AERIAL TOTAL COUNT OF ELEPHANTS, BUFFALO AND GIRAFFE IN THE TSAVO-MKOMAZI ECOSYSTEM* (FEBRUARY 2017)

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* Tsavo-Mkomazi Ecosystem Hereafter: TME

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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EXECUTIVE SUMMARY

The Tsavo-Mkomazi aerial census is a regular cross border survey undertaken every three years within protected areas andtheir immediate neighborhoodsin both Kenya and Tanzania. The protected areas covered during the census include: Tsavo East, Tsavo West, Chyulu and Mkomazi National Parks as well as South Kitui National Reserve, while the adjoining neighborhoods include Taita, Kulalu and Galana Ranches.Jointly, all this areaforms the largest conservation area in Kenya covering an area of over 49,611.4km^2. The 2017 dry season aerial census was carried out between 12thFebruary 2017 and 21stFebruary 2017.

The census commenced with a training component where all participants and especially the observers underwent rigorous training to ensure that the participants were able to capture the right information/ data during the census.

The objectives of the census were to:

(i) determine the number and distribution of elephant carcasses, and calculate a carcass ratio as the key indicator of mortality trend,

(ii) determine the impact of poaching on the elephants population in the TME ecosystem

(iii) understand the distribution of elephants in relation to distribution of available water,

(iv) map human activities inside and outside the protected areas (i.e. logging, settlements, farming, and charcoal burning),

(v) document the distribution and numbers of livestock (cattle, camels, goats and sheep (shoats), and donkeys), in relation to elephants and other large mammals in the ecosystem

(vi) interpret the information obtained and deduce sound management decisions to guide management of elephants and other wildlife in this fragile ecosystem.

Nine light aircraft, 4-seater and 2-seater planes, fitted with observer calibrated streamers were used for the counting exercise. Data was captured by observers in the aircrafts using GPS and digital voice recorders. Flights were made along pre-established transects at altitudes between 300-400ft above ground across the Ecosystem.

The aerial census search effort averaged approximately 148 km^2 per hour. A total of 12,866 elephants were counted; 12843 in Tsavo Ecosystem and 23 in Mkomazi National Park. Overall, the elephant population in TME increased by14.7% over the last three years (2014-2017). This represents an annual increase of 4.9% over the period. However, the increase was only in Tsavo ecosystem where the population recorded an increase of about 15.1% (2014: n = 11,158 elephants; 2017: n = 12,843 elephants). In Mkomazi National Park, the elephant population decreased by 61% (2014: n = 59 elephants; 2017: n = 23 elephants) between 2014 and 2017, which represents about 20.3% annual decrease. Three (3) and twenty seven (27) fresh and recent carcasses (Tsavo and Mkomazi respectively) were recorded during the aerial survey.

The population of buffalo counted in Tsavo-Mkomazi ecosystem during the February 2017 census was 8,623 which is about 46% increase compared to 5,912 buffalo recorded in the same ecosystem in 2014. The population of buffalo in Tsavo ecosystem increased by about 52% (2017: n = 8525 buffalo; 2014: n = 5604 buffalo) whereas that in Mkomazi National Park decreased by 68% (2017: n = 98 buffalo; 2014: n = 308 buffalo).The 2017 Tsavo-Mkomazi census indicated that the ecosystem supports a large number of giraffes (n=4323 giraffe) as compared to (n=2891 giraffe) in 2014 census. Group sizes of up to 80 individuals were recorded in 2017. This represents an increase of 49.5%, which is a very good result considering the threat giraffes are under due to poaching for meat.

There was an increase in human activities within and around the protected areas compared to the situation in the previous years. Incidents of charcoal burning are on the rise, as well as the number of livestock in the ecosystem, both of which pose a threat to wildlife and their habitat.

There is need for further investigation on elephant poaching threat levels in the MkomaziNational Park, Galana Ranch and Tsavo East National Park (North) where a high carcass ratio was found.

LIST OF ACRONYMS

AWF	African Wildlife Foundation
CCA	Coast Conservation Area
CHNP	Chyulu Hills National Pak
CRCA	Central Rift Conservation Area
DEM	Digital Elevation Model
DRSRS	Department of Resource Survey and Remote Sensing
DSWT	David Sheldrick Wildlife Trust
ECA	Eastern Conservation Area
ESRI EA	Environmental Systems Research Institute East Africa
FSO	Front Seat Observer
GIS	Geographical Information System
GPS	Global Positioning System
HAG	Height above Ground
HQs	Headquarters
IFAW	International Fund for Animal Welfare
ITCZ	Inter-Tropical Convergence Zone
IUCN	International Union for Conservation of Nature
KWS	Kenya Wildlife Service
MCA	Mountain Conservation Area
MIKE	Monitoring Illegal Killing of Elephants
MNP	Mkomazi national Park
NP	National Park
NR	National Reserve
RSO	Rear Seat Observer
SCA	Southern Conservation Area
SKNR	South Kitui National Reserve
SSC	Species Survival Commission
STE	Save the Elephants
TANAPA	Tanzania National Park
TAWIRI	Tanzania Wildlife Research Institute
TCA	Tsavo Conservation Area
TENPN	Tsavo East National Park Northern
TENPS	Tsavo East National Park Southern
TME	Tsavo-Mkomazi Ecosystem
TT	Tsavo Trust
TWNP	Tsavo West National Park
UTM	Universal Traverse Mercator
WWF-K	World Wildlife Fund - Kenya

1.0 INTRODUCTION

The Tsavo-Mkomazi Ecosystem (TME) coversan approximated area of 49,611km^2. The extent of the remaining elephant (*Loxodonta africana*) range in Africa is reported to be between 2.3 and 3.4 million km^2 (Chase *et al.*, 2016). TME represents approximately 2.0% of remaining African elephant range. TME therefore significantly contributes to this network of protected and connected area left to the species which have been shown to have a characteristic of long distance movements (Ngene *et al.*, 2009; Douglas-Hamilton *et al.*, 2005; Leuthold, 1977; Thouless, 1995). Tsavo National Park is Kenya's largest contiguous conservation area and combined with Tanzania's' Mkomazi National Park provides a key trans-boundary conservation area in Africa. The elephant population in this ecosystem is also Kenya's largest and provides much impetus internationally for conservation awareness and action.

The TME 2017 elephant census is the 18thsuch total elephant count conducted inthe area. It was conducted between the 13th and 23rd of February, with training taking place during the first three days of the exercise. Past counts date back to 1962, and while not always regularly implemented, they provide a reliable long term trend which is important knowledge for the conservation and management of the population (Ngene *et al*., 2013). A good description of the history of the Tsavo aerial census, the methods used over time and the summarized results are outlined by Kyale *et al.* (2014) and Ngene *et al.*, (2013). Poaching and drought have been constant threats over this period and several population reductions have reduced to below 6000 elephantsat times (Olindo *et al.*, 1988, Douglas-Hamilton *et al.*, 1989). However, when not suffering from drought or rampant poaching, the recovery of the population has been rapid (Thouless *et al.*, 2002, Omondi *et al.*, 2008; Kyale *etal.*, 2014). Recovery rates show the strong and resilient nature of this population and point to the importance of the ecosystem for wildlife conservation in general.

The 2017 census included a shorter list of target species or objects to be counted than in previous years, and mandated a three-day training camp for observer and pilot crews. These standards were put in place to ensure the accuracy of the count given the growing trend in poaching elephant and the need for reliable data from which to prioritize actions towards conservation and management of the ecosystem. This is not the first time the list of wildlife targets have been just three species (elephant, buffalo (*Syncerus caffer*) and giraffe (*Giraffa camelopardalis* and *G. c.reti*culata), and similar focused counts were carried out in the 1980's for example (Douglas-Hamilton et al.1989, 1994). It is also the second time that Systematic Reconnaissance Flights (SRF or Sample Counts) have closely followed the completion of a total count in Tsavo (Chase *et al.*, 2016; Lamprechts unpublished data 2017). The efforts and focus of this count were designed to meet the fast changing scenario in the conservation status of different species in the ecosystem.

Total counts are resource intensive and require significant investments of both time and funding to execute over large areas such as the TME. Advances in high resolution digital photography and remote sensing make SRF a more viable and repeatable option. The value of long term trends generated by consistent methodology, as is the case with the legacy of Tsavo's total counts, cannot be lost and so there is a need to provide a rigorous transition between the two, complimentary, methodologies. Future combined total and SRF counts will develop parallel trends and conversion factors to allow scientists and managers to select the most appropriate method.

Monitoring of elephant carcasses alongside live elephants is crucial for understanding the rate of increase or decrease. It is estimated that up to 4% of elephants in a population die of natural causes. Illegal killing has been attributed to the cause of decline of elephants in Tsavo ecosystem since the 1970s (Ottichilo et al. 1987). Frequent drought, fires and vegetation changes were identified as some of the key threats to elephants in the Tsavo ecosystem in the 1960's (Glover 1968, 1972, Oweyegha-Afunaduula 1982). Total aerial count has provided a basis for estimating elephant mortality in the Tsavo ecosystem since 1970, when 5900 elephants were estimated to have died of drought in a span of two years (Corfield 1973). The mortality was highly selective, with calves and adult females succumbing most (Corfield 1975). A relatively lower number of carcasses, 1800, was recorded during the 1989 aerial count, at least 6.5% of them having died within 12 months, i.e., recent carcasses (Douglas-Hamilton 1990). The rate of population growth of elephants in Tsavo ecosystem slowed considerably in the late 1990's, a time when the ratio of fresh carcasses to old carcasses increased too (Kahumbu et al. 1999). In the year 2002, the carcass ratio was lower and this tallied with an increase of 15% of the Tsavo elephant recorded (Omondi et al. 2002)

As in previous censuses, the objectives, of this aerial census were:

i. To determine the number and distribution of elephant carcasses, and calculate a carcass ratio as the key indicator of mortality trend.
ii. To determine the impact of poaching on the elephant population in the TME ecosystem.
iii. To understand the distribution of elephants in relation to distribution of available water.
iv. To map illegal and habitat destructive human activities inside and outside the protected areas (i.e., logging, settlements, farming, and charcoal burning).
v. To document the distribution and numbers of livestock (cattle, camels, goats and sheep (shoats), and donkeys), in relation to elephants and other large mammals in the ecosystem.
vi. To interpret the information obtained and deduce sound management decisions to guide management of elephants and other wildlife in this fragile ecosystem.

2.0 STUDY AREA

2.1 Location and Climate

The Tsavo-Mkomazi ecosystem is located in southeastern Kenya and northeastern Tanzania between latitude 1°33’S-4°36’S and longitude 37°34’E-39°36’E. This transboundary ecosystem is constituted of several wildlife ranches, Kitui National Reserve, Tsavo East, Tsavo West and Chyulu Hills National Parks in Kenya and Mkomazi National Park in Tanzania (Figure 1).

The rainfall regime in the Tsavo ecosystem is related to the movement of the Inter-Tropical Convergence Zone (ITCZ), (Wijngaarden, 1985). Climate in Tsavo area is semi-arid, with an unpredictable, bimodal rainfall distribution of between 200 and 700 millimeters per annum (Wijngaarden, 1985; Kasiki, 1998). The long rainy season is experienced in the months of March - April/ May and the short rain season in November - December. Rainfall in Tsavo West is generally higher and usually less erratic in spatial and temporal distribution than in Tsavo East (Wijngaarden, 1985; Leuthold and Sale, 1973). Although the seasons described above are usually well defined, rainfall varies considerably in its spatial and temporal distribution. The average normal daily temperatures range between 20°C and 30°C. The temperatures are slightly higher in the dry season than in the wet season.

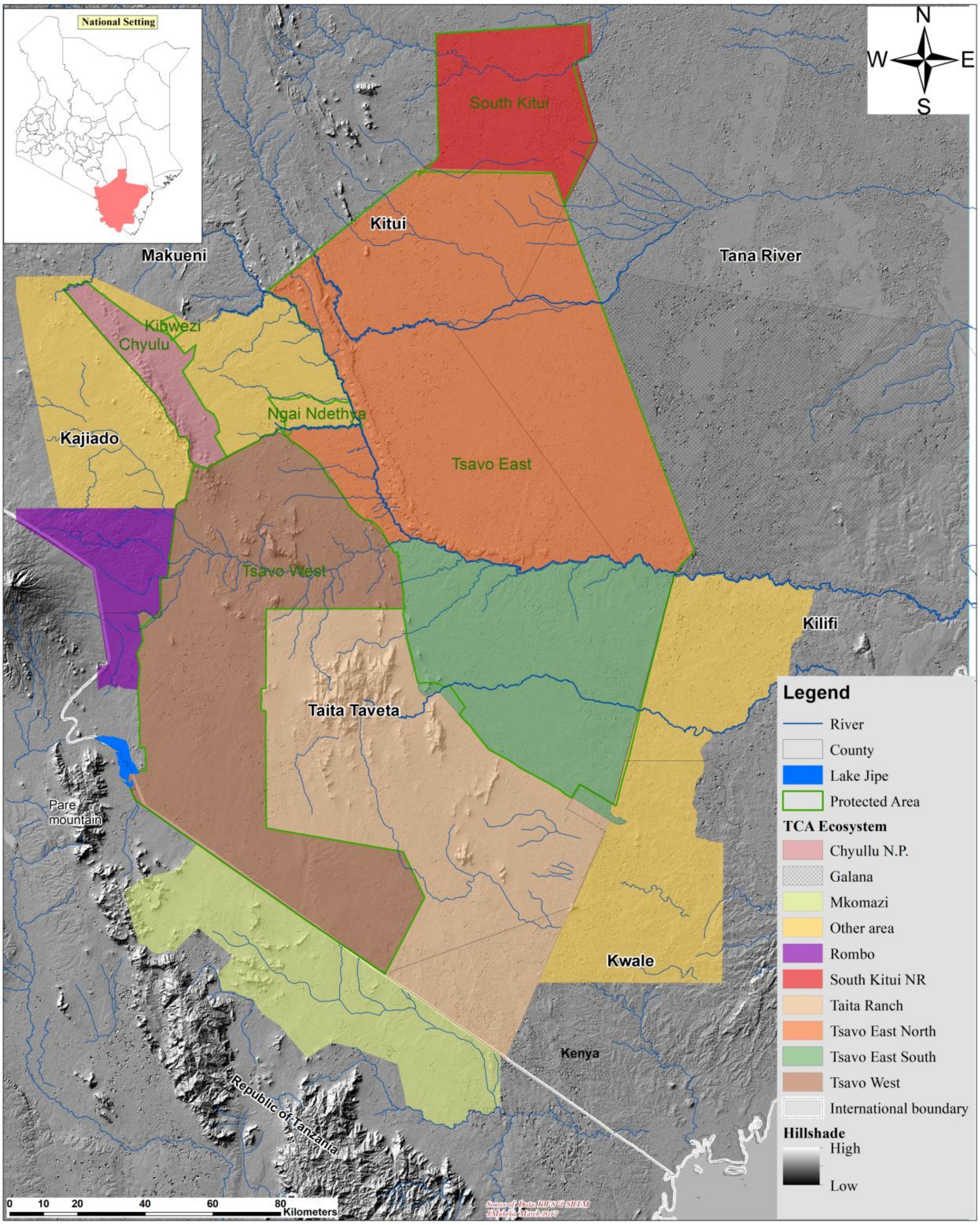

Figure 1: Map showing the aerial survey area during the February 2017 Tsavo-Mkomazi census. Taita Ranch refers to all the ranches in Taita-Taveta

