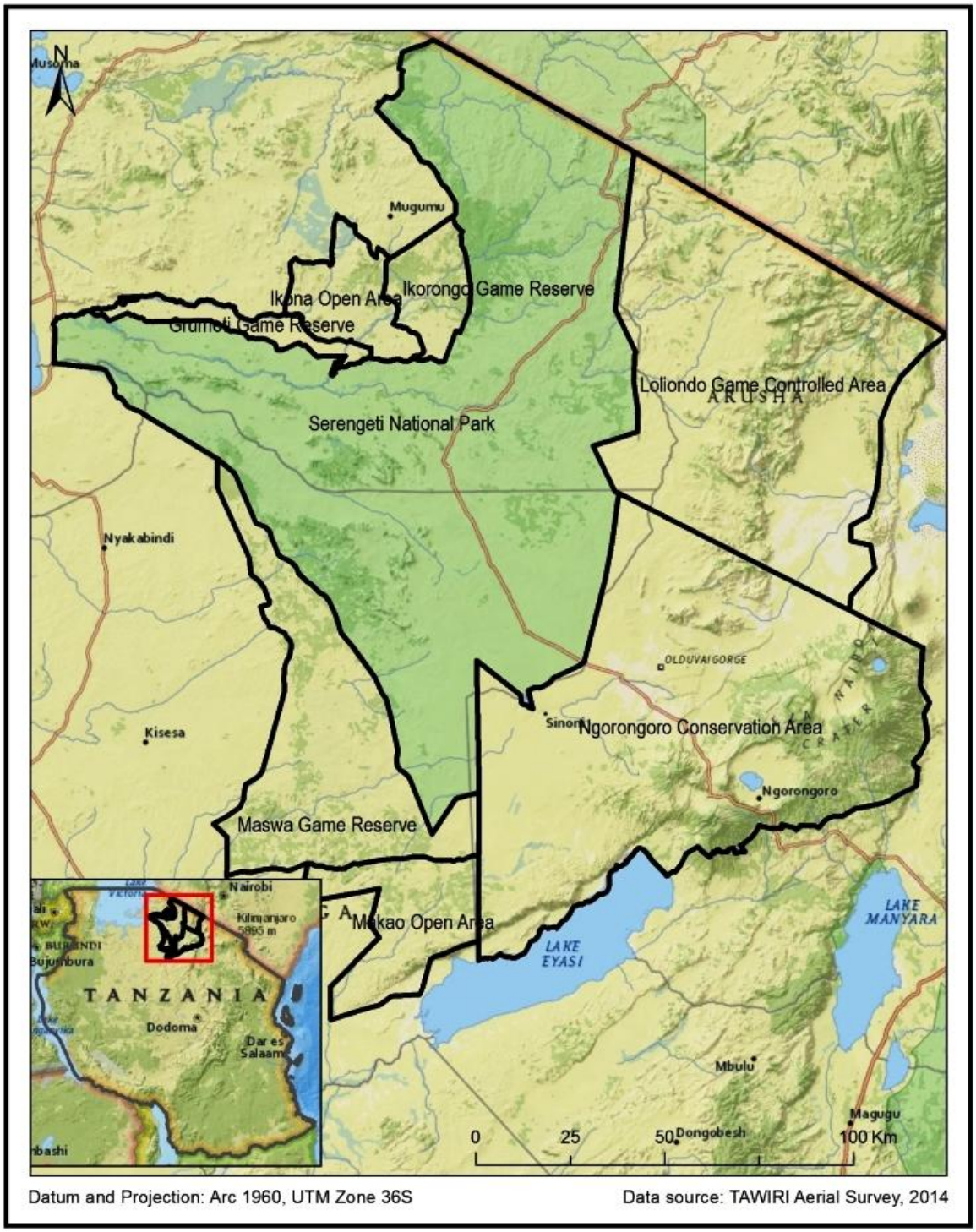

Figure 1: Location of Serengeti ecosystem in relation to other protected areas in Tanzania

THE SURVEY AREA

2.1 Location: Administrative areas

The Serengeti ecosystem covers an area of 33,185 km². The ecosystem lies in Northern Tanzania between 34° and 36° Longitude and 1° 30' to 3° 30' Latitude. The total count covered the entire Serengeti ecosystem, including Serengeti National Park (SENAPA) (14,763 km^2), Ngorongoro Conservation Area (8,252 km^2), Maswa Game Reserve (2,875 km^2), Ikorongo & Grumeti Game Reserves (1,019 km^2) and Loliondo Game Controlled Area (6, 210), IKONA Open and Wildlife Management Area (WMA, 723 km^2) and Makao Open and WMA (1,145 km^2) surrounding unprotected areas (Figure 2). A synchronised census was also conducted in Masai-Mara National Reserves and adjacent group ranches (8,691km^2), which is connected with Serengeti Ecosystem.

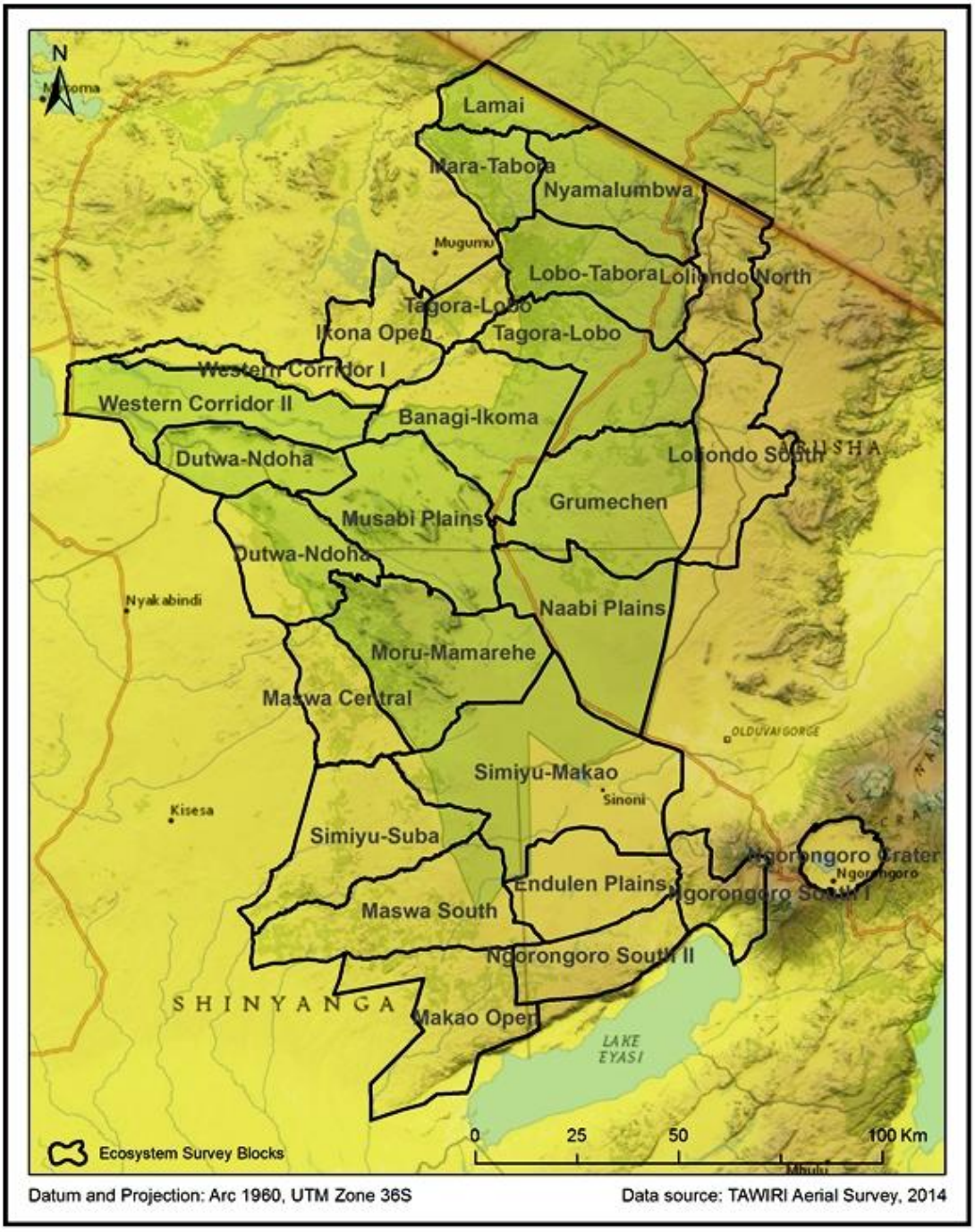

Figure 2: Historical survey blocks

2.2 Climate and Hydrology

The climate of the Serengeti ecosystem is tropical. It is usually warm and dry, with mean monthly maximum temperature of 27-28°C all year round and a mean monthly minimum temperature of 13-16°C (Sinclair and Arcese 1995; Sinclair*et al*., 2000). There are distinct wet and dry seasons, with rainfall determined by topographic relief, and the seasonal

movement of world air masses, which form the inter-tropical convergence zone (ITCZ). This belt of rain-laden winds moves north and south across the equator and brings two main periods of rain between March to June and November to December. The rainfall pattern is often erratic, with both extreme wet and dry years, and variations occurring depending on location: there is a north to south and west to east rainfall gradient, with the northern and western parts receiving more rainfall than the southern and eastern parts. The middle ranges receive 900-1000mm/year while lowlands like Mugumu and Musoma areas are the most arid with 500-800mm/year.

The Mara River is the main source of available surface water both for wildlife and human use. Other important rivers in the ecosystem include the Sand, Orangi-Grumeti and Mbalageti rivers. Studies have established two peaks in the Mara River water discharge that correspond to the peaks in the rainfall pattern. The June peak that corresponds with the wildebeest migration has created what has now become the 7th wonder of the new world in the Serengeti. Although the river has always been permanent, drought and erratic rainfall coupled with unprecedented destruction of the water catchment area pose a threat to this important water source.

2.3 Topography and Soils

The topography and soils of the Serengeti ecosystem are comprehensively covered in the Serengeti-Masai Mara trans-boundary protection and monitoring plan (EAC, 2012). The basement complex of the ecosystem is made of pre-Cambrian igneous and metamorphic rocks. Erosion and volcanic activities have changed the surface of this ecosystem to the present topographic forms characterized by extensive plains, hill crops, escarpments and valleys. The rangelands and escarpments are characterized by rich volcanic soils while poorly drained brown soils occur in the plateaus and plains where extensive grasslands are common. River basins and valleys have clay soils enriched with accumulated sediments (EAC, 2012).

2.4 Fauna

The Serengeti plains are internationally recognized for having the highest density and most diverse combination of large herbivores on earth, some of which are renowned for their seasonal migration between the Serengeti and Masai-Mara plains. The major herbivores are African Elephant (*Loxodonta africana*), African buffalo (*Syncerus caffer*), Wildebeest

(Connochaetes taurinus), Cape Eland (*Taurotragus oryx*), Coke's Hartebeest (*Alcephalus buselaphus cokii*), Burchell's Zebra (*Equus quagga burchelli*), Impala (*Aepyceros melampus*), Giraffe (*Giraffa camelopardalis),* Black Rhinoceros (*Diceros bicornis*), Hippopotamus (*Hippopotamus amphibius*) and Grant's Gazelle (*Gazella grantii*).

The common carnivores are Leopard (*Panthera pardus*), Lion (*Panthera leo*), Cheetah (*Acinonyxjubatus*) Black-backed Jackal (*Canis mesomelas*), Wild Dog (*Lycaonpictus*), Spotted Hyena (*Crocuta crocuta*). Other species found in the ecosystem include the Olive Baboon (*Papio anubis*), Vervet Monkey (*Chlorocebuspygerythrus*), Black and White Colobus (*Colobussatanas)* and Patas Monkeys (*Erythrocebuspatas*).

2.5 Flora

Savanna grasslands and acacia woodlands form the major vegetation types of the Serengeti ecosystem. The dominant tree species includes *Acacia seyal var fistula*, *Acacia tortilis*, *Acacia polyacantha* and *Euphorbia candelabrum* while the dominant grass species are *Eragrostis cyndiflora, Chloris pycnothrix, Pennisetum meziannum* and *Themeda triandra (Rusch et al. 2005).*

2.6 Economic Activities

The Serengeti ecosystem supports a number of economic activities, the most important of which is tourism. The two main protected areas; Serengeti National Park and Ngorongoro Conservation Area, are the most visited protected areas in the country. Livestock rearing is common practice in surrounding communities keeping cattle, sheep and goats. Sports hunting is practiced in the game reserves and game controlled areas only. Charcoal production, agricultural activities, mining, logging and other forms of land use also take place in the unprotected parts of the ecosystem. With increasing human population, the socio-political arrangement of the ecosystem uses is rapidly changing, and competition among different land users (pastoralists, farmers, tourism industries and conservationist) are evident. The various forms of land use help to provide livelihoods to local,communities but, if not carefully managed, conflicting incentives amongst different actors may result in habitat degradation.

MATERIALS AND METHODS

3.1 Block Design and Flight Plan

In the past, aerial total counts were based on irregular counting blocks with boundaries defined by physical features such as rivers, mountain ridges and roads. These blocks were designed to easily identify the beginning and end of the survey block to simplify the navigation for both the pilot and the Front Seat Observer (FSO). In addition, such physical features became the turning points of each survey flight line, which increased chances of making bias associated with double counts (Douglas-Hamilton, 1996). To address these challenges, regular census blocks were designed that were easily navigatable using GPS (Global Positioning System) technology. The average block size was set at 900 km², which takes a maximum of six hours to survey spaced by 1km transects.

3.2 Data Collection

The Serengeti aerial total count followed the principles prescribed by Douglas-Hamilton (1996) and Norton–Griffiths (1978). Four 4-seater Cessna 182 aircraft were used during the survey (

Table 2), with a maximum of three in operation at any one time to fly on transects. In total count transects are guiding flight lines that ensure the area is well covered. Markers were fitted on either side of the aircraft to guide the observers in distance estimation on the ground.

Table 2: Aircraft used during census

Plane Registration	Plane Type	Seat capacity	Country
5H ZGF	Cessna 182	4	Tanzania
5H GNU	Cessna 182	4	Tanzania
5H MPK	Cessna 182	4	Tanzania
5H CFA	Cessna 182	4	Tanzania

The survey was conducted from 19th May to 6th June 2014. The ecosystem covered 33,193 km², which was divided into 31 census blocks (Figure 4), and each block was systematically

searched one at a time with aircraft flying at a target altitude of 400ft above ground and an average speed of 180 km/hour. The search pattern was guided by established flight path (transects) spaced at 0.6, 1.0, 1.2 or 2 km, depending on habitat type and terrain (Figure 3). To maintain flight precision over the planned transect, maps of the survey blocks were uploaded on to pilot GPSs. Garmin GPSmap 695s were used, as this version has the capability of showing the actual position of the aircraft, which enhances coverage accuracy. In addition, Gamin GPSmap 62s was used to track the flight path of each aircraft and record waypoints. Each time a herd of elephant or buffalo was encountered, the aircraft circled above the herd and the location and size of the herd was recorded. Where the buffalo herd exceeded 20 individuals or elephant herd exceeded ten individuals, photographs were taken using high-resolution digital cameras, and exact numbers determined on the ground. Care was taken to avoid double counting where multiple photographs were taken of a single herd.

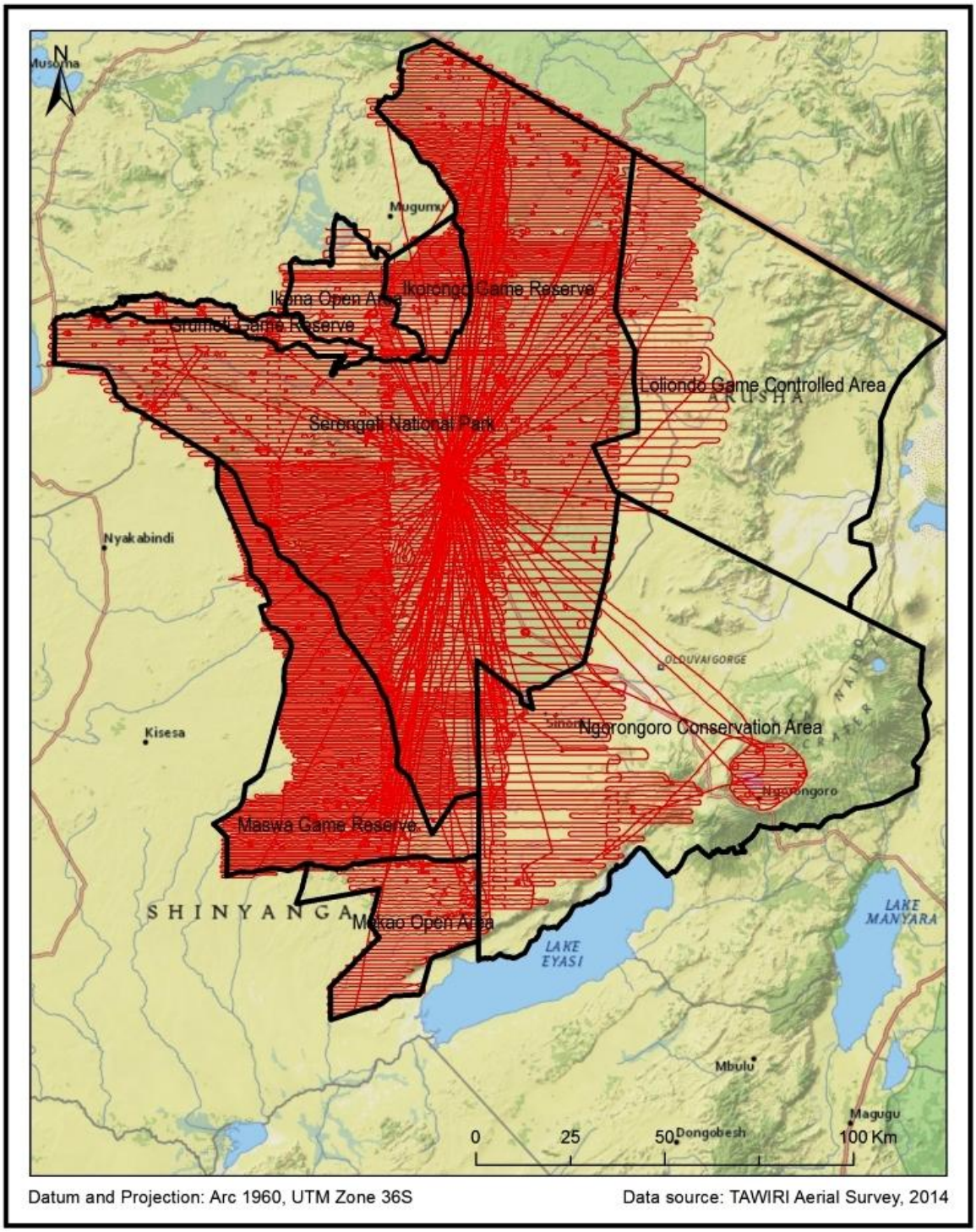

Figure 3: Track-logs that indicate flown flight lines and transfers from and to Seronera Airstrip, Serengeti National Park.

3.3 Training of Survey Crew

All enumerators and observers underwent a two day intensive training course. This included theory and practical elements, and focused on:

- Crew communication – clear communication of detection and need to circle large groups
- Group size estimation and photography
- Use and handling of equipment (GPS, receivers and cameras)
- Navigation within blocks
- Species identification and enumeration, and aging of elephant carcass

3.4 Data capture and handling

In-flight data was captured using GPS, voice recorders and datasheets. Observers marked their count estimates on datasheets, and digital cameras were used to capture large herds (buffalo > 20, elephant > 10). This enabled the census team to confirm visual observations on the ground, and to avoid double counting of individuals on photographs. The Paint program in Microsoft Windows 8 was used to mark counted individuals. In-flight data collected by GPS were downloaded using Garmin Base camp© Version 4.3.1. The downloaded data included waypoints for recorded observation and track logs for flight lines. The GPS waypoints and recorded count data from datasheets and photographs were matched to create complete observation records.

Data were entered in Microsoft Excel (Microsoft 2013) and then exported to ArcGIS 9.3.1(ESRI 2006) for statistical and spatial analyses.

3.5 Data analysis

Double counts due to flight overlaps were identified and cleaned:

- Crews mapped and discussed observations in-flight, removing duplicate herds after checking previous flight line observations;
- Same-day, same-session observations (between-aircraft) were mapped and likely duplicate herds were removed on the basis of proximity (< 1.5 km);
- Observations from blocks that were flown for more than one day between adjacent blocks only duplicates of large herds (> 10) were checked guarding against double-

observation of large herds but assuming that random movement of small herds could not be caught or detected over longer periods of time.

Descriptive statistics were used for summation of numbers. Data from past censuses that were conducted during a similar season were used to determine population trend. Spatial analysis and Kernel density analysis were undertaken using Arc GIS 10 to generate distribution and density maps.

3.6 Possible Sources of Bias (Double Counting)

While total count methods attempt to ensure that all individuals are counted and that no individuals or groups are double-counted, there are some sources of bias that remain (Jachmann 2001; Douglas-Hamilton 1996, Norton-Griffiths 1978). A comprehensive list of potential errors may be found in the aforementioned references, and in this particular survey the following possible sources of bias were identified:

- Incomplete coverage of the planned survey area in some parts of the census zone due to difficult topography
- Double counting on aircraft turning areas between blocks
- Double counting due to animals moving ahead of a transect or being seen from both transects
- Counting bias from aerial estimate and count from photos
- Missing animals hidden under tree canopies especially in gallery forests and Ngorongoro highland forests.

3.7 Minimising biases

3.7.1 Incomplete coverage of the planned survey area:

Some parts of the survey area, including Lake Eyasi and Satiman Mountain, were not counted due to difficult terrain. Despite this, the effect of this potential bias was insignificant since the area is very small; very few individuals would be present in this area, due to difficult terrain; and previous censuses also omitted these areas, so it will not have any effect on trend analysis.

3.7.2 Double counts due to overlap and animal movement

In order to minimize this bias, we took a number of measures presented in Appendix III:

- Track logs, observations and blocks were overlaid, and carefully inspected. We then checked for the possibility of being the same group, and overlapping groups were removed whenever detected.
- We checked for the possibility of double counting in adjacent blocks, and removed double counts whenever detected.
- For a group with > 10 elephants or > 20 buffaloes, where there was a difference in survey flight date or sessions within or between survey blocks, we calculated separation distance between the observations that suspected to be double count.
- Where there were groups with more than 50 individuals; photos were recounted to verify numbers and discrepancies were addressed.
- In certain instances, we dropped corrected counts (Counts in frames) in the database and replaced with observer estimates when we had no enough evidence to take the corrected number (Appendix III).

RESULTS AND DISCUSSION

4.1 Elephant

4.1.1 Population Status and Distribution

A total of 6,087 elephants were observed in the Serengeti Ecosystem during this count (Tables 3 & 4). Elephants were not evenly distributed across the ecosystem: relatively higher densities were found in the central and northern Serengeti (Figures 4), and 95% (n=5,774) of the 6,019 elephants were found inside protected areas, with only 5.0% (n=313) in open areas.

Table 3: Elephants counted in different population numbers per administrative areas of the Serengeti Ecosystem, wet season 2014

Protected Area	Population	Sample (N)	Proportion	Average Group size
Ikona Open Area	232	12	3.81	19
Makao Open Area	81	12	1.33	7
Loliondo Game Controlled Area	76	6	1.25	13
Grumeti Game Reserve	-	-	-	-
Ikorongo Game Reserve	160	7	2.63	23
Maswa Game Reserve	179	29	2.94	6
Ngorongoro Conservation Area	199	40	3.27	5
Serengeti National Park	5,160	529	84.77	10
Total	**6,087**	**635**	**100**	**10**

NB: Boundary discrepancy between Makao O.A, Maswa and Ngorongoro resulted in different numbers in the Makao block

Table 4: Elephant population numbers shown per survey block in the Serengeti Ecosystem, from 1986 to 2014