The area has only one permanent river - the Tsavo-Athi-Galana, and two major seasonal rivers, the Voi and Tiva. The main rivers have their major water supply outside the study area in higher rainfall areas. Natural waterholes, which often contain water for over four months into the dry season are an important source of water for the wildlife.

2.2 Topography and Soils

The topography of the study area consists of an undulating landscape dotted with hilly areas like the Yatta Plateau, Taita hills, Ngulia hills, Chyulu hills, Kasigau, Pare mountains and the low lying areas forming extensive plains which have very high wildlife diversity. The soils are generally deep, well drained and slightly acid, except near the major rivers where the landscape has been rejuvenated; here the soils are shallow, stony and fairly rich. The soils of the Tsavo area show a wide range in depth, colour, drainage condition, structure, and chemical and physical properties (Wijngaarden, 1985).

2.3 Vegetation

The lowland savanna vegetation is dominated by Acacia–Commiphora bushlands and thickets, in which the density of trees and shrubs varies significantly over time and space. Common tree species occurring in forests along rivers include *Dobera glabra*, *Newtonia hildebrandtii*, *Acacia elatior* and *Kigelia africana*. Tree species found in woodlands include *Cassia abbreviata*, *Delonix elata*, *Platyceliphium voense, Melia volkensii, Acacia tortilis, Acacia reficiens, Acacia thomasii* and *Adansonia digitata* as an occasional emergent. In wooded bushlands, several*Commiphora* species anda few*Lannae* species dominate the tree layer. When the tree layer has been destroyed by humans, fire or large herbivores, these species are still present as saplings but other shrub species such as *Premna* species, *Bauhinia taitensis* and *Sericocomopsis pallida* then become the dominant woody species.

In the poorly drained soils which are often alkaline, the vegetation structure is open bushed grassland or bushland with *Grewia tenax, Cordia haraf, Boscia coriacea, Acacia tortilis, Acacia reficiens, Grewia vilosa* and *Erythrochlamys spectabilis*. On bright orange-red loam soils adjacent to granitic intrusion, the shrub and small tree species include *Dirichletia glaucescens, Euphorbia engleri, Hymenodction parvifolium, Commiphora riparia, Strychnos decussata, Lannea elata, Adenia globosa, Premna resinosa, Boswellia hildebrandtii, Bauhinia taitensis, Sesamothamnusrivae, Calyprotheca somalensis* and *Grewia fallax*. On brown sandy clay loam soils the shrubs and small trees species consist of *Combretum aculeatum, Dobera glabra, Cadaba heterotricha, Caesalpinia trothae, Acacia tortilis, Sericocomopsis hildebrandtii* and *Ehretia taitensi* among others. On buff-brown sandy loam soil the shrub and small tree species include *Acacia bussei, Acacia mellifera, Boscia coriacea, Combretum aculeatum, Commiphora africana, Cordia monoica* and *Grewia tembensis*. Other common bushland communities include *Bauhinia taitensis thicket, Ochna inermis thicket, Givotia gosai thicket* and *Anisotes parvifolius* thicket.

In areas with water (e.g., near water-pans with permanent water), the trees and shrubs species include *Newtonia hildebrandtii, Thylachium thomasii, Salvadora persica*, and scattered bush clumps of *Echbolium revolutum, Maerua denhardtiorum*, and *Maerua subcordatum*. The scattered waterholes and wallows may have clumps of shrubs of *Lawsonia inermis, Ziziphus* *mucronata* or *Gardenia jovis-tonantis* and occasionally *Tamarindus indica* and *Kigelia africana.*

The grass cover varies greatlybecause of the difference in soil structure, climate and land use. Grasses and other herbs are generally perennial, either scattered or in small isolated groups with the main grass species being *Brachiaria deflexa*, *Brachiaria leersoides, Cenchrus ciliaris, Digitaria macroblephara, Latipes senegalensis, Panicum maximum, Aristida adscensionis, Chloris roxburghiana, Tetrapogon tenellus* and *Sporobolushelvolus* (Andanje, 2002). The common shrubs in grasslands include *Acacia bussei, Cadaba heterotricha, Combretum aculeatum,* Commiphora species, *Terminalia orbicularis, Boscia coriacea, Acacia tortilis, Caesalpinia trothae, Caucanthus albidus, Cassia longiracemosa, Ehretia taitensis* and *Thylachium thomasii* (Andanje, 2002).

2.5 Fauna

The common wildlife species in Tsavo ecosystem are elephants (*Loxodonta africana*), Giraffe (*Giraffa camelopardalis*), African buffalo (*Syncerus caffer*), hippopotamus (*Hippopotamus amphibius*), Burchell's zebra (*Equus burchellii*), eland (*Taurotragus oryx*), waterbuck (*Kobus ellipsiprimnus*), Coke’s hartebeest (*Alcelaphus buselaphus*), Grant’s gazelle (*Gazella grantii*), Impala (*Aepyceros melampus*), lesser kudu (*Tragelaphus imberbis*), gerenuk (*Litocranius walleri*), warthog (*Phacochoerus aethiopicus*) and fringe-eared oryx (*Oryx beisa callotis*). The Tsavo ecosystem also hosts a significant number of endangered species like the black rhino (*Diceros bicornis*) and African wild dog (*Lycaon pictus*) which occur within their natural range, as well as small populations of species that have been translocated outside their natural geographic range like the Grevy’s zebra (*Equus grevyi*) and Hirola (*Beatragus hunteri*). This significant herbivore community supports a guild of large carnivores that include lion, cheetah, leopard, African wild dog, spotted and striped hyena.

2.6 Land Use

There are different types of land uses. In this paper, we identify and highlight six categories of land use important in the study area as: wildlife conservation, agriculture, transport and commercial.

2.6.1 Agriculture

Agriculture is practiced in form of crop farming and livestock rearing. Crop farming is both subsistence and commercially intensive with reticulated irrigation. The rise in human population has led to intensification of small-scale farming in areas bordering the wildlife conservation areas resulting to isolated farms and settlements with land use often incompatible with conservation. Livestock rearing is mainly by pastoral communities who live a nomadic lifestyle and whose movements are determined by the location of pasture. Livestock keeping is mainly practiced by the Masai and Somali communities who have sentimental attachment to livestock and often overstock, thus having to move into protected areas when pasture is depleted on the community areas. In the past five years, there has been an increase in livestock numbers in ranches that initially acted as wildlife dispersal areas and this has led to increased competition with wildlife for both water and pasture.

2.6.2 Transport

The ecosystem has a large network of transport infrastructure constituted of roads, old railway, standard gauge railway, oil pipelines, water pipelines and high voltage power transmission lines. These infrastructural developments are critical as the country's economic development continues to grow yet they also put a strain to conservation and as they lead to habitat loss and fragmentation, hinder ecosystem connectivity and thus genetic flow, encourage urban growth and settlements.

2.6.3 Wildlife Conservation

This is a major land use type accounting for over 55% of the study area with the land either under the national park system, private and community conservancies. The Tsavo (East and West) national parks have the highest diversity of wildlife and host the largest single elephant population in Kenya. The Tsavo-Mkomazi ecosystem is also very important for conservation of endangered species which are found in small populations. The ecosystem is therefore maybe the most important for hosting viable populations of different species in the country.

2.6.4 Commercial

In this study, we refer to commercial land use as land that is taken up by urban and peri-urban development. The main towns, which are business centers, are found along the Mombasa – Nairobi highway and include Mackinon, Bachuma, Maungu, Voi, Ndii, Mtito Andei, Kibwezi, Makindu, Kiboko. Other than the shops, hotels and open markets, more area is taken by commercial property and residential houses. These commercial centers continue grow and take up land that was previously wildlife dispersal area. The land under commercial use is expected to expand with the opening up of the standard gauge railway and as the Taita ranches continue to be subdivided into commercial plots in areas next to the Mombasa – Nairobi highway.

3.0 MATERIAL AND METHODS

The methodology adopted for the 2017 census isa continuation of total count methodsdeveloped from standard operating procedures and employed in Tsavo since the early 1970's (Norton-Griffiths, 1978; KWS, 1989, Douglas-Hamilton *et al.*, 1994, Douglas-Hamilton 1997, Kahumbu *et al.*, 1999; Bitok *et al.*, 2002; Omondi and Bitok, 2005; Jachmann 2005, Omondi *et al.*, 2008; Ngene *et al.*, 2013; Kyale *et al.*, 2014).

The 2017 census targeted three species; elephants, giraffes and buffalo. The census was also preceded by three-day training for observers and pilots. These standards were put in place to maximize the accuracy of the count. A similar short list of target species was counted in the 1980’s and 1990s as reported by Douglas-Hamilton *et al.* (1989) and Douglas-Hamilton *et al.* (1994). The efforts and focus of this count were designed to meet the fast changing scenario in the conservation status of different species in the ecosystem.

A total aerial count was implemented following procedures described by Douglas-Hamilton (1996). The aircraft flew adjacent flight lines spaced at 1km intervals. Crews counted target species and human activity within the 500m strip-width on each side of the aircraft, with no overlap except for the edges of a block for the purpose of ensuring that animals crossing in or out were not missed by either crew. Records from the overlaps at the edge of blocks were screened for possible double counts by the data cleaning team in consultation with the flight crews.

The survey area covered about 49,611.4km^2, and was divided into 91 counting blocs ranging in size between 226Km^2 and 600Km^2 (Figure. 2).The blocks were designed and sized in a manner that ensured complete coverage within a day to minimize missing out of animals as they move between specific blocks.

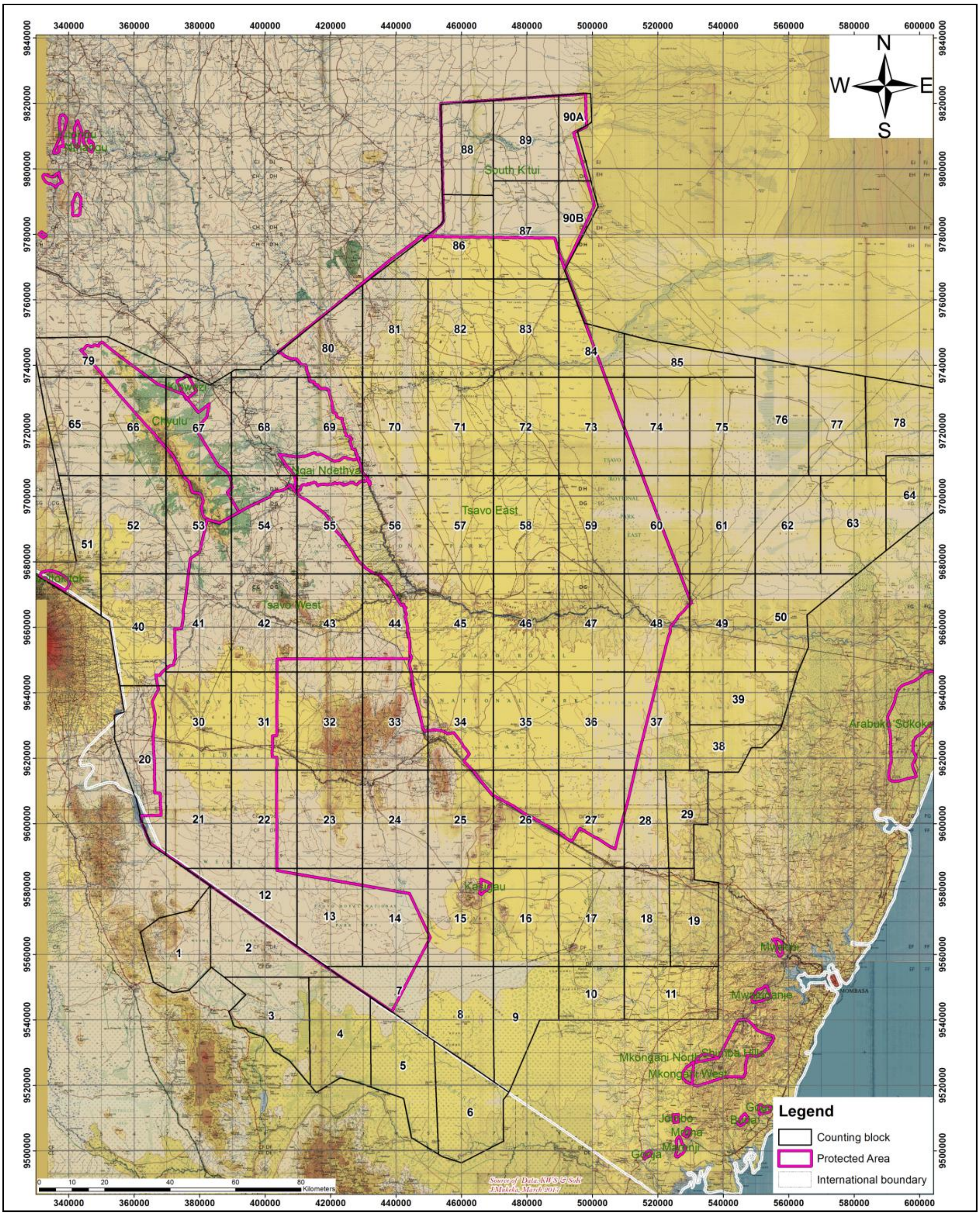

Figure 2: The Tsavo-Mkomazi ecosystem with counting blocks for the 2017 census of elephant, buffalo, giraffe and human activities