Census block	Block Name	1986	1992	1994	1998	2000	2003	2006	2008	2009	2014
T0	Lamai	0	13	2	168	140	50	272	30	176	351
T1	Mara-Tabora	0	0	0	0	0	0	12	22	274	538
T2	Nyamalumbwa	56	38	233	122	296	186	34	123	154	483
T3	Lobo-Tabora	19	19	119	130	0	289	184	1003	1003	884
T4 + T4w	Tagora-Lobo	491	491	195	134	66	24	80	578	126	556
Subtotal – Northern Serengeti		**566**	**561**	**549**	**554**	**502**	**549**	**582**	**712**	**1733**	**2812**
T5	Banagi-Ikoma	6	3	0	143	371	169	422	393	253	300
T6	Grumechen	144	140	90	788	175	211	53	201	262	404
T7	Musabi	28	0	125	287	36	0	95	293	194	230
Subtotal – Central Serengeti		**178**	**143**	**215**	**1,218**	**582**	**380**	**570**	**887**	**709**	**934**
T8 +T8n	Western Corridor	0	0	0	25	156	26	178	286	10	262
T9n+T9s	Dutwa-Ndoha	0	0	0	0	66	0	66	55	39	298
Subtotal – Western Serengeti		**0**	**0**	**0**	**25**	**222**	**26**	**224**	**341**	**49**	**560**
T10	Moru-Mamarehe	69	79	396	54	49	100	27	49	290	729
T11	Simiyu-Makao (1986)	--	--	--	--	--	--	49	379	103	375
T12	Naabi-Plains	0	0	0	121	0	141	0	117		78
Subtotal – Plains and Southeast		**124**	**268**	**478**	**192**	**119**	**648**	**76**	**545**	**393**	**1182**
T13	Maswa Central	--	--	--	--	0	0	53	18	9	14
T14	Simiyu-Suba	--	--	--	--	15	2	65	11	106	123
T15	Maswa South	--	--	--	--	0	130	40	462	10	25
Subtotal – Maswa		**0**	**0**	**0**	**0**	**15**	**132**	**158**	**491**	**125**	**162**
T16	Loliondo North	--	8	50	0	17	0	88	210	10	52
T17	Loliondo South	--	0	65	26	171	373	0	83	21	0
Subtotal – Western Loliondo			**8**	**115**	**26**	**188**	**373**	**88**	**293**	**31**	**52**
T18+T19	Ngorongoro South	--	--	--	--	0	0	0	25	9	92

T20	Ngorongoro Crater**	--	27	30	82	22	35	-	147	19	76
Subtotal – Ngorongoro South			**27**	**30**	**82**	**22**	**35**	**0**	**172**	**28**	**168**
T21	Makao Open	--	--	--	0	--	0	0			67
Subtotal – Makao Open					**0**		**0**	**0**			**67**
Ikona Open											**150**
TOTAL (in 1986 blocks only)		**868**	**972**	**1,242**	**1,989**	**1,440**	**1,733**	**1,718**			
TOTAL Excluding NCA Crater (T20)		**868**	**980**	**1,357**	**2,015**	**1,628**	**2,108**	**1718**			
GRAND TOTAL		**868**	**1,007**	**1,387**	**2,097**	**1,650**	**2,143**	**1,718**	**3,421**	**3,068**	**6,087**

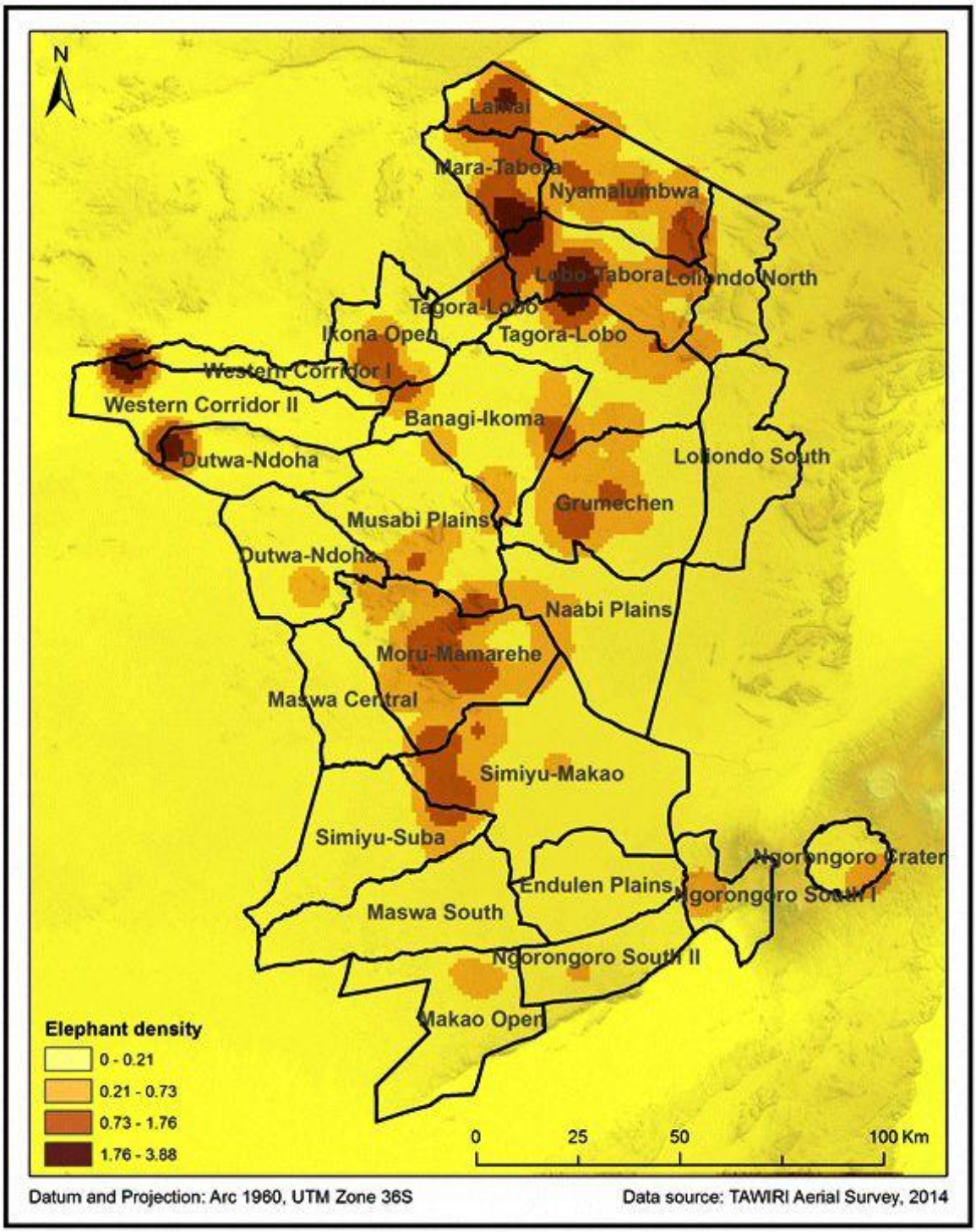

Figure 4: Elephant density distribution in the Serengeti Ecosystem, wet season 2014

4.1.2 Elephant carcasses status and distribution

A total of 75 carcasses were counted in the entire Serengeti ecosystem (Figure 5). Out of the total, only five carcasses were in stage I & II (new and recent). The remaining 70 carcasses were in stage III & IV (old and very old). Of the carcases counted, 75% were recorded inside protected areas and only 25% were recorded outside. No elephant carcass was recorded inside Ngorongoro Conservation Area (Figure 5). Three of the five recent carcases in the ecosystem were found in Serengeti National Park; one with tusks intact.

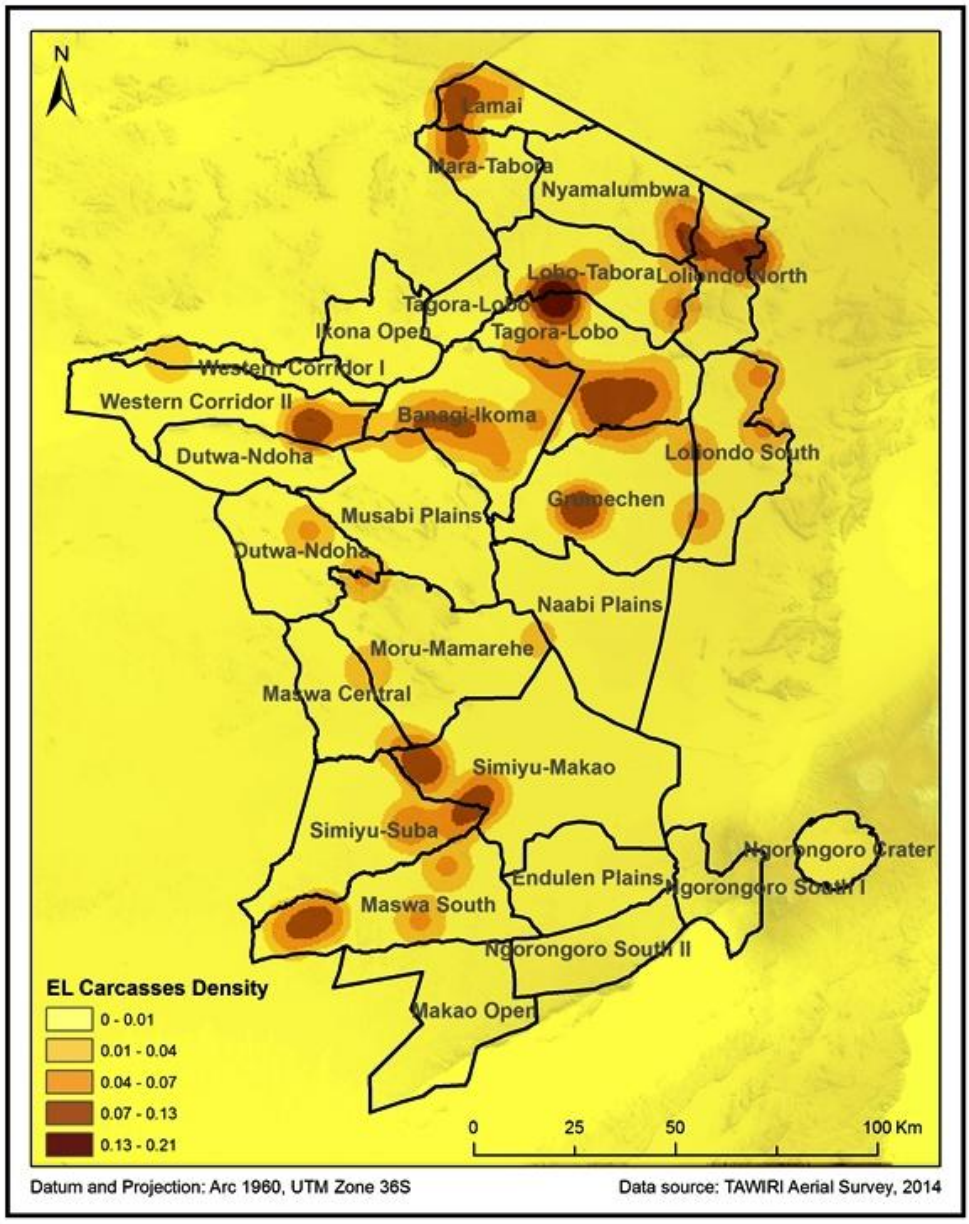

Figure 5: Densities distribution of elephant carcases in the Serengeti Ecosystem

4.1.3 Elephant Carcass Ratio

Carcass ratios can be used as an index of mortality in elephant populations. Using counted numbers of live elephant (6,087) and skeletons (75), the calculated carcass ratio was 1.2% indicating a population that experiencing natural mortality levels. A carcass ratio of up to 8% is considered to represent natural mortality (Douglas-Hamilton and Burrill, 1991).

4.1.4 Population increase of elephants in the Serengeti Ecosystem

Over the last five years, elephant numbers in the Serengeti ecosystem have increased beyond our expectation, particularly surprising at a time when elephants are faced with a surge of poaching. The current increase could be a result of several reasons including: natural growth (healthy population); immigration especially from Maasai-Mara; and, inclusion of IKONA, and Makao WMA in the census zone, which were previously not counted.

The data of elephant population size from 1986 to 2014 exhibits a general increase in the elephant numbers (Figure 6). The data used in this analysis based on the census that synchronised with the Masai-Mara ecosystem counts.

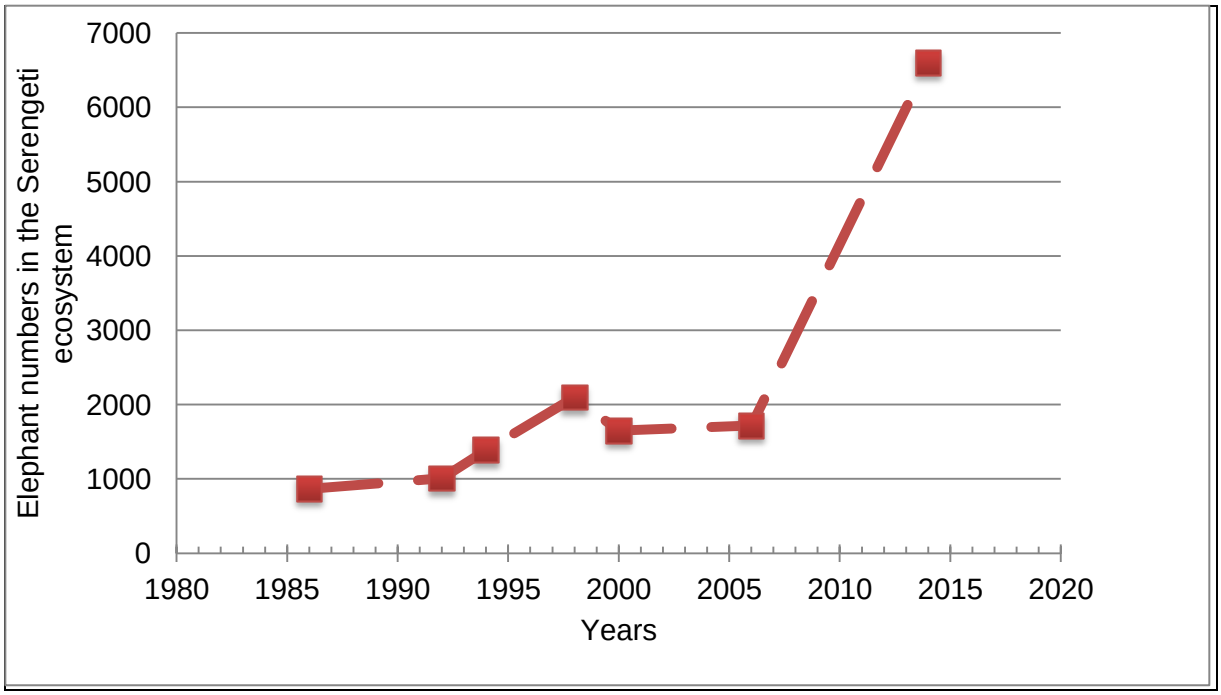

Figure 6: Trend in elephant numbers in the Serengeti ecosystem (1986-2014)

Using data on the Serengeti elephant population structure i.e., age and sex (Anna Estes 2006, unpublished data) and a birth interval of three years, we modelled predicted population growth using 2009 numbers as the baseline (3,068 elephants). This model predicts a total of 4,896 elephant individuals by 2014 (Maximum fecundity, Figure 7). We also used long-term data from the Amboseli National Park demographic rates (4 years inter-birth intervals, survival between age classes, Moss 2001), with this model predicting a total of 3,926 individuals in 2014.

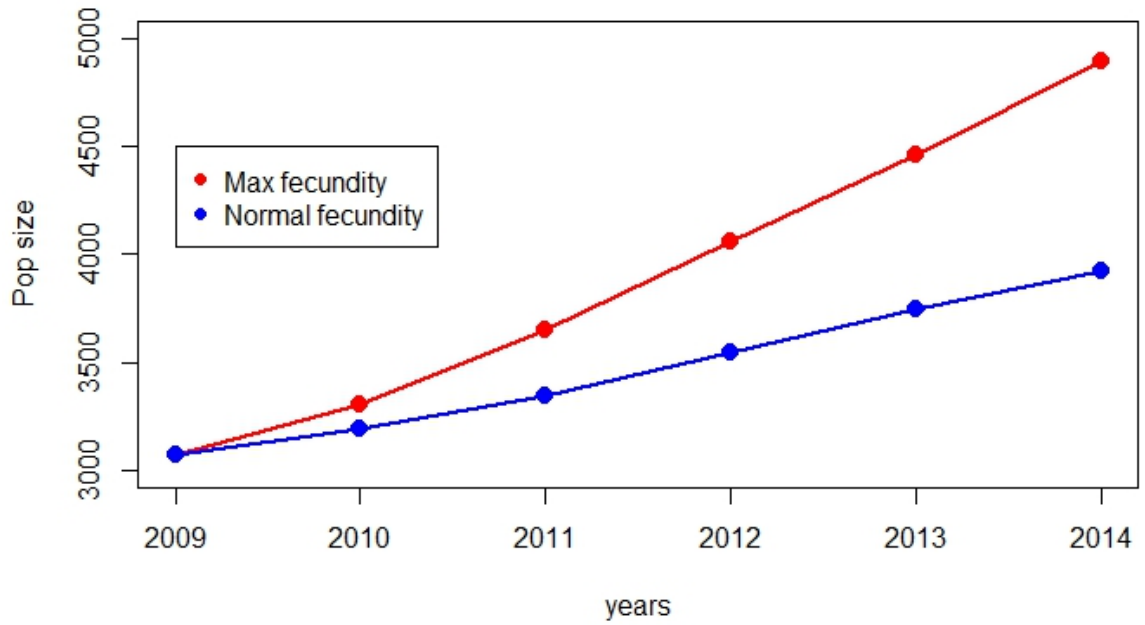

Figure 7: Prediction of elephant population in the Serengeti Ecosystem

The Ikona and Makao open areas, which were not counted in 2009, account for a total of 217 elephants. In Kenya, a count in the Masai Mara ecosystem, which is functionally connected to the Serengeti, gave a total of 1,448 elephants, which is down by 1,452 individuals on the previous count in 2010, which was 3017. The missing individuals could not be explained by the number of carcasses counted (n = 117).

Summing the modeled maximum population; with the additional elephants counted in Ikona and Makao; and the reduction of elephants in the Masai Mara, which we postulate have migrated into the Serengeti, give a total close to the 6,087 individuals counted in the Serengeti Ecosystem. Some increase may also be attributed to enhanced searching effort and counting methods of the census.

4.2 Buffalo

4.2.1 Population status and Distribution

A total of 55,411 buffaloes were observed in the Serengeti ecosystem. The species was counted in both protected and non-protected areas (Figure 8). High proportional of buffalo were counted inside the protected areas (97%=53,626) and few outside protected areas (3%=1,785). No buffaloes were observed in the short grass plain of Enduleni in the southeast and one observation in the Naabi plain. Very few buffalo were counted in most areas of the Loliondo game controlled area. In Loliondo South no buffalos were observed since the 2009 counts. In western Loliondo block also only 5 buffalos were seen in 2014 counts. In these areas there are a high number of livestock and human settlement mostly Maasai community (Table 5).

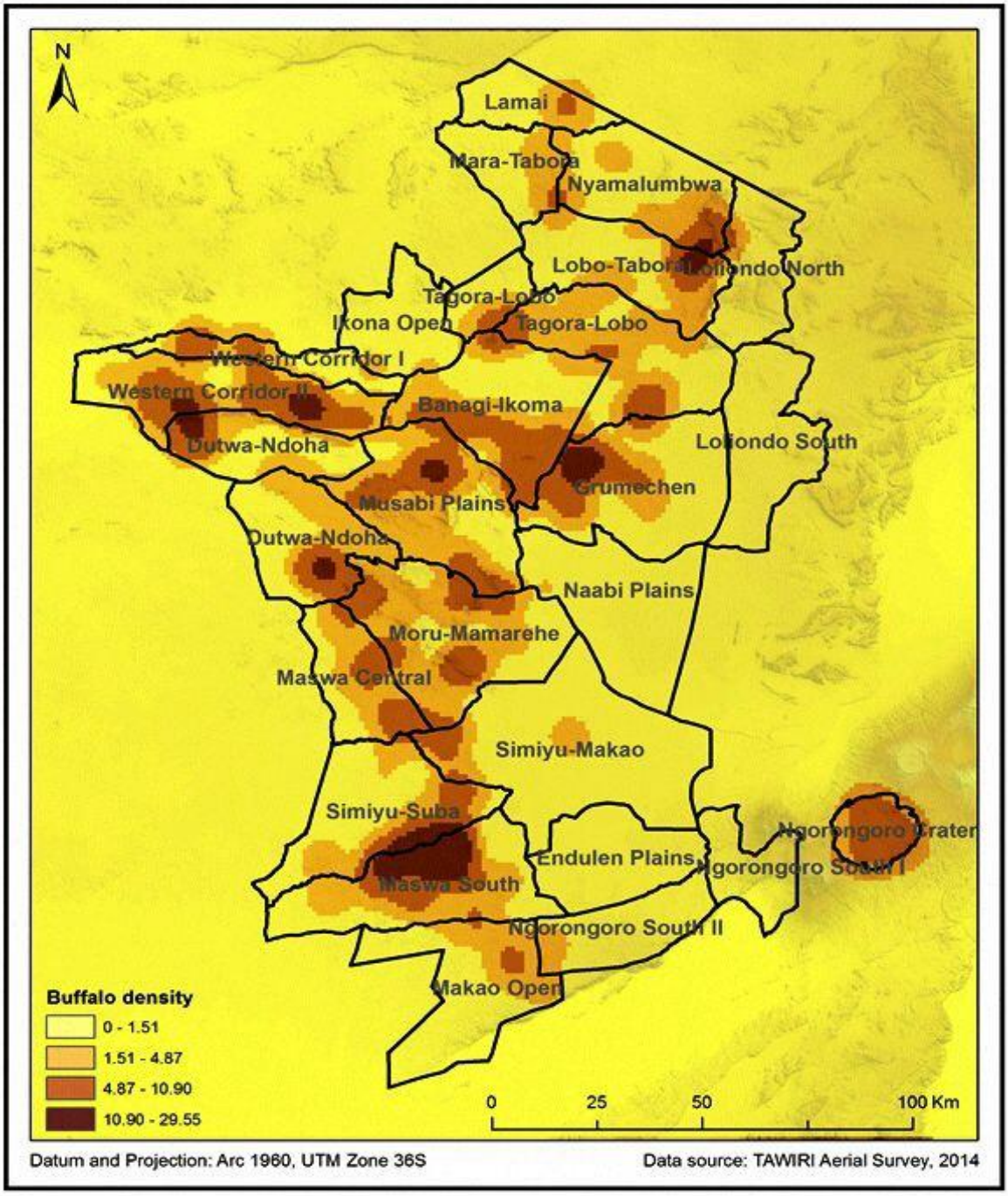

Figure 8: Wet season distribution of buffaloes in the Serengeti ecosystem, 2014

4.2.2 Buffalo Population Trend

An analysis of buffalo numbers from the year 1986 to 2014 indicates a decline in the 1990s followed by a steady growth thereafter (Figure 9). This decline was attributed by a severe drought recorded in 1993 (Ogutu*et al.*, 2009) and poaching (Sinclair and Arcese, 1995). In 2014 census buffalo increased by 73% (55, 411 buffalo) compared to 2009 count (32, 041 buffalo).

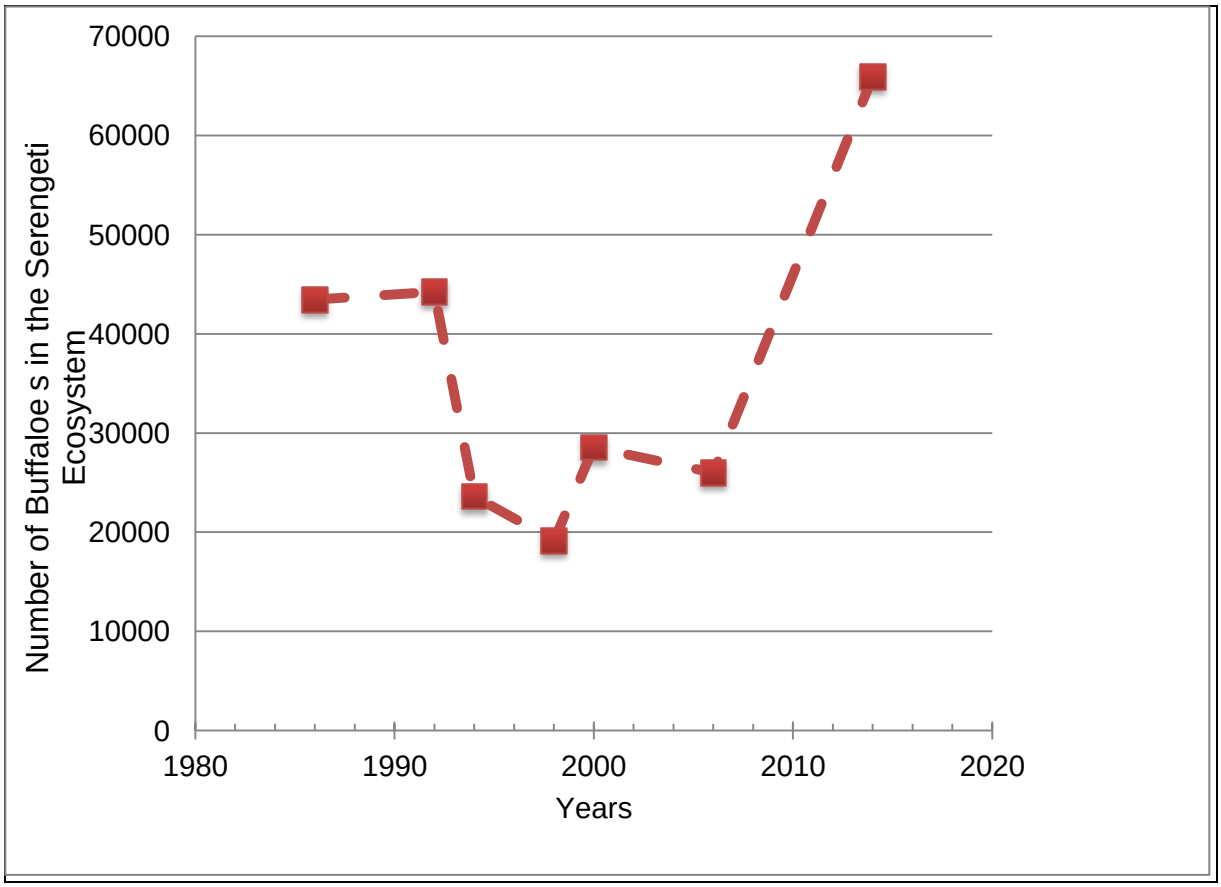

Figure 9: Trend of buffalo numbers in the Serengeti ecosystem (1986-2014)