The following were the species, human activities and objects that were recorded during thecount:

- Elephants

- Elephant Carcasses, delineated by age: Fresh, Recent, Old and Very Old(see: CITES, MIKEhttps://cites.org/eng/prog/mike/tools_training_materials/forensic-training/carcass-class)
- Giraffe
- Buffalo
- Water points with water
- Human activity:
  - Active and Abandoned Boma sites
  - Mabati Roof (a metal roof denoted a more permanent structure)
  - Livestock: Cattle, Camels, Shoats and Donkeys
  - Charcoal Kilns
  - Agricultural Cultivation

The crew circled and counted elephants spotted further away from the flight line, partially obscured by vegetation or groups of more than 10 animals as described by Douglas-Hamilton (1996) and illustrated in figure 3 below.

3.1 Survey Design

The Survey design included:

i. Full coverage of the survey area, divided into survey blocks no larger than 600Km^2. This area was found to be an achievable target for one aircraft in a single day (based on previous surveys experience, and the calculation of available flying time).

ii. An East- West Flight direction wherever terrain allowed. This was done to maximize visibility for the crew given the position of the sun. See Appendix 3. For the final orientation of transects in the survey' execution.

iii. Including only experienced, well trained (or new but well trained and vetted – see Training below) observers in air crews.

iv. Using appropriate analytical methods in the determination of population sizes and in the case of elephant carcasses, carcass ratios.

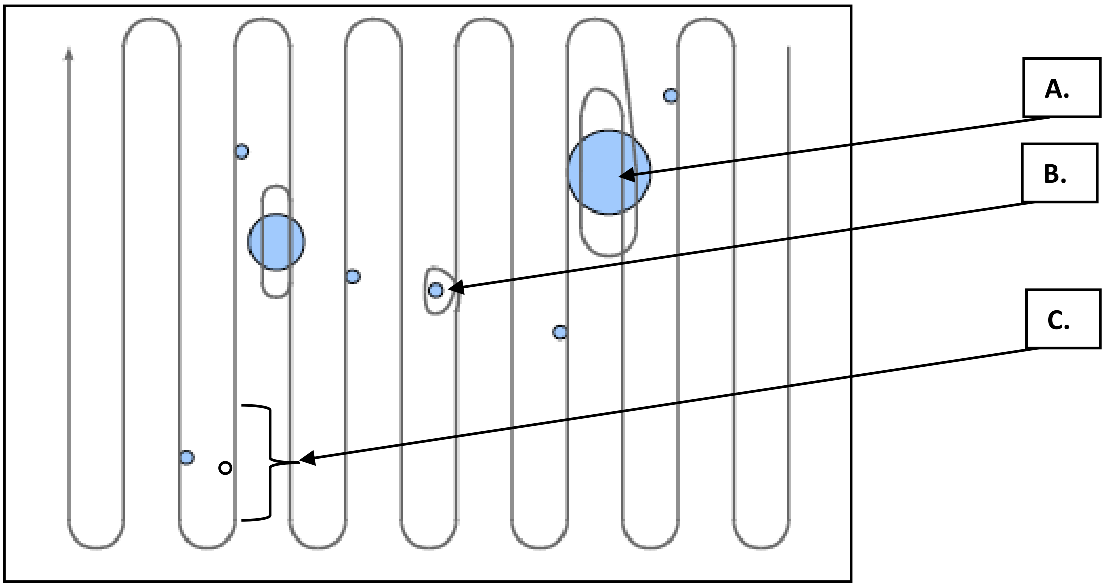

Figure 3: Total count Transect pattern and flight protocol, adapted from WCS Aerial Survey Manual (Fredericks *et al.*, 2011).**A:** Large group circled to verify count. **B:** Small group circled to verify count owing to dense bush. **C:** potential double count to be cleaned in post count data verification with crew.

3.2 Data Collection

Each Front seat observer (FSO) operated a GPS receiver and each rear seat observer (RSO) used a digital voice recorder and a camera to document observations. The crew spotted target species on their respective sides of the and recorded on the Dictaphone: the Species name, total count, side of the aircraft, and the GPS waypoint number, for example "Elephant, 12, Right, GPS 124" and recorded by the relevant Rear Seat Observer (RSO). When the count was uncertain or more than 10 animals were seen the aircraft circled the herd and where possible, a photograph was taken.

A GPS enabled digital camera was provided in each aircraft to capture geo-located photographs of large or partially obscured groups of elephant, buffalo and giraffes. The specified flight parameters adhered to during the survey were: (height; 300 - 350ft Above Ground Level (AGL), speed; 80 - 90Knots; Flight duration of 2.5 hours' max before a rest period and no counting between 11:00 and 15:00). These were done so as to reduce fatigue and inter-crew variability and provide optimal conditions for counting from the air given environmental conditions.

Streamers on aircraft wing struts were calibrated to counting strip width (500m), using an outer streamer set to the specific observers' eye level in the aircraft. This served as a guide to transect width, but crews were prepared to adjust their reference point depending on aircraft attitude and variations in altitude. This technique, borrowed from SRF methodology, is useful in preventing the observer from focusing their search in adjacent counting areas. The approach minimized double counting and the potential of missing animals closer to the aircraft in case crew attention might be focused elsewhere. It is important to note that this is not a proxy for sample counting. All targets are counted within the strip width and all strips are consecutively adjacent to one another, and abutting. Hence total count coverage is achieved and observers are provided with visual guides to ensure rigor.

Elephant carcasses were counted alongside live elephants, buffalo and giraffes. Four categories of carcasses, by age, were recorded; fresh, recent, old and very old (Douglas-Hamilton and Hillman 1981). The first and second categories, and the third and fourth are pooled in analysis and referred to as "Recent" and "Old". The proportion of "Recent" in relation to the live population is an indicator of the previous year's mortality. This so called "Carcass Ratio" was calculated as "dead / (dead + live elephants)" (Douglas-Hamilton and Burrill 1991).

Photography of large groups of elephants, buffalo and giraffe procedures were as follows:

a) The pilot makes a pass to the side of the group, or circles it;
    i. Photographs are taken by the RSO facing the group as positioned by the pilot.
    ii. All crew agree on the estimate and the RSO responsible makes a new recording if needed, stating the photograph sequence numbers e.g. "Repeat Elephant 15 Right, photo 1254 to 1262, GPS 125".
    iii. The FSO makes a paper backup recording of the sighting on a data sheet whenever possible.
    iv. Aircraft returns to the flight line where it left the transect.
b) Crews are all actively involved in keeping accurate track of groups and areas counted.
    i. Possible duplicate observations are noted by the FSO in flight;
    ii. Possible missed observations on the previous flight line are checked.
c) After the block is counted, data was downloaded from the Dictaphones, GPS and cameras. The photographic data counted immediately prior to transcription of the recordings into the voice recordings and/or hard copy records into the database.
d) Data are mapped and independently checked for duplicate observations. Any suspected duplicates are reviewed with observer crews.
e) Flight lines are mapped to ensure complete coverage.
f) Once duplicates are removed, totals are produced for entire survey region.

Full details of this process are available in the survey manual accompanying this report (Davidson and Eldridge 2017).

3.3 Training

In order to enhance the accuracy of the count and minimize inter- observer variability, the actual census was preceded by three days of training for all participants. The objectives of the training were:

i. To ensure that all crews were fully conversant with the survey protocol.

ii. To ensure that the process of data collection was well practiced and that all participants had a clear knowledge of the pattern of data collation using the survey tools.
iii. To evaluate the survey crew's performance and capability before the count was initiated.
iv. To train a pool of observers than was required so as to build capacity for aerial surveys personnel for other future counts in Kenya.

The training and evaluation comprised of a series of ground and airborne sessions as described below. These sessions were delivered through formal presentation, practical exercises and aptitude tests. A survey manual is available for all crew as a revision tool for future similar surveys (Zeke, 2017).

3.3.1 Ground based Training

Training comprised of five sessions each with a specified set of activities;

i. First session - Introduction to survey methods; the overall survey protocol and standards were explained in full.
ii. Second session - Explaining target species, activities or objects; target species and human activity was defined. Relevant aerial photos were used for identification and to practice counting groups as described by Norton-Griffiths 1978.
iii. Third session - simulated counts from aerial photos; the Wildlife Counts™ simulation software (Hodges 2017)[1] was used to build speed, accuracy and competence in estimating group sizes of large groups of animals. This was particularly important for the accurate estimation of livestock herd sizes which were not circled. An individual observer simulated counting animals using the software. Each observer had free access to the software for unlimited practice over the three days. Once confident they ran a standardized simulation for 5 repetitions. Results were saved and recorded for review in evaluating each crew member.
iv. Fourth session - Cockpit simulation: A practical cockpit management simulation in which observer crews and pilots sat on chairs to mimic their respective seating positions in the aircraft was enacted. Observers were then given their recording equipment and instructors simulated sightings for them to record. A trainer issued instructions of "random sightings" and the crew practiced relaying the information as if they were in the air. Trainers rotated to various teams. This was meant to practice the systematic relay of specific information in the right order amongst all crew members, necessary for efficient data capture. As proficiency increased the observers were placed under increasing pressure to record more frequent and diverse sightings. The simulation ended when crews could accurately record all sightings suggested by trainers.
v. Fifth session - Vision Test: all crew were informally tested for visual acuity using a standard Snellen chart (Appendix 2). Only observers with a minimum visual acuity of 20/40 were selected as observers.

3.3.2 Airborne Training

Crew members were taken through several hours of in-flight training and practice to ensure their both familiarity with cabin environment and that they could record data smoothly. Two one-hour flights using only GPS and Dictaphones were undertaken for each crew. Crews flew predetermined transects in four different blocks to allow for aircraft separation as a safety measure, and to enable comparison between crews in the same blocks. On the second training flight cameras were taken on board and the crews were directed to blocks pre-surveyed for presence of large herds and the crews were instructed to circle and photograph their sightings.

Inter Observer Variability: Three one-hour flights were undertaken using all equipment and with all aircraft passing along the same predetermined set of four transects (about 130km of transect length). Transects were pre-checked for the presence of wildlife to ensure sufficient opportunity for matched observations by front and back seat observers. The rear seat observers were screened off using a curtain from the seat observer and pilot to limit inter-observer collaboration. Observers on the right side of the aircraft then worked in isolation, without headsets for communication or visual cues from their counterparts. Observers were shuffled between seat positions within each aircraft and amongst aircrafts on successive flights. Results were then compared between front seat and pack seat observers on the RHS of the aircraft to assess inter-observer variability.

Finally, results of the Wildlife Counts™ simulation, the practical cockpit management simulation, eye test and inter observer variability were used to perform a selection of crew members for the TME 2017 count. A small number of observers were advised to get professional eye testing done and return for the next training event to be re-assessed. Generally, observer capability was good and all observers met satisfactory standards for accuracy. The final selection proved difficult and came down to selecting for experience wherever no obvious differentiator existed. The list of available survey crew is now well established and it is recommended that members of this list should stay in practice using Wildlife Counts ™ and be available for inclusion in future surveys. Results of the inter-observer and crew variability are presented in Appendix 3.

3.4 Statistical analyses

Simple percentages were calculated to compare the changes in elephant, buffalo and giraffe populations in different census periods as described by Zar (1996). One way ANOVA (F-Test) was used to test the significance of group sizes inside and outside protected areas as well as regions following procedures described by Zar (1996). Regression analysis was performed to discern the trend of elephants, elephant carcasses, buffalo and giraffe as described by Zar (1996). The population density and distribution maps were prepared using ARCMAP 10 as outlined by ESRI (2010).

4.0 RESULTS

4.1 Elephants

4.1.1 Elephant population status and trends

The aerial census search effort was approximately 148 km^2 per hour. A total of 12,866 elephants were counted during this dry season count in the Tsavo-Mkomazi ecosystem, with 12,843 and 23 elephants being counted in the Tsavo ecosystem and Mkomazi National Park respectively. The southern section of Tsavo East National Park recorded the highest abundance of elephant followed by Tsavo West National Park with elephant densities of 7.0 elephants/km^2 and 2.99elephantskm^{-2}respectively(Table 1). Mkomazi and Chyullu National Park had the lowest densities.