Table 5 Buffalo population numbers shown per survey block in the Serengeti Ecosystem, from 1986 to 2014

	Block Name	1986	1992	1994	1998	2000	2003	2006	2008	2009	2014	Status
T0	Lamai	60	510	74	0	110	0	0	0	1	690	Recovered
T1	Mara-Tabora	195	2	2	2	2	50	0	0	129	484	Increase
T2	Nyamalumbwa	2,521	812	898	338	123	306	705	73	1978	2138	Increase
T3	Lobo-Tabora	2,917	1,603	463	57	7	548	1,124	1,218	1596	2477	Increase
T4 +T4w	Togoro-Lobo	5,511	3,215	2,267	3,766	2,036	2,502	756	2,091	4033	3908	Decline
Subtotal – North Serengeti		**11,204**	**6,142**	**3,704**	**4,163**	**2,278**	**3,406**	**2,680**	**3,465**	**8284**	**9697**	Increase
T5	Banagi-Ikoma	3,224	3,436	1,235	1,097	2,815	1,797	4,121	1,143	3078	I4221	Increase
T6	Grumechen	6,174	7,090	3,704	2,262	1,189	5,088	5,358	2,897	3412	3783	Increase
T7	Musabi	7,933	7,005	4,265	2,239	5,255	0	3,042	4,066	4964	I3838	Increase
Subtotal – Central Serengeti		**17,331**	**17,531**	**9,204**	**5,598**	**9,259**	**6,885**	**12,521**	**8106**	**11454**	**31842**	Increase
T8 +T8n	Western Corridor	1,895	2,689	2,272	1,244	3,146	2,797	2,792	2,508	0	7618	Recovered
T9+T9s	Dutwa-Ndoha	5,218	4,352	2,042	2,416	2,602	3,032	1,771	2,798	1019	3934	Increase
Subtotal – Western Serengeti		**7,113**	**7,041**	**4,314**	**3,660**	**5,748**	**5,829**	**4,563**	**5,306**	**1019**	**11552**	Increase
T10	Moru-Mamarehe	6,054	2,662	3,469	20	3,416	4,409	1,000	4,195	4571	4644	Increase
T11	Simiyu-Makao (1986)	1,754	--	--	--	--	--		1,126	966	1289	Increase
T12	Plains	0	354	200	630	14	0	500	790	0	164	Recovered
Subtotal – Plains and Southeast		**7,808**	**5,759**	**3,963**	**1,723**	**3,817**	**7,342**	**2,183**	**6,111**	**5537**	6097	Increase
T13	Maswa Central	--	--	--	--	359	40	379	202	1891	2204	Increase
T14	Simiyu-Suba	--	--	--	--	--	1,501	1603	2,691	1701	2169	Increase
T15	Maswa South	--	--	--	--	1,981	1,731	833	2,878	0	7484	Recovered
Subtotal – Maswa		**0**	**0**	**0**	**0**	**2,340**	**3,272**	**2,833**	**5,771**	**3592**	11857	Increase

	Block Name	1986	1992	1994	1998	2000	2003	2006	2008	2009	2014	Status
T16	Loliondo North	--	1,758	26	2	14	0	1,189	1,186	60	5	Decline
T17	Loliondo South	--	407	80	1,248	52	1,143	0	338	0	0	Disappeared
Subtotal – Western Loliondo			**2,165**	**106**	**1,250**	**66**	**1,143**	**1,189**	**1,524**	**60**	5	Decline
T18+T19	Ngorongoro South	--	--	--	--	48	0	50		4	275	Recovered
T20	Ngorongoro Crater**	--	5,608	2,310	2,378	5,008	3,149		2,641	2091	2305	Increase
Subtotal – Ngorongoro South			**5,608**	**2,310**	**2,378**	**5,056**	**3,149**	**50**		**2095**	2580	Increase
T21	Makao Open	--	--	--	384	--	--	0		-	1502	New survey
Ikona Open					**384**					-	283	New survey
GRAND TOTAL		43,456	44,246	23,601	19,156	28,564	31,026	26,001	32,919	32, 041	55,411	Increase

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The Serengeti Ecosystem Aerial total count of elephant and buffalo was intensively conducted in the census zones by minimizing flight paths to improve the level of detection. This survey increased the level of integration between observed counts and photo counts, with the aim of improving accuracy of the census.

The population status of elephant and buffalo has significantly increased in the Serengeti Ecosystem since previous counts. The elephant counts have almost doubled since the 2009 census, with a population increase of 98%, from 3,068 to 6,087. This is an impressive growth, and Tanzania has not experience such a growth in an elephant population for many years. This dramatic increase is attributed to various factors, including but not limited to: migration from Maasai-Mara Reserves; improved survival rate by increasing levels of protection; and, enhanced searching effort and use of camera to improve count.

Similarly, the buffalo population in the ecosystem has increased tremendously from 32, 041 in 2009 to 55,411, which represents a 73% increases. Majority of buffalo (96%, n=53,450) were counted inside the protected areas, of which the 62% of buffalo were counted in the Serengeti National Park and 22% Maswa Game Reserve.

Serengeti National Park forms the core of both elephant and buffalo populations in the ecosystem. Sustaining viable population of these two species is highly dependent on how Serengeti National Park performs, both ecologically and protection (i.e., anti-poaching).

The 2014 census also adopted a new approach that aimed to increase count accuracy. This included reducing flight path spacing from 1km to 0.6km in difficult woodland areas, and photographing all herds of elephants larger than 10 individuals and buffalo larger than 20 individuals, to reduce the counting bias of observers for large groups. Therefore, in order for effective monitoring to continue, and further improve, there is a need to increase census funding to accommodate for variations in searching effort.

5.2 Recommendations

- To conduct an intensive study to more precisely determine the causal factors influencing the large variation in elephant numbers observed in 2014, in comparison to previous censuses.
- To collect and collate existing data and information to document land use change, and its possible impact on elephant and buffalo distribution.
- To carry out a study to advise on the most appropriate management approaches for addressing observed shifts in elephant numbers, distribution, and land use changes.
- To fit collars on elephants (lead by TAWIRI) to determine spatial and temporal movement patterns.
- To complement aerial censuses with ground surveys in order to collect demographic parameters on elephants and buffalo.
- To develop a correction factor for visual counts and photographs for each census.
- To carry out a study on ecosystem services in the surveyed area.

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LIST OF APPENDICES

Appendix I: List of flying crews of the 2014 wet season aerial census of the Serengeti Ecosystem.

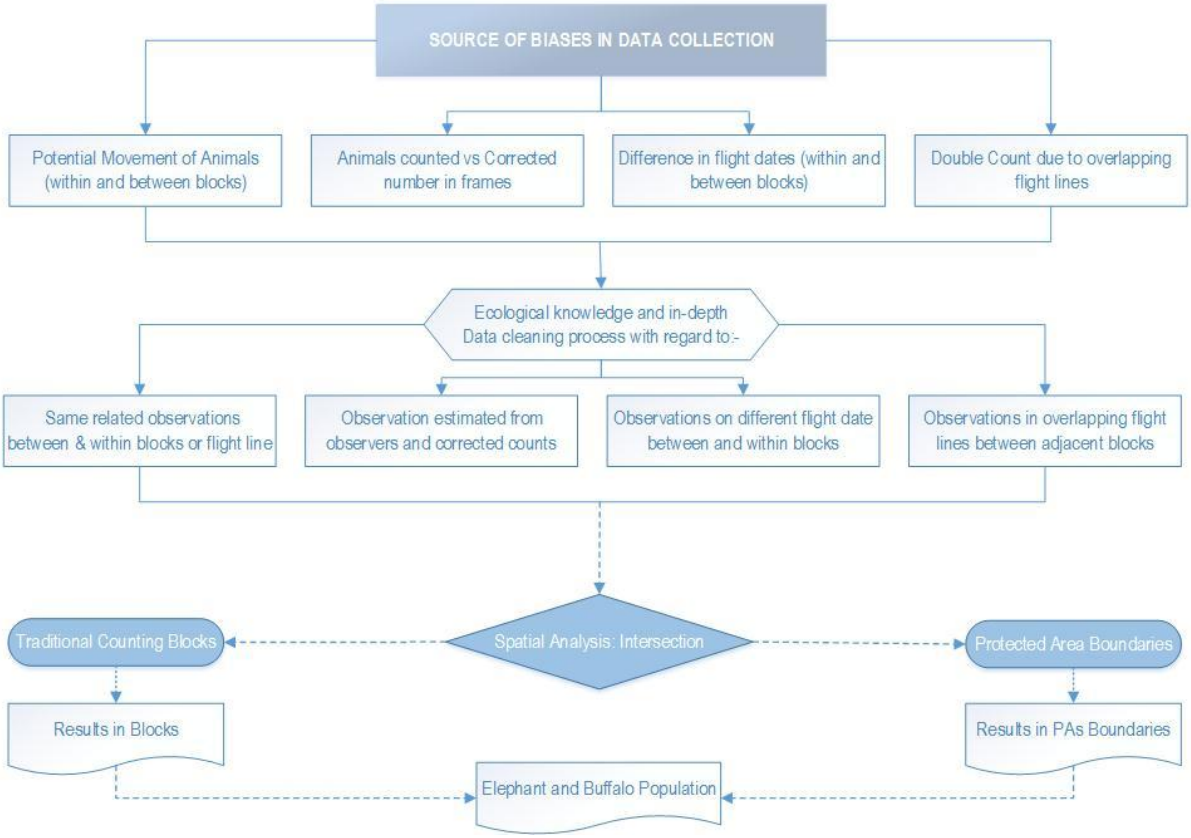
NAME OF PARTICIPANT	ACTIVITY	ORGANIZATION
Mackiyu Kajwangya	Pilot (5H-GNU & 5H-MPK)	TANAPA
David Moyer	Pilot (5H-CFA)	Consultant
Felix Borner	Pilot (5H-ZGF)	FZS
Hamza K. Kija	Front seat observer	TAWIRI
Mwita Machoke	Front seat observer	TAWIRI
Anna Laroya	Front seat observer	TAWIRI
Mosi Azori Migezo	Rear seat observer	Wildlife Division
Wilfred Njama Marealle	Rear seat observer	TAWIRI
Gabriel Nyaki	Rear seat observer	TANAPA
Damari Samwel	Rear seat observer	TANAPA
Samwel Bakari	Rear seat observer	TAWIRI
Greyson Mwakalebe	Front seat observer	TAWIRI
Goodchance Chao	Rear seat observer	TANAPA
Edward Kohi	Rear seat observer	TAWIRI

Appendix II: Survey planning, execution, data processing and analysis and reporting team.

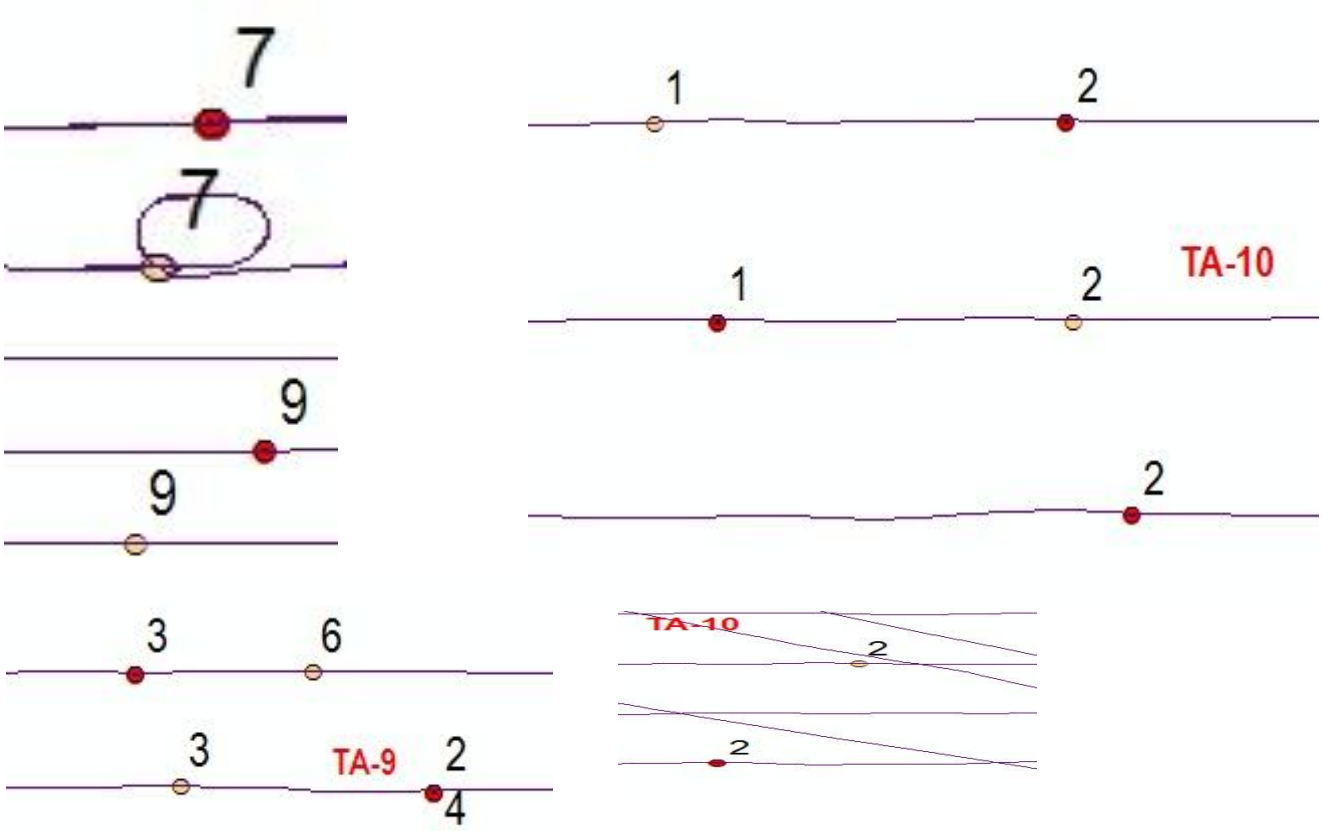
Survey Supervision	Dr. Simon Mduma
Survey co-ordination:	Mr. Honori Maliti (TAWIRI) and Felix Borner (FZS)
Survey ground logistics:	Felix Borner (FZS), Dr. Stephen Nindi (TAWIRI)
Survey adviser	Mr. Howard Frederick
Data handling and verification:	Dr. Stephen Nindi (TAWIRI), Dr. Edward Kohi (TAWIRI), Ms. Damari Samwel (TANAPA), Mr. Richard Lyamuya (TAWIRI), Ms. Cecilia Leweri (TAWIRI) and Mr. Noel Alfred (TAWIRI).
Georeferencing and Mapping	Mr. Honori Maliti and Mr. Hamza Kija (TAWIRI)
Data analysis and validation	Mr. Hamza Kija and Mr. Mwita Machoke
Report writing	Dr. Simon Mduma, Dr. Stephen Nindi, Dr. Edward Kohi Mr. Honori Maliti and Mr. Samweli Bakari,

Appendix III: Possible Source of Bias (Double Counting)

SERENGETI ECOSYSTEM: POTENTIAL BIASES IN ELEPHANT & BUFFALO TOTAL COUNT AERIAL SURVEY, WET SEASON, 2014



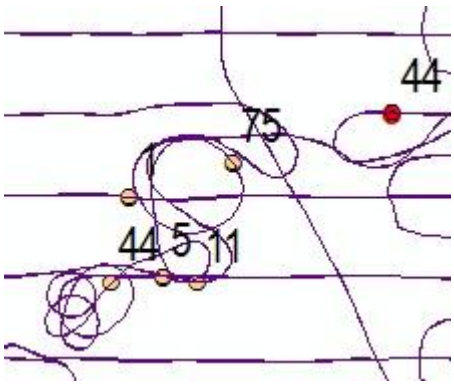
(i) **Potential Movement of Animals:** This can happen within or between blocks, in the same or different session (the animal being observed in both flight lines), same or different day, or in different sessions or in the adjacent block.

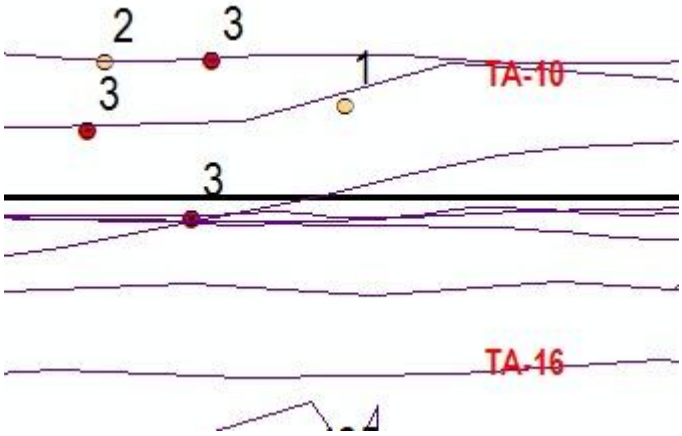


There were six individuals in one location instead of 18 individuals in five locations and two instead of four in the other screen shot

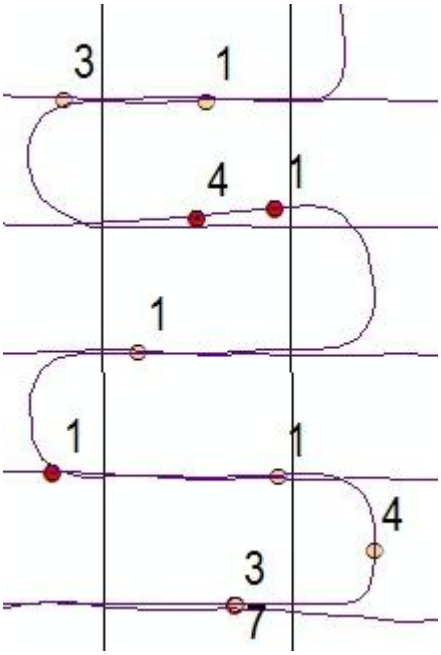
(ii) Block or Flight line overlap: This happened when there was an overlap between flown blocks or overlap of flight lines in the same block (north or south of the block) or in adjacent blocks (flight turns) in the same or different block and dates.

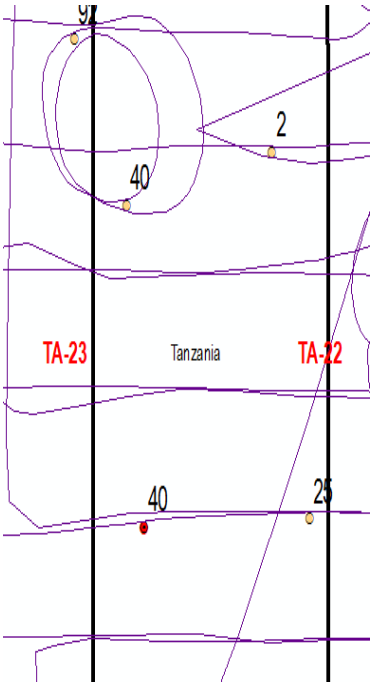
In the same block



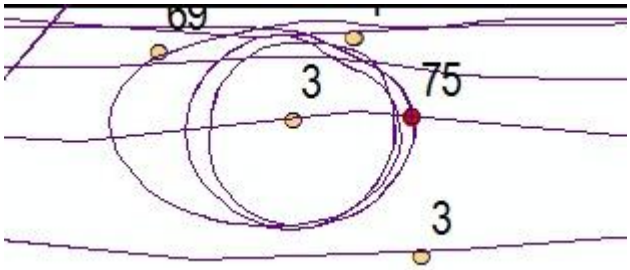


In overlapping blocks

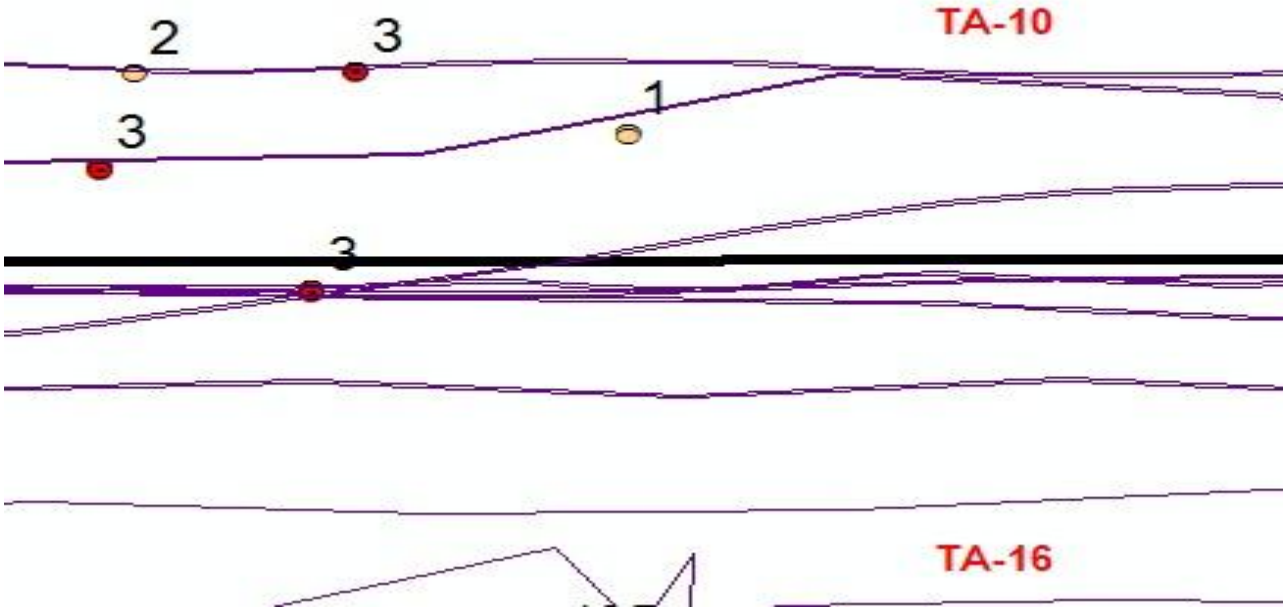




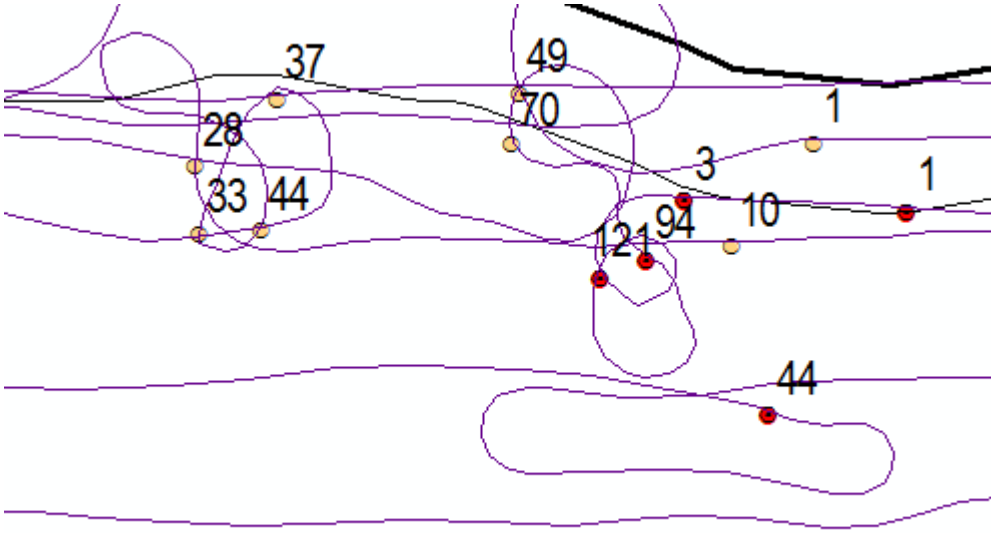
Condition B and D: Counted by two aircrafts in different day intervals: This is the same group in block TA-16 counted by 5H-CFA (75 individuals) on 22nd May. The same group spitted upon cycling and re-counted by 5H-GNU (69 + 3 + 3 individuals) after two days lapse. The actual count here looks to be 75 individuals and not a total of 150 individuals as would be summed up. We retained the three observations (69 + 3 + 3) to represent better the spatial distribution.