Table 1: Elephant abundance in the Tsavo-Mkomazi ecosystem (February 2017)

Regions	No. of elephants	No. of herds	Elephants/km^2
Tsavo East National Park (South)	6072	779	7.01
Tsavo West National Park	2833	352	2.99
Taita Ranches	1746	129	1.86
Tsavo East National Park (North)	1655	298	2.28
Other Areas	364	36	0.04
Galana Ranch	93	8	0.13
Rombo	60	3	0.05
Mkomazi National Park	23	9	0.01
Chyulu National Park	20	5	0.02
Total	12,866	1,619	14.39

Overall, the elephant population in TME increased by14.7% over the last three years (2014-2017). This represents an annual increase of 4.9% over the period, which implies an increase by approximately 1649 elephants into the population during the period. However, the increase was only in Tsavo ecosystem where the population recorded an increase of about 15.1% (2014: n = 11,158 elephants; 2017: n = 12,843 elephants). In Mkomazi National Park, the elephant population decreased by 61% (2014: n = 59 elephants; 2017: n = 23 elephants), which represents about 20% annual decrease. Figure 4 below shows an overall increasing trend of elephant population in TME from 1988 onwards with some slight declines in 1994, 2002, 2008, and 2014.

A total of 1,619 elephant herds were encountered during the survey with group sizes ranging from 1-210 individuals and a mean herd size of about 8 elephants in a herd for the entire ecosystem. There was a statistically significant difference in elephant group dynamics within and outside protected area $P<0.001$, ($F_{1,\ 1617}=42.72$), n=1618, where there was a generally higher group composition for elephants outside the protected area, with a mean herd size of around 7 elephants/herd, as compared to a mean herd size of about 13 elephant/herd outside the protected area. Similarly, there was a significant statistical difference in elephant herd sizes based on the nine survey regions $P< 0.001$, ($F_{8,\ 1610}=7.69$), n=1618, where largest herd sizes were encountered in Taita, Galana and other dispersal areas, with mean herd sizes of about 14, 12 and 10 elephants/herd for Taita, Galana and other dispersal areas respectively, as compared to a low density of about 3, 4 and 6 elephants/herd in Mkomazi National Park, Chyulu National Park and Tsavo East National Park (North) respectively.

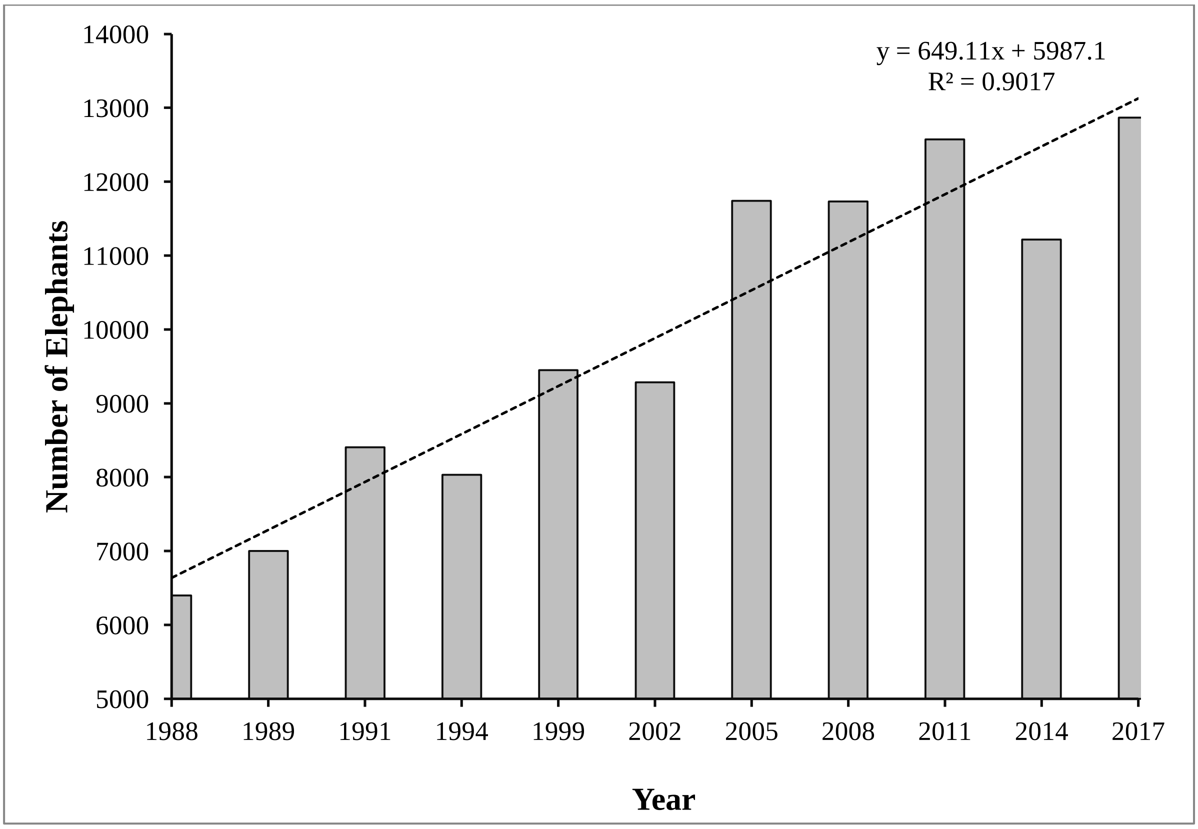

Figure 4: Elephant population trend for the Tsavo-Mkomazi ecosystem for the period 1988 to 2017

Table 2 below summarizes the population of elephants in Tsavo-Mkomazi ecosystem belween 962 and 2017. Since 1990s the elephant population shows an increasing trend with declines being recorded in a few years.

4.1.2 Spatial distribution and density of elephants

Most of the elephants were counted in Tsavo East National Park and in Tsavo West National Park (Table 1 and Table 2; Figure 5 and Figure 6). High concentrations were recorded in the southern sector of Tsavo East National Park (Figure 6), Tsavo West National Park,in an area of approximately 45km width along the Galana River. There were general low concentrations of elephants in Galana Ranch, Eastern dispersal area, Chyulu National Park, Mkomazi National Park and the southern tip of Tsavo West National Park (Figure 5 and Figure 6a and Figure 6b).

Table 2: Elephant numbers by location in Tsavo-Mkomazi ecosystem (1962-2017)

Location	2017	2014	2011	2008	2005	2002	1999	1994	1991	1989	1988	1978*	1973	1972	1970*	1969*	1965*	1962
Tsavo East (N)	1655	1257	2094	4118	2499	4089	1337	399	450	134	770	220	9011	6435	0	6619	8,056	4,073
Tsavo East (S)	6072	5329	4120	3731	3896	2087	3221	2733	3436	3020	2283	2469	3955	6633	6008	5709	4,744	1358
Tsavo West	2833	2918	2142	2161	2626	2168	2119	3132	1233	2106	1274	1938	9208	4328	6592	8134	2,238	1394
Chyulu NP	20	42	135	131	-	-	-	-	-	-	-	-	-	-	-	-		-
South Kitui NR	0	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
Mkomazi NP	23	59	256	8	41	63	77	302	131	11	93	667		2067	-	-	-	-
Galana Ranch	93	12	398	308	11	14	27	46	50	74	90	1076	500	4379	-	2964	-	3540
Taita Ranch	1746	1420	2751	1108	1292	828	1245	287	1413	642	853	79	-	1235	-	500	-	-
Rombo Area	60	149	0	0	31	2	12	446	-	193	-	-	-	-	-	-	-	-
Other blocks	364	31	509	130	1	35	30	26	50	46	-	-	-	300	100	-	-	-
Outside	0	0	168	38	1376		1391	1107	1644	966	1036	-	-	-	-	-	-	-
Total (parks)	10603	9605	8614	10149	9062	8344	6754	6566	5250	5271	4420	5294	22174	19463	12600	20462	15038	6825
Total (non-parks)	2263	1612	3959	1584	2680	940	2693	1466	3157	1728	1979	1155	500	5914	100	3464	-	3540
Grand Total	**12866**	**11217**	**12573**	**11733**	**11742**	**9284**	**9447**	**8032**	**8407**	**6999**	**6399**	**6449**	**22674**	**25377**	**12700**	**23926**	**15038**	**10365**

The hyphen (-) represents periods when no aerial census took place in respective locations. N = North, S = South, NP = National Park, NR = National Reserve. Years with a star (*) indicates data was acquired using sample counts method whereas in years without a star, the data was acquired using total count method. From 1999 to 2017, data was collected in late January or early February (dry season) whereas from 1962 to 1994, data was collected in June, immediately after the April-May wet season (**Source:** Laws, 1969;Leuthold, 1973; Otichillo, 1983; Olindo *et al.*, 1988; Douglas-Hamilton *et al.*, 1994; Kahumbu *et al.*, 1999; Omondi and Bitok, 2008; Ngene, *et al*, 2011; Kyale *et al.*, 2014 and Lala *et al.*, 2017).

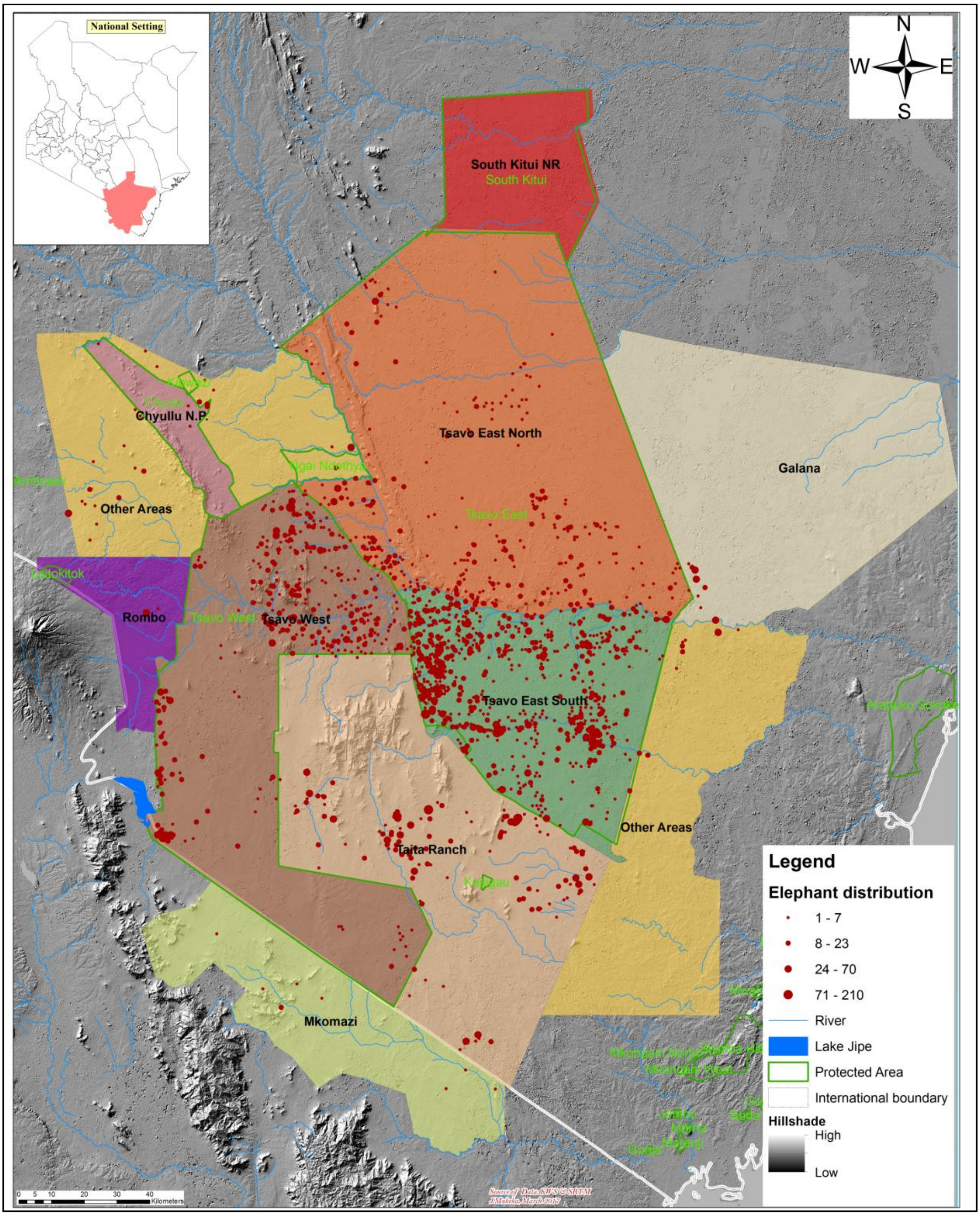

Figure 5: Distribution of elephantsTsavo-Mkomazi in Ecosystem against water points (February 2017).

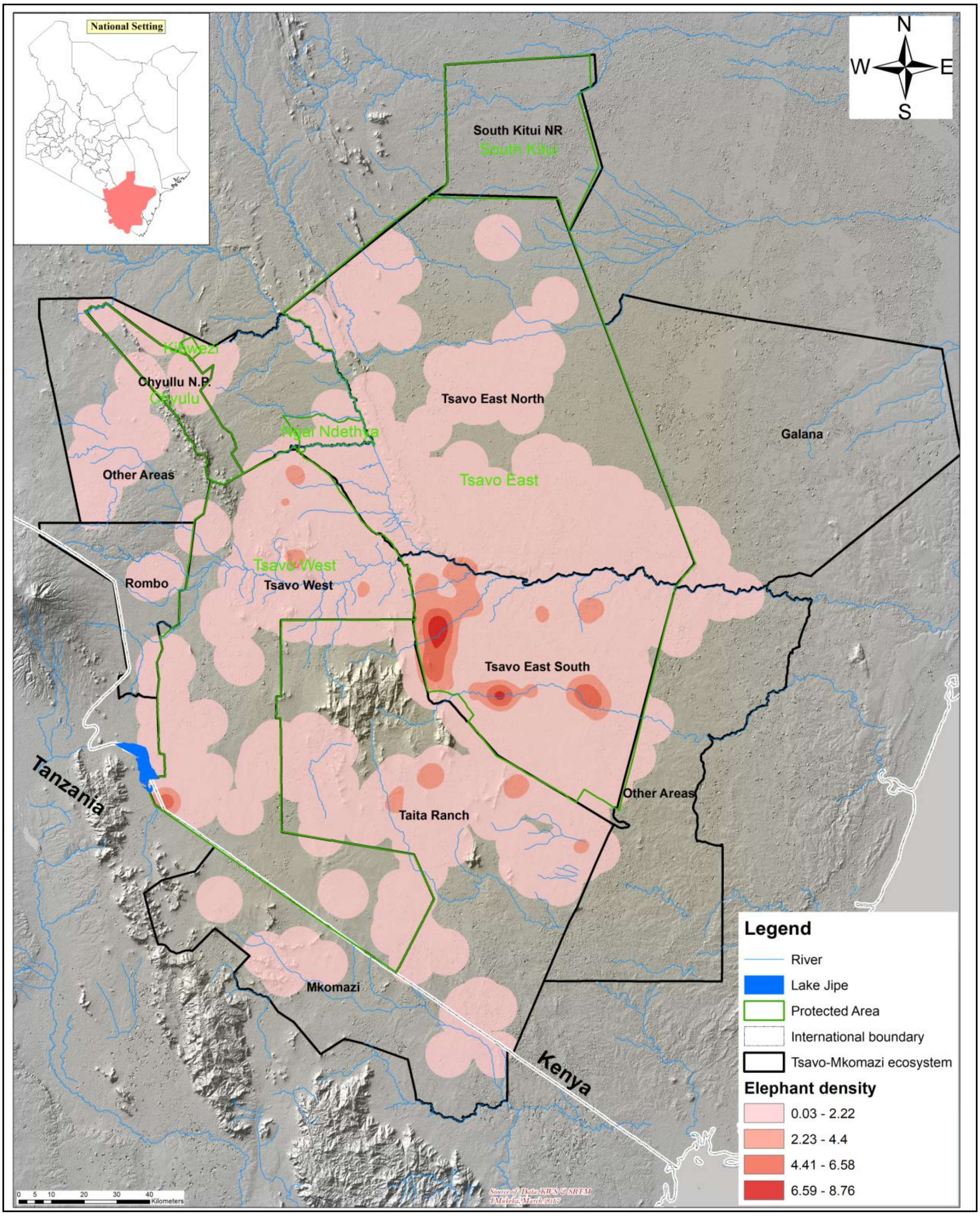

Figure 6a: The kernel density of elephants in the Tsavo-Mkomazi ecosystem (February 2017)

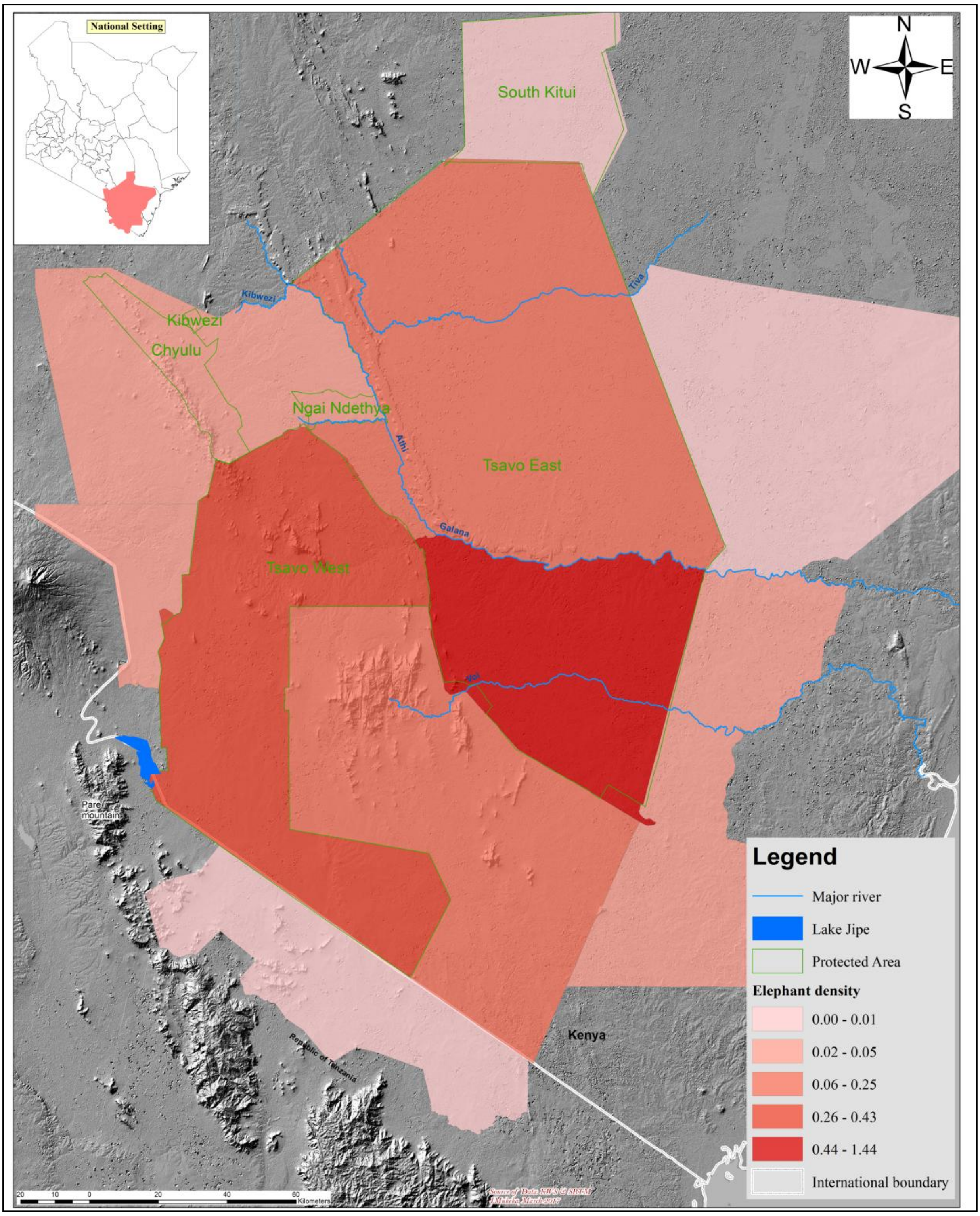

Figure 6b: The density of elephant in the Tsavo-Mkomazi ecosystem according to counting regions (February 2017)

4.1.3 Elephant Mortality and carcass ratio

A total of 1,167 carcasses were recorded during the survey. The 'very old' carcasses had the highest proportion with more than 53.4% (n=623) of the total carcasses, followed by old carcasses at 44.0% (n=514). Only three and 27 fresh and recent carcasses respectively were encountered during the survey (Table 3). Overall, there was an 8.3% carcass ratio for the Tsavo-Mkomazi ecosystem.

Table 3: Distribution of carcasses within various regions of the Tsavo-Mkomazi Conservation Area. The carcass ratio for the ecosystem was 8.3%.

Counting region	Live elephant	Fresh Carcass	Recent Carcass	Old Carcass	Very Old Carcass
Chyullu National Park	20			1	
Galana Ranch	93			8	13
Mkomazi National Park	23		3	6	35
Other Areas	424		1	29	21
Taita Ranches	1746	1	3	124	86
Tsavo East National Park (North)	1655	2	3	127	197
Tsavo East National Park (South)	6072		10	134	182
Tsavo West National Park	2833		7	85	88
Total	**12866**	**3**	**27**	**514**	**623**

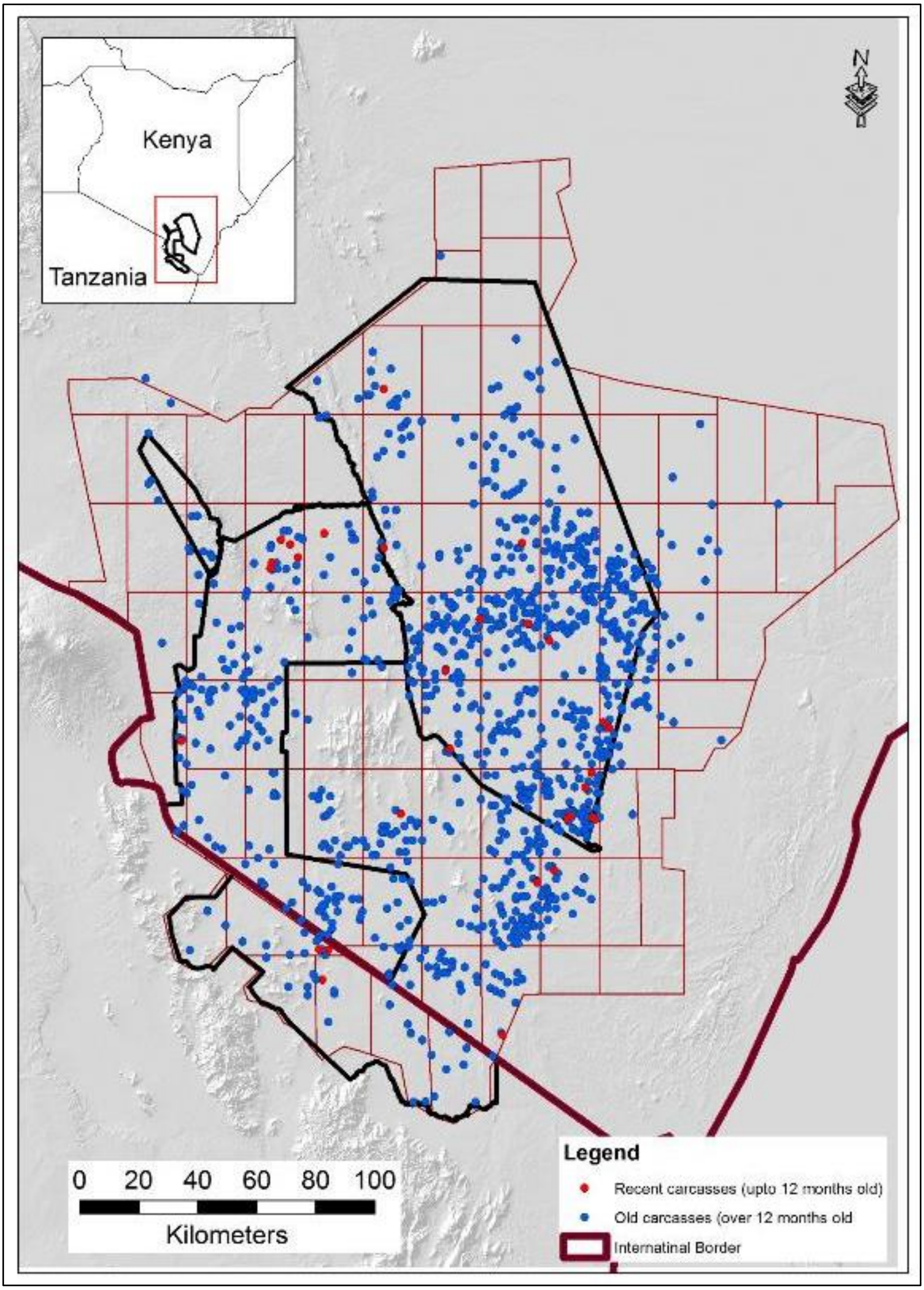

Figure 7: The locations of the carcasses of elephants that were estimated to have died within one year and over one year from the aerial count data.

4.2 Buffalo

4.2.1The population status and trend of buffalo

The total number of buffalo counted was 8,623; 46% increase from the 5,912 buffalo counted in 2014. However, on a longer term scale, the population of buffalo has declined by about 18% since the year 2005 when 10,236 buffalo were counted (Figure 8).