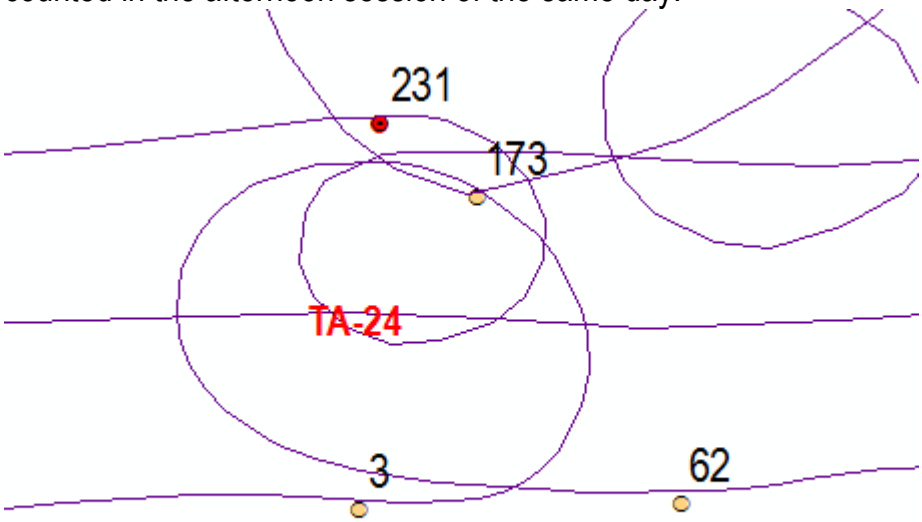
Adjacent blocks (TA-10 and 16) on two days lapse difference by two aircrafts above. The actual count here looks to be 3 individuals and not a total of 12 individuals. We retained the two observations (2 + 1) to represent better the spatial distribution.



The same group (94 + 3 = 97) in northern Makao O.A was counted on 4th June and repeated after two days lapse and counted as three different observations (33 + 28 + 37 = 98). In the same screen shot, 70 + 49 = 119 was re-counted again as 121 individuals; the same applies to 44 where counted as 44 after two days interval. All these represents double count due to overlapping blocks (TA-25 and 29) flown in different date.



Double count: Same day, different sessions: The group of 231 individuals was counted in the morning session and splitted into 173 and 62 (235 individuals) and re-counted in the afternoon session of the same day.

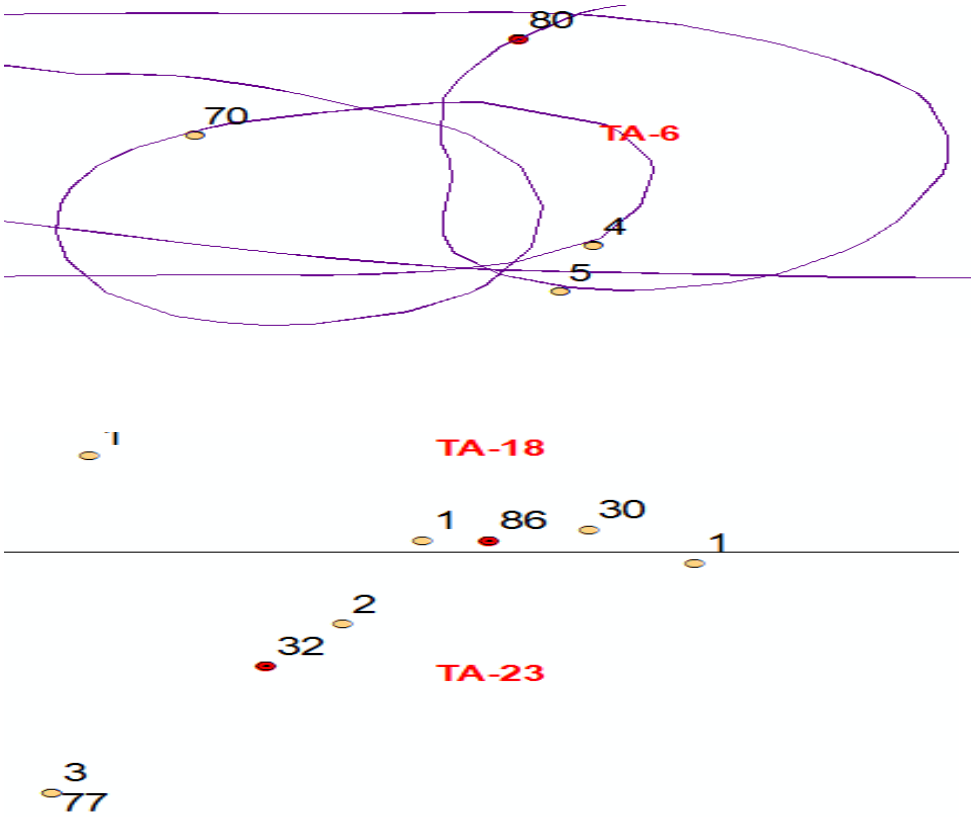


(iii) **Corrected vs Counted:** This bias happened when the data entry team summed up photos, without being careful on looking the overlapping photos, e.g a group of 40 animals taken in two different/overlapping or non-overlapping frames and are considered as different groups in data entry.

(iv) **Animals split/merge up during counting and re-counted and differences in flight dates between blocks:** Double counting in the same or adjacent blocks and when animals split during cycling the groups or merge-up during the same in the same (block/flight line) date or different.

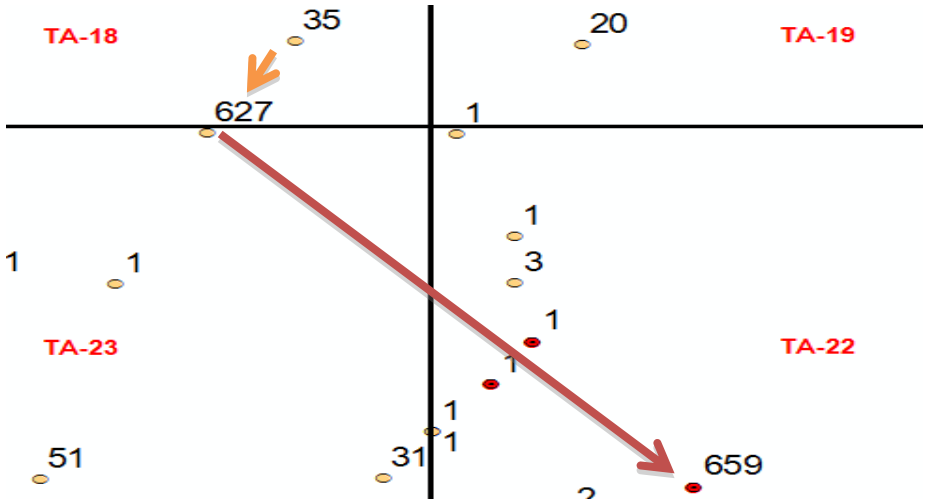
This is the same group of 79 or 80 animals but splitted/flushed during cycling, therefore an observation of 80 was dropped in favour of three groups (70+5+4) to better represent spatial distribution. There is also a possibility of being a group of 159 animals but recorded into four small groups.

Difference in dates between flown Blocks: The below screen shot shows two groups of 83 and 31 individuals. The observation with 86 individuals in TA-18 was counted on 25th

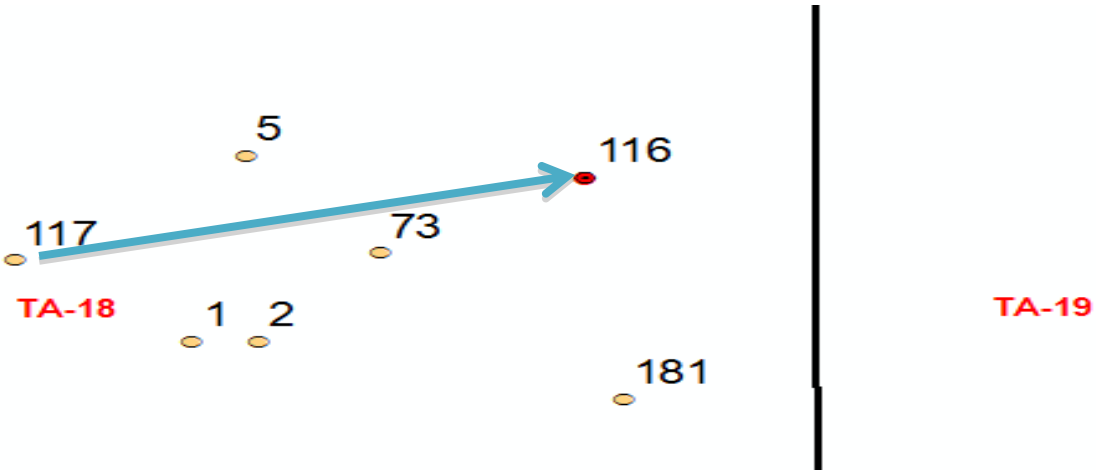


May as a single group then splitted and after 8 day was re-counted as in TA-23 as four different observations of 77 + 3 + 2 + 1 (83 individuals). In the same screen, the 30 + 1 individuals in TA-18 were re-counted as 32 individuals in TA-23 after the lapse.

The two groups (627+35 =662) converged and moved down 5.7 Km to TA-22 as 659 after two and a half days.



Different date in the same block: The group of 117 individuals was counted on 25th May morning session then moved 2.2 Km and re-counted on 27th May as a group of 116 individuals.



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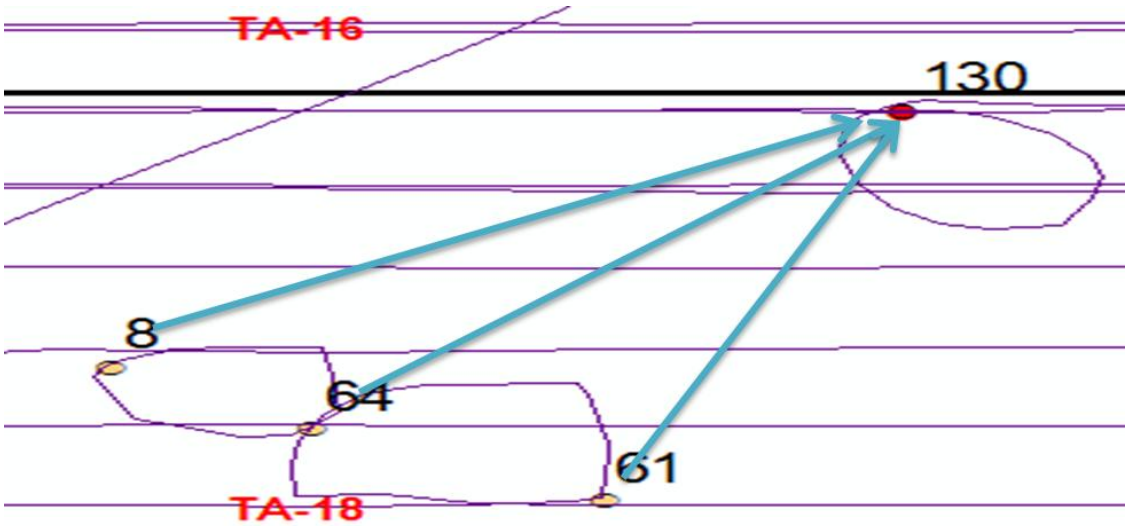
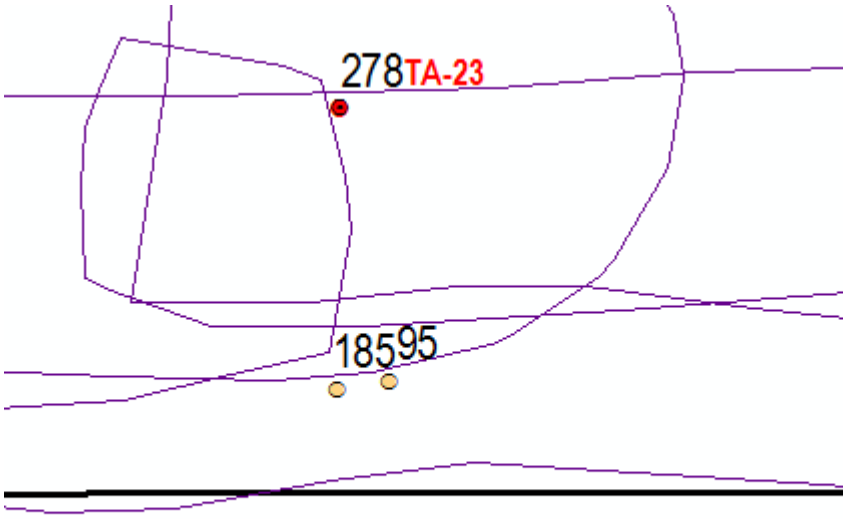
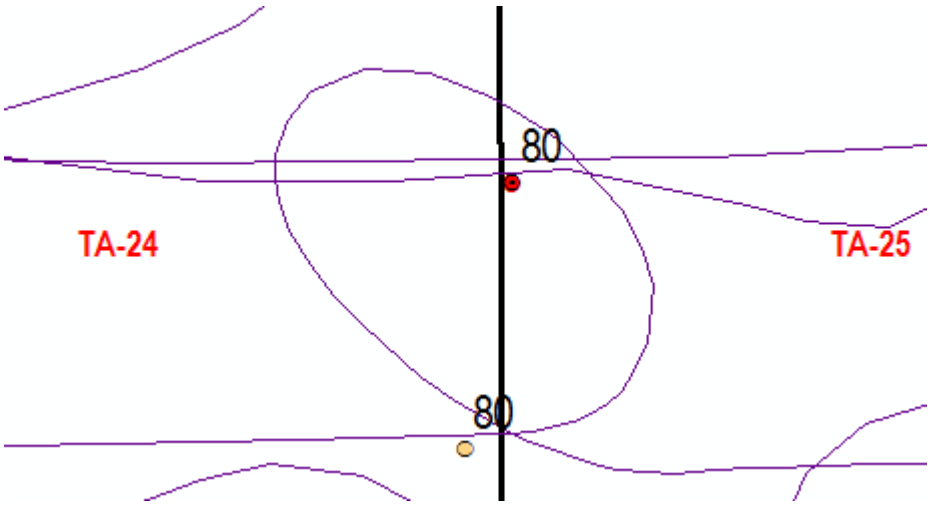