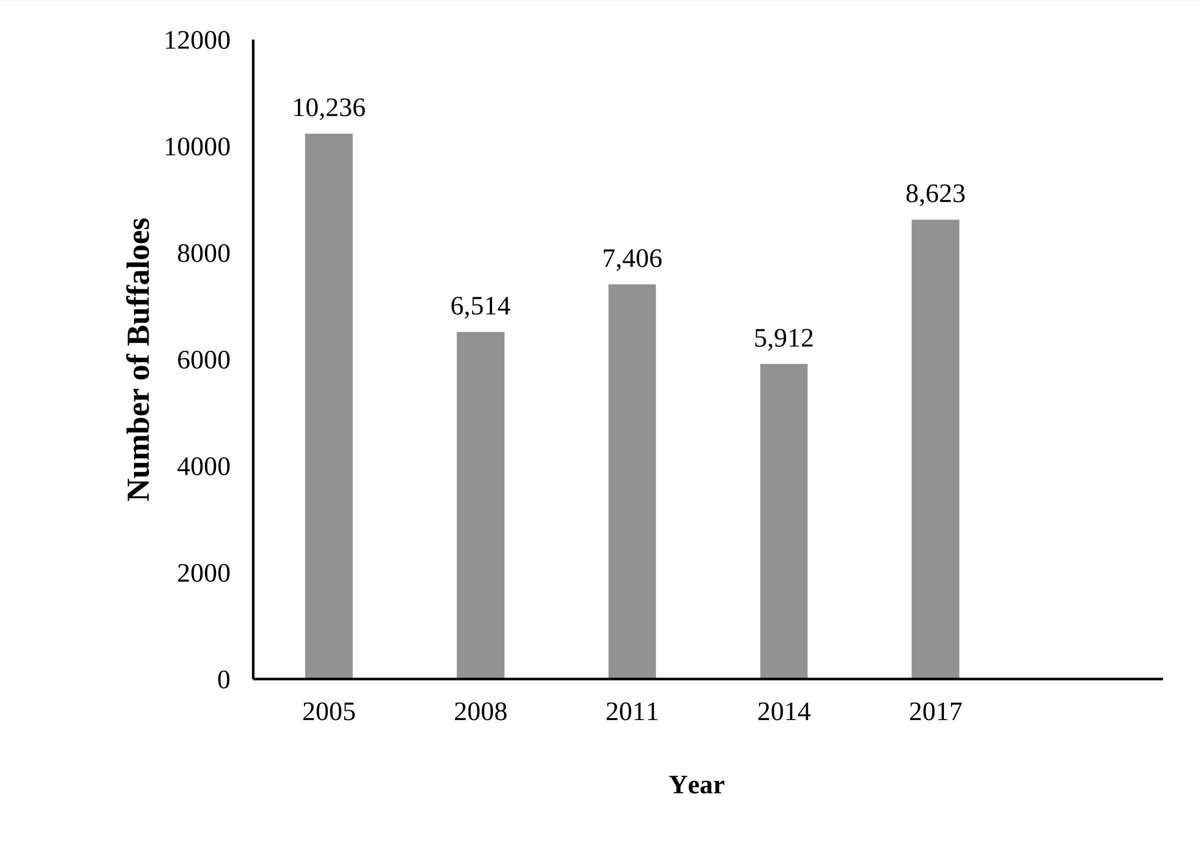

Figure 8: The number of buffalo counted in Tsavo-Mkomazi ecosystem from February 2005 to February 2017

Considering regions, there were variations in changes of buffalo population between 2014 and 2017. For example, in Tsavo East National Park (Northern; TENPN) and Tsavo East National Park (Southern; TENPS) regions, there was an increase of buffalo population of about 171% and about 76% respectively. Rombo and Taita regions also had about 275% and about 63% increase in the same time period. Regions that recorded a decline include Galana (about 96%), Mkomazi NP (MNP) (about 68%), Tsavo West National Park (TWNP) (about 3%) and other blocks (about 96%).

However, between 1988 and 2017, the population of buffalo in Galana region regarded a significant decline (r=0.73, n=11). An insignificant increase were recorded for TENPN (r=0.26, n=11), TENPS (r=0.45, n=11) and Taita (r=0.25, n=11). It is worth to mention that, only Taita region has been experiencing a significant increase of buffalo population (r=0.95, n=11) between 2005 and 2017. The remaining regions recorded insignificant decline (e.g., TWNP: r=0.55, n=11; MNP: r=0.41, n=11; and, other blocks: r=0.22, n=11). It is necessary to note that only two data sets for Rombo were available and no buffalo were observed in Kitui South National Reserve and Chyullu Hills National Park (though 71 buffalo were recorded in 2008).

The density of buffalo in Tsavo-Mkomazi ecosystem was about 0.18 buffalo km^{-2}, which is an increase from 0.13 buffalo km^{-2} recorded in 2014. TENPS had the highest sub-population density followed by Taita and TWNP respectively (Table 4). Table 5 below summarizes the population trend of buffalo in Tsavo-Mkomazi ecosystem by counting region from 2005 to 2017.

Table4: Population number and density of buffalo in Tsavo-Mkomazi ecosystem (February 2017)

Location	Area (km^2)	Count	Buffalo/Km^2
Chyulu	726.7	0	0.00
Galana	6434.2	2	0.00
Mkomazi	3193.4	98	0.03
Other Areas	8306.7	5	0.00
Rombo	1176.6	30	0.03
South Kitui NR	1930.3	0	0.00
Taita	6871.9	1768	0.26
Tsavo East North	9694.5	1461	0.15
Tsavo East South	4231.0	3534	0.84
Tsavo West	6531.4	1725	0.26
Total	**49096.6**	**8623**	**0.18**

Table 5: The number of buffalo counted in the Tsavo-Mkomazi ecosystem from 2005 to 2017

Location	2005	2008	2011	2014	2017
Tsavo East NP North	1274	1376	2613	540	1461
Tsavo East NP South	2325	2229	3142	2007	3534
Tsavo West NP	4907	1945	641	1786	1725
Chyulu NP		71	0	0	0
South Kitui NR	0	0	0	0	0
Galana	235	45	44	51	2
Taita	442	583	797	1082	1768
Mkomazi NP	182	73	121	308	98
Other Areas	871	192	48	130	5
Rombo				8	30
Total	**10236**	**6514**	**7406**	**5912**	**8623**

4.2.2 The distribution of buffalo

The buffalo were distributed either in permanent or supplemented watering points in the landscape. In TENPN, they were concentrated around rivers Tiva, Athi and Galana while in TENPS were concentrated around Galana River or in supplemented water points around Irima and Manyani areas (Figure 9). In Taita region, distribution was clumped around Taita sanctuary, ranches in Rukinga and Taita near Maungu area. For TWNP, the distribution was around permanent water points near Lake Jipe in the south west and Kamboyo, Mzima springs to the north. In MNP, the buffalo were sparsely distributed with more groups to the south east of the park. Large buffalo concentrations were sighted in the southeast of MNP.

Majority of the buffalo were in groups (about 82%) while the remaining ranged individually (about 18%). The largest group had 485 individuals with the average group size for the whole landscape being 27 individuals. There were significant differences in the number of buffalo counted in the different regions ($F=2.896$, $df=5$, $p=0.014$). Most of the buffalo in the ecosystem were found within 10km from Galana River in TENP and northern parts of TWNP (Figure 9). TENPS had the largest group size of 485 with 76 groups counted in the region where an average group size of 46 individuals. In Taita ranches, 52 observations were made with a range of 1-300 buffalo, which translates to average group size of 34 individuals. TENPN followed the sequence with 61 observations sighted ranging from 1-200 and average group size of about 24 individuals. TWNP had 101 groups whereby groups ranged from 1-145 with a mean group size of 16 individuals. MNP had 12 groups with the largest group of 50 individuals, though the average group size was about 8 buffalo. Galana region had 2 sightings of one each while other blocks had a group of 5 buffalos.

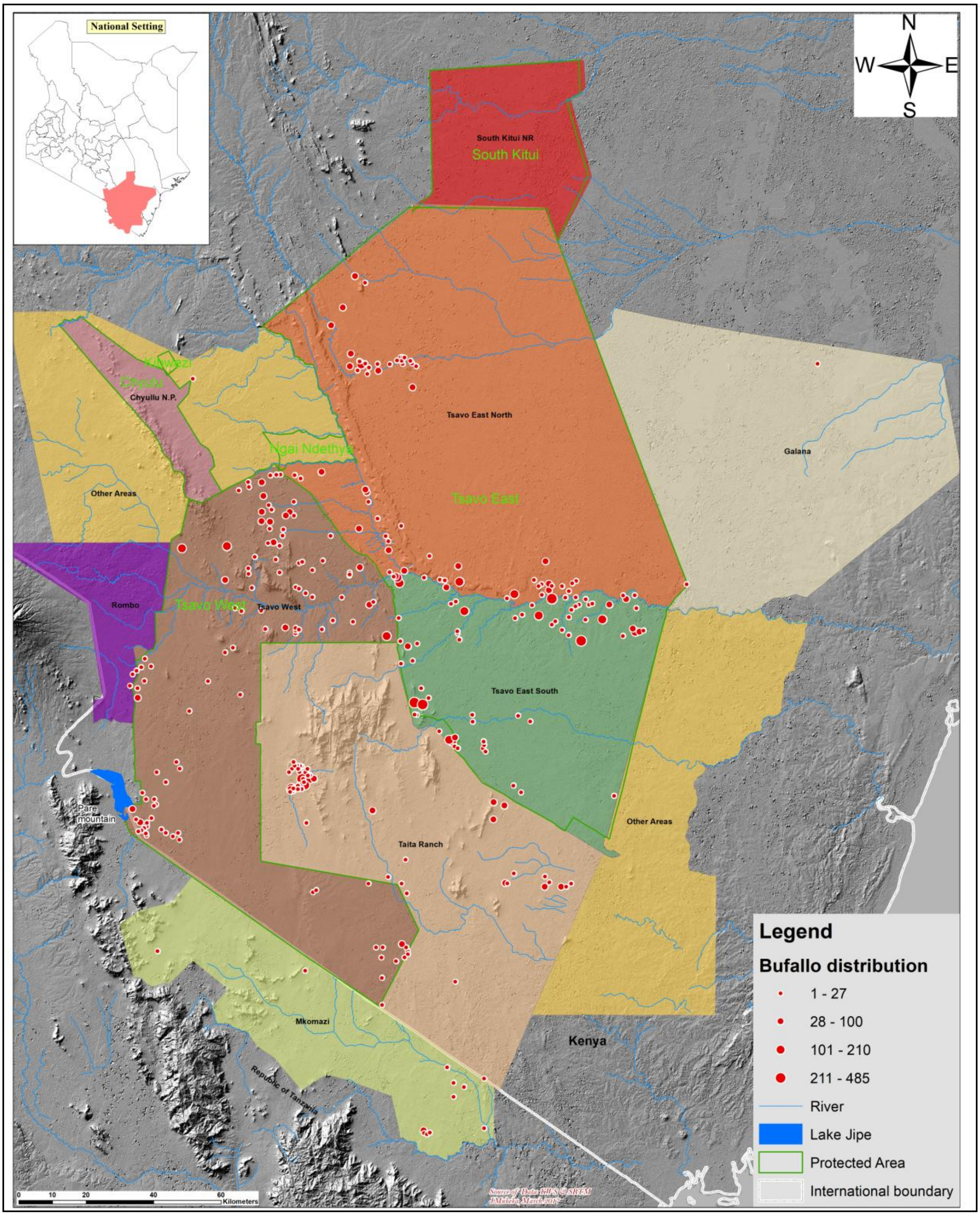

Figure 9: The distribution of buffalo in Tsavo-Mkomazi ecosystem (February 2017)

4.3 Giraffe

4.3.1 Giraffe distribution and status

The total number of giraffes counted in the ecosystem was4,323 giraffe, which an increase from 2891 giraffe counted in 2014. The highest number of giraffes in 2017 (Table 6 and Table 7) was counted in Tsavo West National Park as compared to 2014 whereby the highest number was on the areas of the ecosystem other than protected areas (Table 6 and Table 7). The 2017 census results indicated the highest decline of about 98% in South Kitui National Reserve and the highest increase of about 655% in the protected area of Tsavo West National Park. Tsavo East National Park (north and south) reported about 299% and about 466% increase in giraffe numbers since 2014 (Table 7). Galana area showed a population increase of about 394% while South Kitui National Reserve recorded a drastic population decline compared to 2014 census (Table 7). Mkomazi National Park had the least increase in giraffe population of about 8%; overall, the giraffe population in Tsavo-Mkomazi landscape increased by approximately 50% in 2017 as compared to approximately 41% in 2014 (Table 7). Figure 10 summarizes the trend of giraffe in the ecosystem between 2005 and 2017. The giraffe population increased by about 112% between 2005 and 2017) (2015: n = 2040 giraffe; 2017: n = 4,323 giraffe). A summary of the population of giraffes between 2005 and 2017 by counting region is presented in table 8 below. Group sizes of up to 80 individuals were recorded in 2017 (Figure 11).

Table 6: The giraffe population number and density in Tsavo-Mkomazi ecosystem (February2014 and February 2017). **NP** = National Park; **NR** = National Reserve

Location	Area (Km^2)	Count	Density (Giraffes/km^2)
Chyulu NP	726.7	48	0.07
Galana NP	6434.2	84	0.01
Mkomazi NP	3193.4	255	0.08
Other Areas	8306.7	823	0.10
Rombo Area	1176.6	321	0.27
South Kitui NR	1930.3	4	0.00
Taita Ranches	6871.9	510	0.07
Tsavo East NP (North)	9694.5	351	0.04
Tsavo East NP (South)	4231.0	538	0.13
Tsavo West NP	6531.4	1389	0.21
Total	**49096.6**	**4323**	**0.09**

Table 7: The trend of giraffe population in Tsavo-Mkomazi ecosystem (February 2014 and February 2017). **NP** = National Park; **NR** = National Reserve; **n** = number of Giraffe counted; **%** = percentage

Locations	**2014**		**2017**		**% Increase (+)/Decrease (-)**
	n1	**%**	**n2**	**%**	
Chyullu NP	461	15.95	48	1.11	-89.6
Galana Ranch	17	0.59	84	1.94	394.1
Other Areas	428	14.80	823	19.04	92.3
Rombo Area	881	30.47	321	7.43	-63.6
South Kitui NR	187	6.47	4	0.09	-97.9
Taita Ranches	315	10.90	510	11.80	61.9
Tsavo East NP (North)	88	3.04	351	8.12	298.9
Tsavo East NP (South)	95	3.29	538	12.45	466.3
Tsavo West NP	184	6.36	1389	32.13	654.9
Mkomazi NP	235	8.13	255	5.90	8.5
Grand Total	**2891**	**100**	**4323**	**100**	**49.5**

Table8: The number of giraffes in various wildlife management units within Tsavo-Mkomazi ecosystem (2005 to 2017)

Location	**2005**	**2008**	**2011**	**2014**	**2017**
Tsavo East NP North	281	424	170	88	351
Tsavo East NP South	261	257	222	95	538
Tsavo West NP	568	678	691	184	1389
Chyulu NP		534	292	461	48
South Kitui NR		3	6	187	4
Galana	153	95	93	17	84
Taita	148	193	282	315	510
Mkomazi NP	62	116	120	235	255
Other Areas	567	150	179	428	823
Rombo					321
Total	**2040**	**2450**	**2055**	**2010**	**4323**

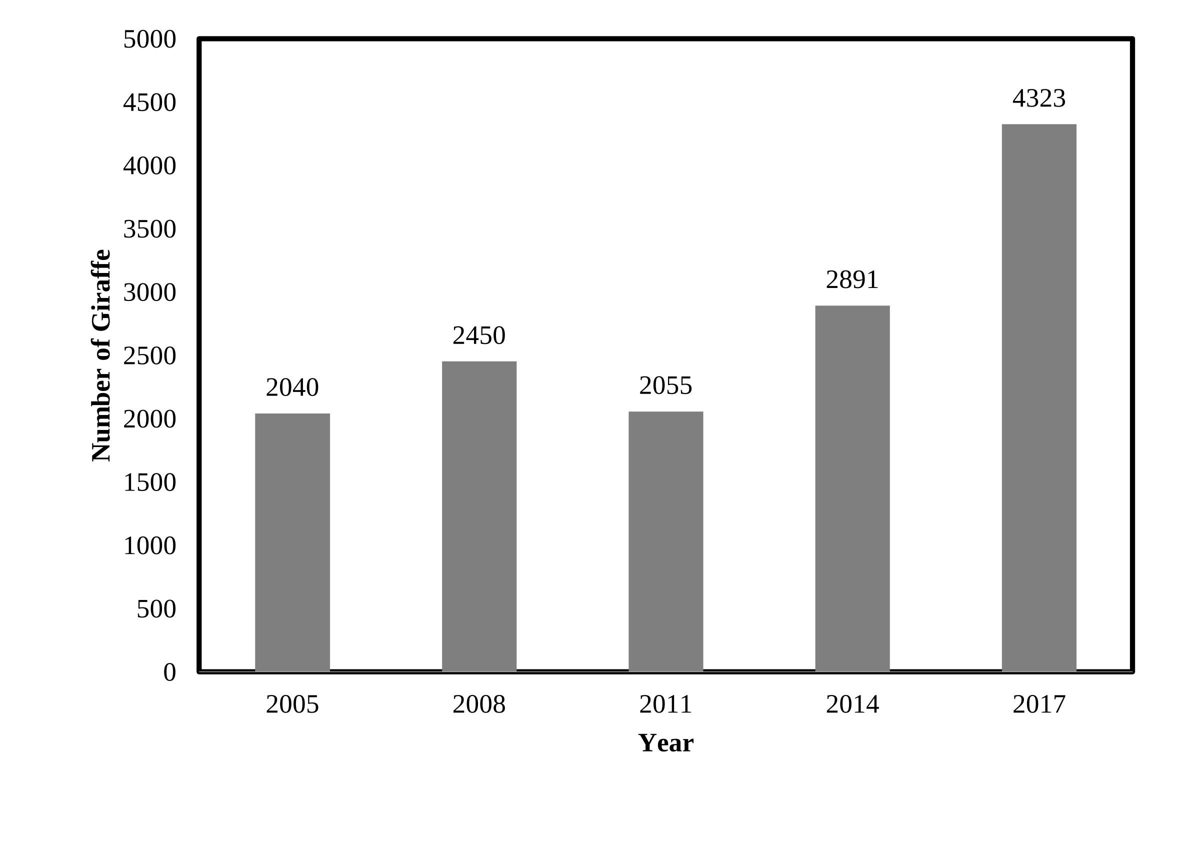

Figure 10: The numbers of giraffes in Tsavo-Mkomazi ecosystem (February 2005 to February 2017).

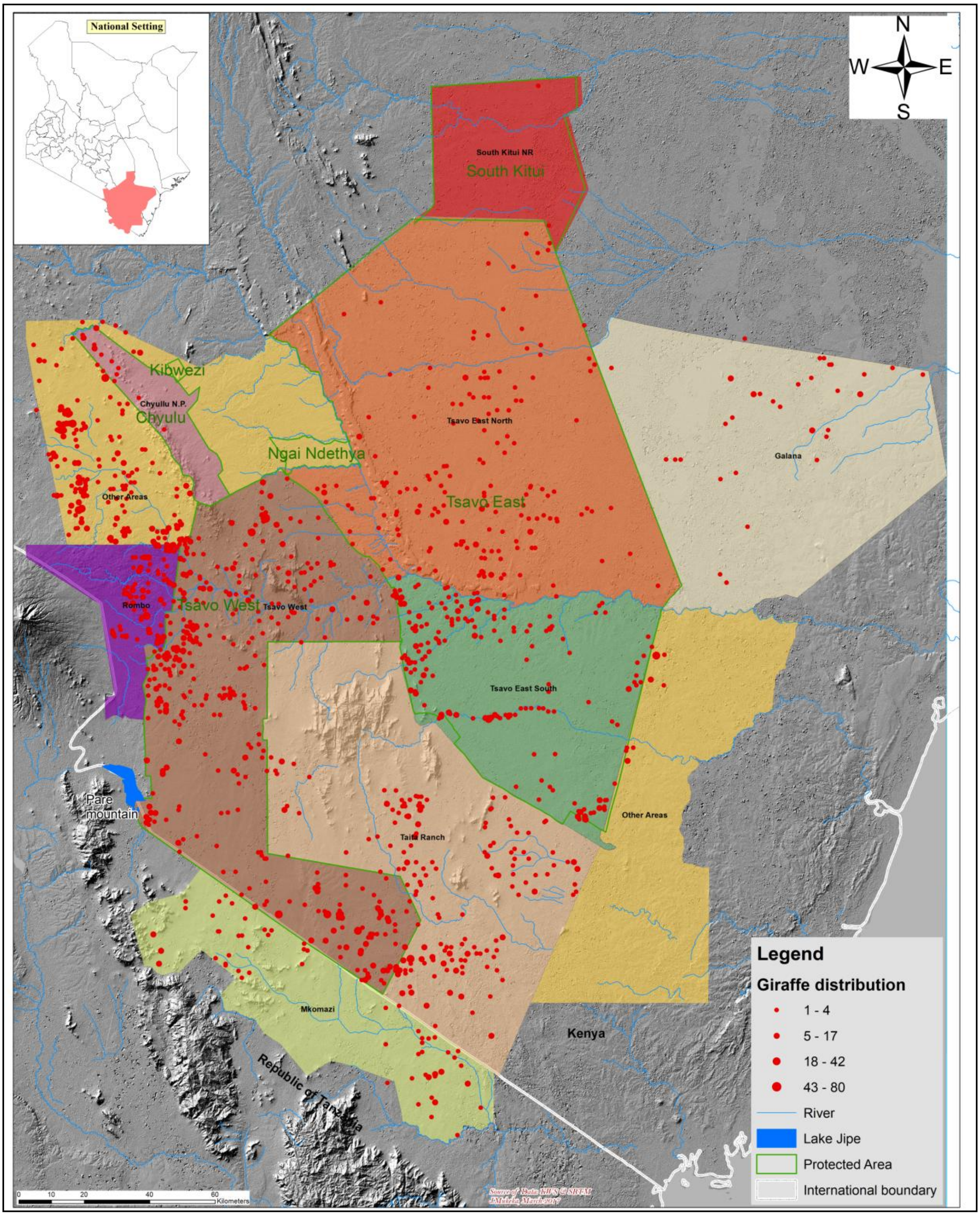

Figure 11: The distribution of giraffes in Tsavo-Mkomazi ecosystem (February 2017)

4.4.4 Human Activities

4.4.1 Status and distribution of cattle

Unlike the three wildlife species whose every effort was applied to obtain an accurate total count, the numbers of cattle are estimates. The estimated the number of cattle in the ecosystem was 227,704, approximately 34% increase from the 2014 census using similar methodology (Table 9). The results indicate a sharp increase in the number of cattle in the protected areas especially Tsavo East NP which previously had low incursion (Table 9).

Figure 12 shows serious invasion by livestock in the Tsavo-Mkomazi ecosystem especially around Maungu area where livestock was seen to gain access through the SGR wildlife underpasses, culverts and bridges.

Table 9: The population trend of cattle in Tsavo-Mkomazi ecosystem (February 2015 February 2008, February 2011, February 2014, and February 2017). **NP** = National Park; **NR** = National Reserve

Location	2005	2008	2011	2014	2017
Tsavo East NP (North)	1,110	2,286	3,810	8,210	17,016
Tsavo East NP (South)	3,715	5,051	3,932	631	22,464
Tsavo West NP	44,277	30,745	27,054	42,116	45,358
Chyulu NP	-	27,188	12,373	883	7,073
South Kitui NR	-	4,567	885	5,566	1,082
Galana Ranch	16,827	12,297	4,460	24,448	10,604
Taita Ranches	24,672	37,688	39,586	26,441	53,208
Mkomazi NP	3,035	7,534	5,085	6,231	7,546
Other Blocks	38,992	35,999	16,204	48,094	60,337
Rombo	83,526	13,500	2,409	7,429	3,016
Total	216,154	176,855	115,798	170,049	227,704

(***Source:***KWS database; February 2017 aerial survey)

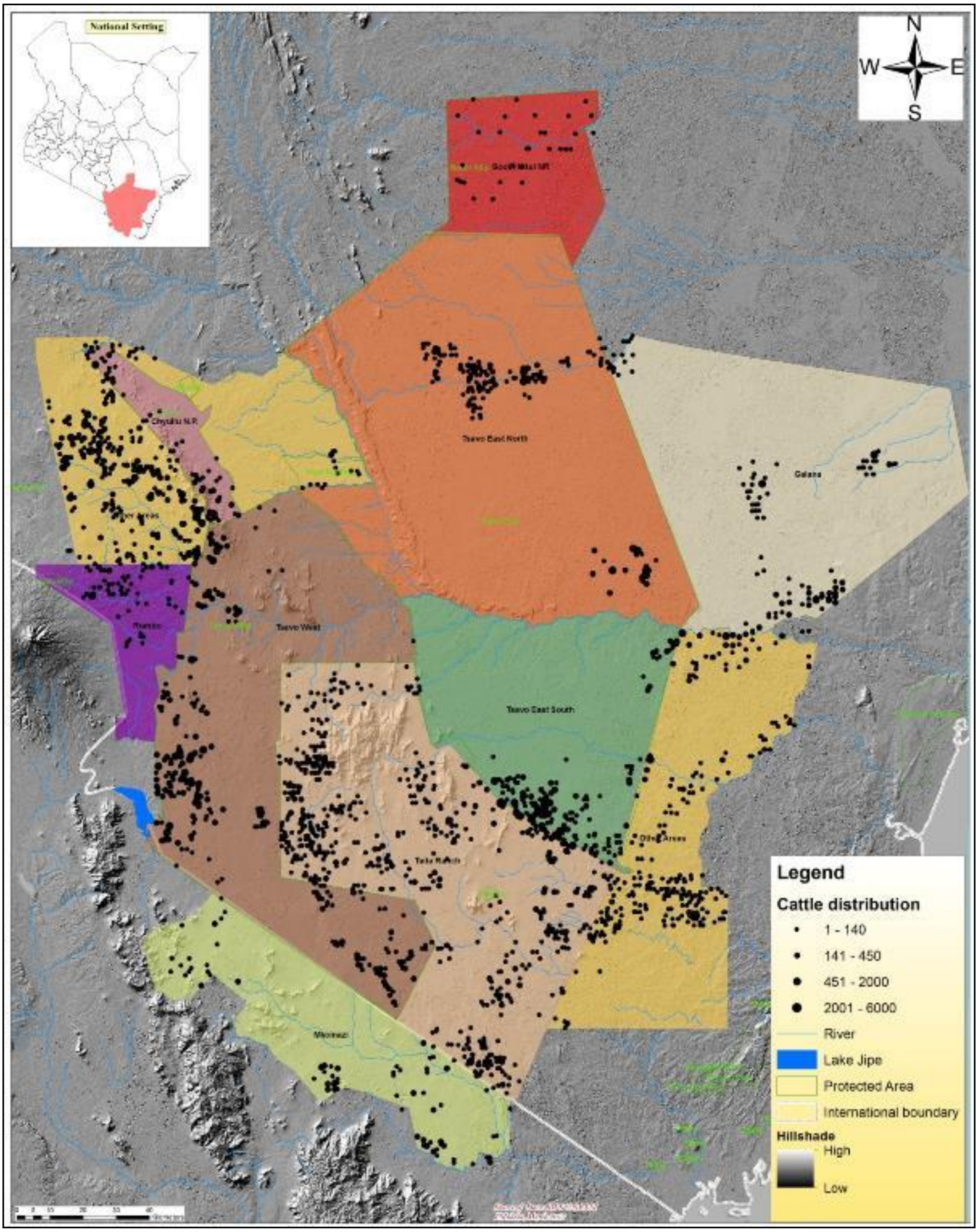

Figure 12: Distribution of cattle in the Tsavo Mkomazi ecosystem February 2017

4.4.1 Status and distribution of shoats

Table 10, shows that shoats increased in 2017 in the protected areas of Tsavo East north, Tsavo West and Mkomazi National Park compared to previous years. This increase of shoats in the protected areas is likely to lead to competition for browse with closely related herbivores. Livestock grazing has been identified as a threat to protected areas (Kiringe and Okello, 2005; Janzen, 1983) as it leads to ecosystem degradation and therefore, there is need for responsible government agencies to enforce the law. Figure 12 below shows the distribution of shoats in the Tsavo-Mkomazi ecosystem.