The group counted as 278 and splitted into two groups (189 +95 = 280) and re-counted the next day as an overlapping flight line for TA-24



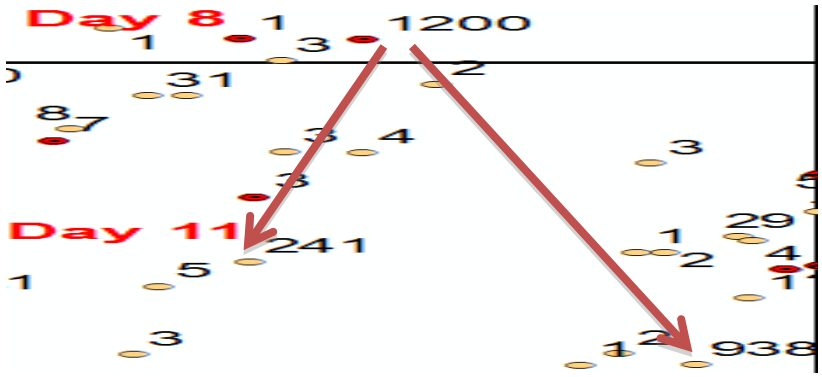
TA-24

The same group counted by CFA and 5H-GNU in overlapping blocks (TA-24 and 25) on the same day



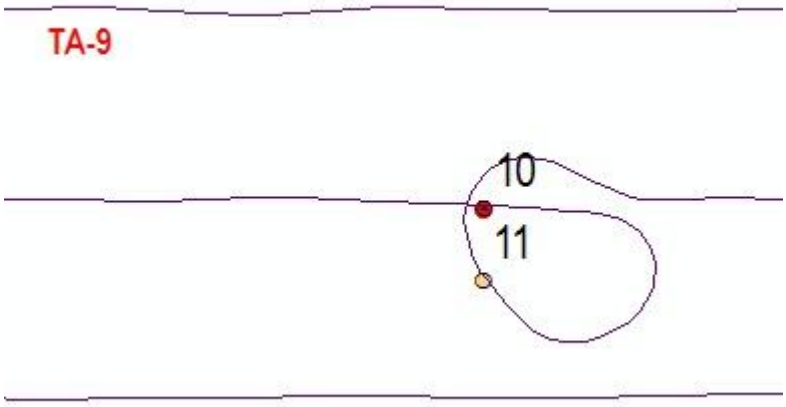
Difference in flight days between blocks: The same group of 225 was counted in TA-11 on 24 May and re-counted in TA-12 on 2nd June.

INTERESTING SITUATION: The group of 1200 in TAKE-2 splitted and moved down to TA-2 (241 for 20 Km) and (938 for 30 Km) after 3 days and a half

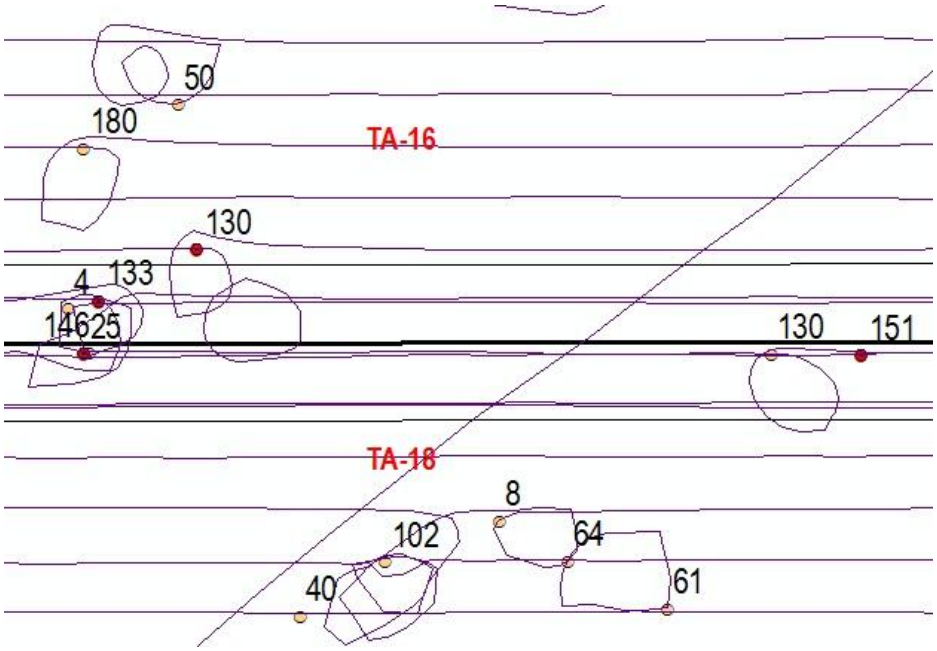


DIFFICULTIES IN DECISION DURING RE-ANALYSIS

This observation was counted twice by different observers, is it the same group or there were 21 individuals which splitted and counted independent by each observators?. In time being, I considered as a duplicate.



Double count due to overlapping blocks by 5H-ZGF check on the three tight flight lines around the borer of the two blocks.


50
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TA-16
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4
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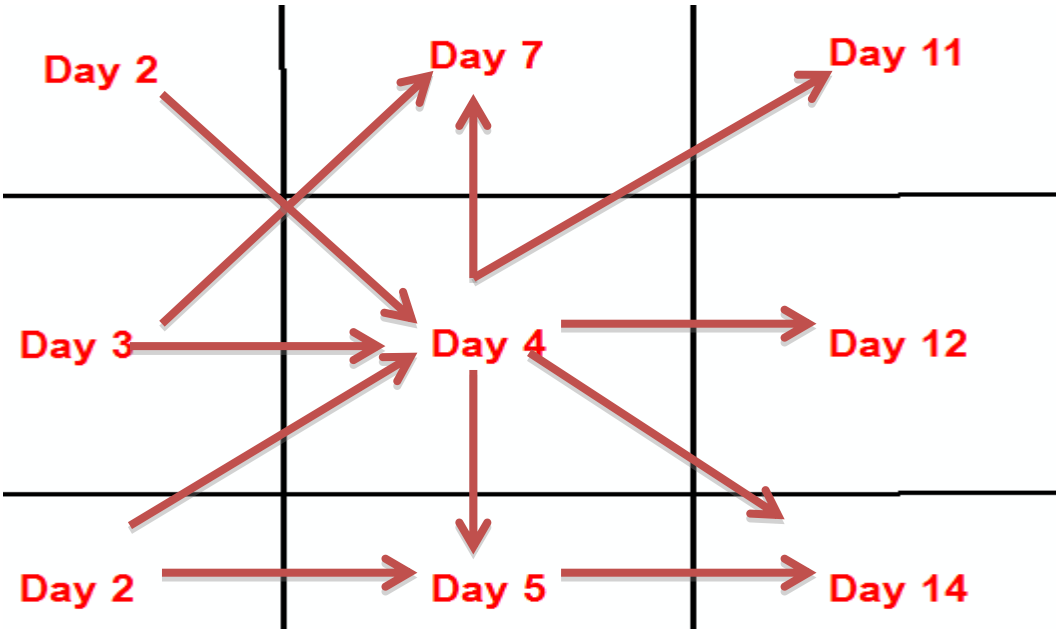
14625
130
151
TA-18
8
102
64
40
61


Day 2
Day 7
Day 11
Day 3
Day 4
Day 12
Day 2
Day 5
Day 14

Appendix IV: Elephant population per block count in Serengeti Ecosystem

SERENGETI ECOSYSTEM: WET SEASON ELEPHANT TOTAL COUNT, 2014							
Block Name	**Block Code**	**Original Count**	**Double Count**	**Corrected Count**	**Proportion**	**Sample**	**Group size**
Lamai	T0	409	58	351	5.8	33	11
Mara-Tabora	T1	629	91	538	8.8	29	19
Nyamalumbwa	T2	571	88	483	7.9	59	8
Lobo-Tabora	T3	1104	220	884	14.5	77	11
Tagora-Lobo	T4 + T4w	736	180	556	9.1	57	10
Banagi-Ikoma	T5	443	143	300	4.9	44	7
Grumechen	T6	542	138	404	6.6	64	6
Musabi Plains	T7	324	94	230	3.8	28	8
Western Corridor	T8 + T8n	263	1	262	4.3	8	33
Dutwa-Ndoha	T9n + T9s	311	13	298	4.9	19	16
Moru-Mamarehe	T10	830	101	729	12	81	9
Simiyu-Makao	T11n + T11s	473	98	375	6.2	48	8
Naabi Plains	T12	80	2	78	1.3	9	9
Maswa Central	T13	16	2	14	0.2	4	4
Simiyu-Suba	T14	128	5	123	2	17	7
Maswa South	T15	27	2	25	0.4	5	5
Loliondo North	T16	71	19	52	0.9	5	10
Loliondo South	T17	0	0	0	0	0	0
Ngorongoro South	T18 + T19	92	0	92	1.5	9	10
Ngorongoro Crater	T20	78	2	76	1.2	22	3
Makao Open	T21	67		67	1.1	9	7
Ikona Open	T22	191	41	150	2.5	8	19
Grand Total		**7385**	**1298**	**6087**	**100**	**635**	**10**

Results summary: Corrected count 82% (6087 elephants); Double count: 18% (1298 elephants)

Appendix V: Buffalo population per block count in Serengeti Ecosystem

Block Name	Block Code	Original Count	Double Count	Corrected Count	Proportion	Sample	Group size
Lamai	T0	1,142	452	690	1.25	23	30
Mara-Tabora	T1	534	50	484	0.87	9	54
Nyamalumbwa	T2	4,269	2135	2134	3.85	61	35
Lobo-Tabora	T3	3,269	792	2477	4.47	107	23
Tagora-Lobo	T4 + T4w	4,938	1030	3908	7.05	117	33
Banagi-Ikoma	T5	5,145	924	4221	7.62	81	52
Grumechen	T6	5,534	1751	3783	6.83	127	30
Musabi Plains	T7	5,248	1410	3838	6.93	116	33
Western Corridor	T8 + T8n	8,070	452	7618	13.75	114	67
Dutwa-Ndoha	T9n + T9s	4,926	992	3934	7.1	80	49
Moru-Mamarehe	T10	6,335	1691	4644	8.38	87	53
Simiyu-Makao	T11n + T11s	3,087	1798	1289	2.33	49	26
Naabi Plains	T12	169	5	164	0.3	6	27
Maswa Central	T13	2,758	554	2204	3.98	39	57
Simiyu-Suba	T14	3,342	1173	2169	3.91	67	32
Maswa South	T15	9,186	1702	7484	13.51	140	53
Loliondo North	T16	5		5	0.01	2	3
Loliondo South	T16	-	0	0	0	0	
Ngorongoro South	T18 + T19	279	4	275	0.5	13	21
Ngorongoro Crater	T20	2,378	73	2305	4.16	65	35
Makao Open	T21	1,771	269	1502	2.71	44	34
Ikona Open	T22	414	131	283	0.51	7	40
Grand Total		72,799	17,388	55,411	100	1354	41

Results Summary: Corrected Count: 76.12% (55,411 Buffaloes) Double Count: 23.88% (17,388 Buffaloes)