Table 10: The number of shoats counted in Tsavo Mkomazi Ecosystem (February 2008 - February 2017 at a census interval of 3 years). **NP** = National Park; **NR** = National Reserve

Location	2005	2008	2011	2014	2017
Tsavo East NP North	780	220	3,145	6,931	13,794
Tsavo East NP South	560	392	763	1,360	1,330
Tsavo West NP	5,359	2,805	2,995	2,025	13,457
Chyulu NP	-	23,632	9,120	1,685	4,078
South Kitui NR	-	8,445	4,255	17,441	4,025
Galana	4,265	5,015	1,502	18,760	10,807
Taita	9,664	6,943	8,504	12,803	18,667
Mkomazi NP	800	266	790	220	2,832
Other Blocks	42,521	39,071	34,087	42,803	46,613
Rombo	57,250	8,875	4,130	17,334	18,610
Total	**121,199**	**95,664**	**69,291**	**121,362**	**134,213**

(*Source: KWS database*)

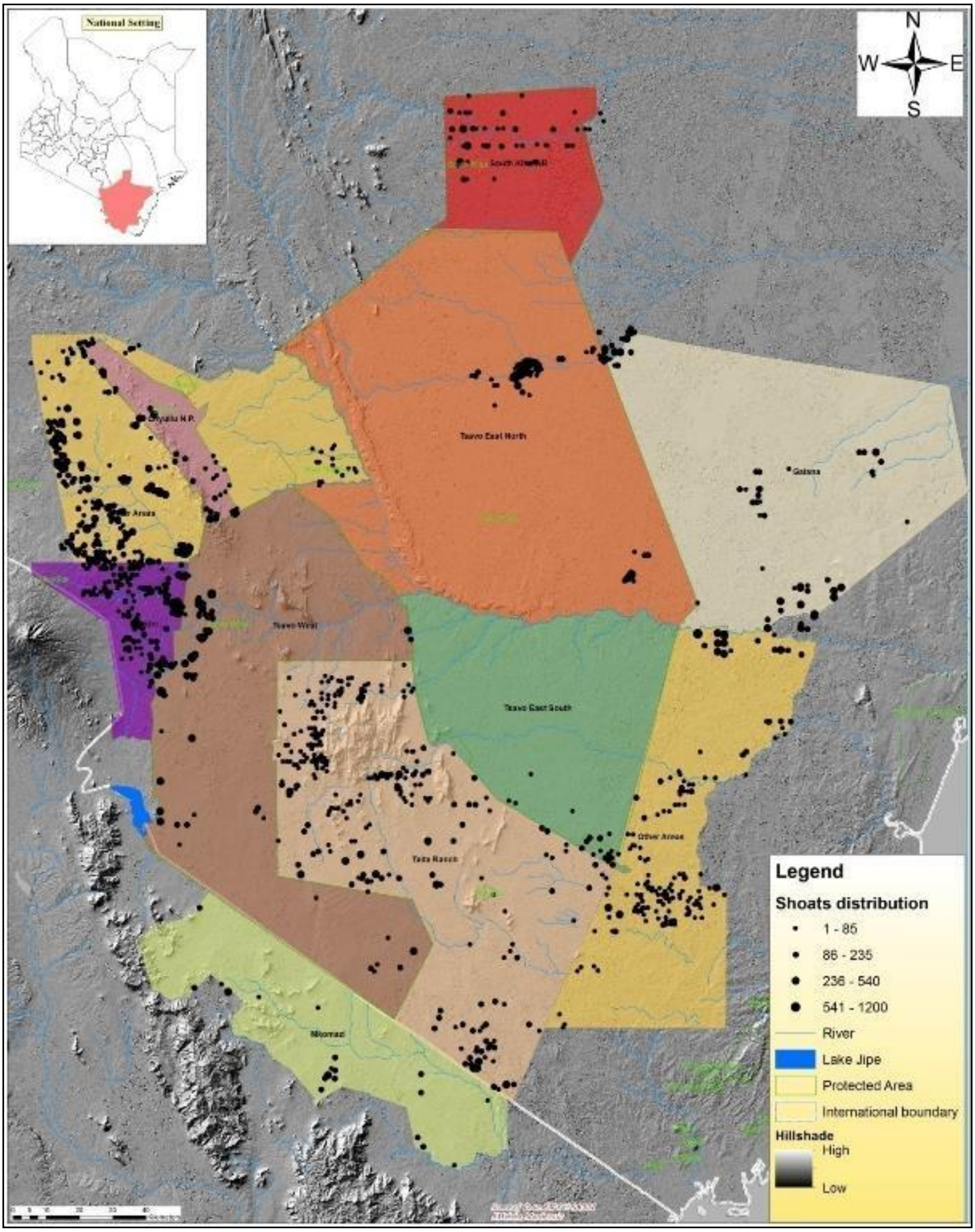

Figure 12: Distribution of shoats in the Tsavo Mkomazi ecosystem (February 2017)

4.4.3 Status and distribution of donkeys and camels

A total of 11,853 camels and 168 donkeys were recorded in the Tsavo-Mkomazi ecosystem. Table 11 summarizes the number of camels and donkeys recorded in the ecosystem by counting region. Figure 14 shows the distribution of donkeys and camels. South Kitui National Reserve recorded high concentration of camels and a few donkeys. Donkeys and camels were also concentrated in Taita ranches (Figure 13).

Table 11: The number of camels and donkeys counted in Tsavo-Mkomazi ecosystem (2005-2017)

Year	Camels	Donkeys	Total
2005	917	34	**951**
2008	3739	269	**4008**
2011	3218	110	**3328**
2014	8873	290	**9163**
2017	11853	168	**12021**

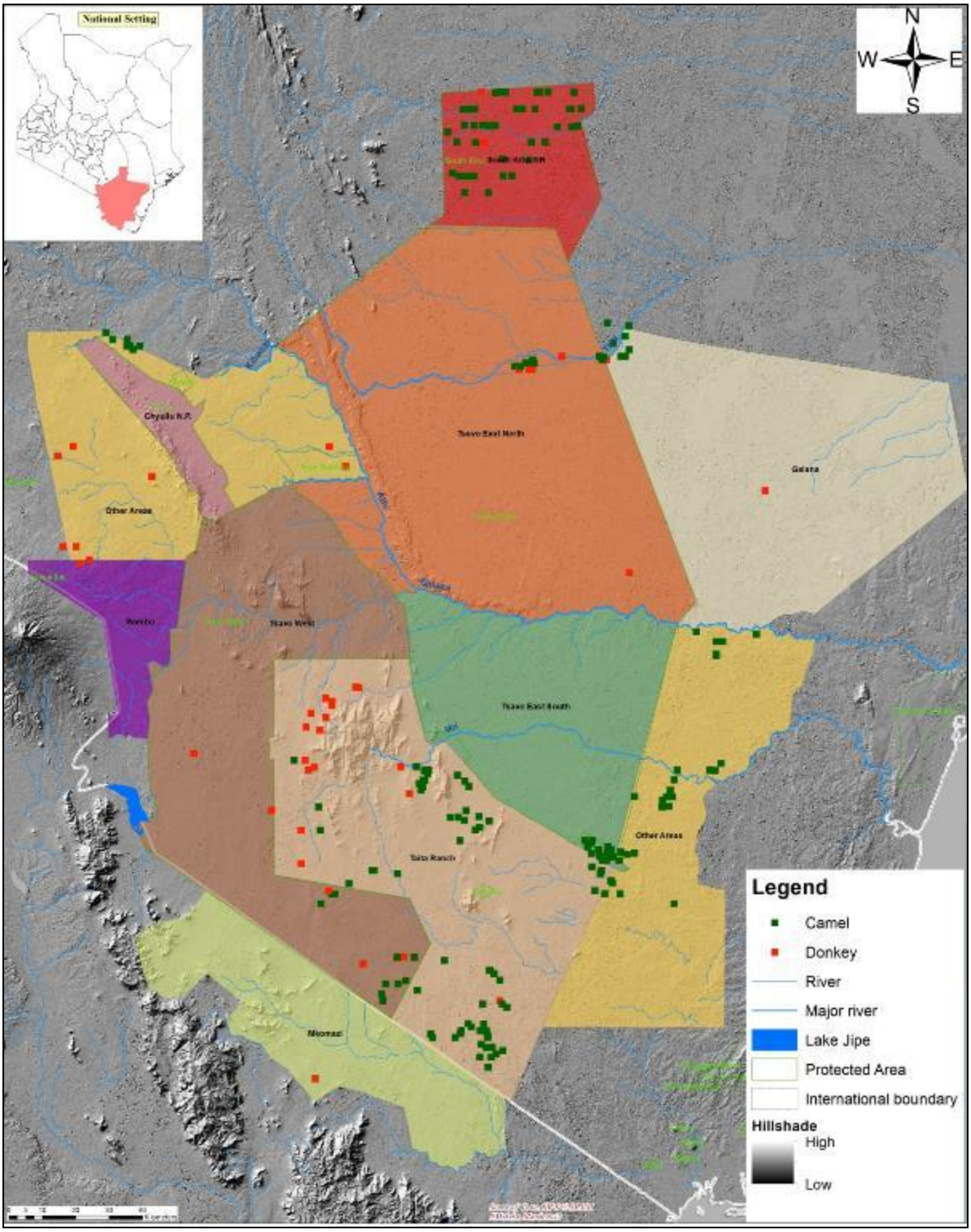

Figure 13: The distribution of donkeys and camel in Tsavo-Mkomazi ecosystem (February 2017)

4.4.4 Charcoal burning and cultivated areas

Figure 14 shows the distribution of charcoal burning and cultivated areas. Cultivation and charcoal were concentrated in South Kitui National Reserve, Southern parts of Chyulu

National Park and outside the protected areas (Taita Ranches, Galana Ranch, Kulalu Ranch, Rombo area among others; Figure 14).

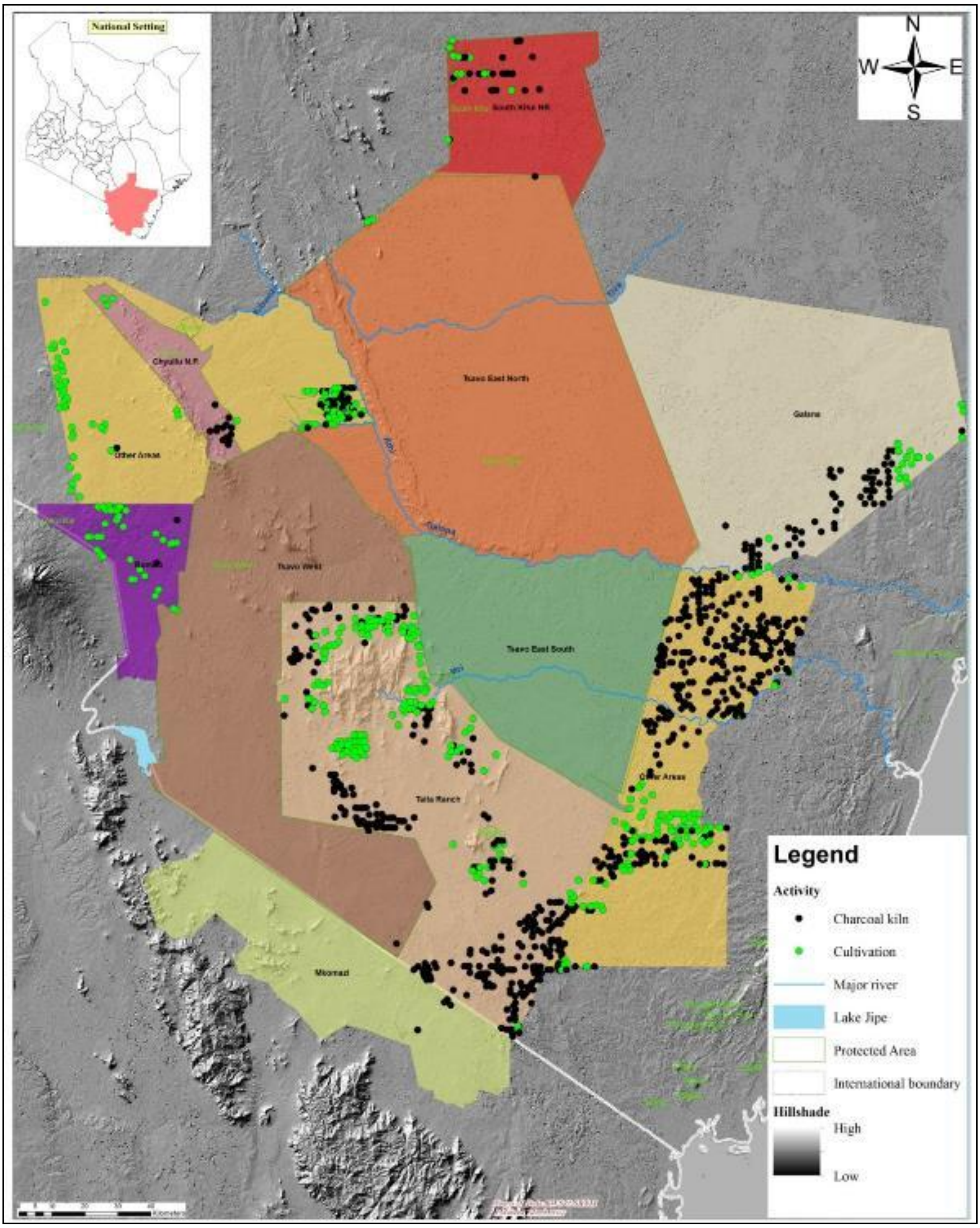

Figure 14: The distribution of charcoal burning and cultivated areas in Tsavo-Mkomazi ecosystem (February 2017)

5.0 DISCUSSIONS

5.1 Elephants

The results revealed that the population of elephants in the Tsavo–Mkomazi ecosystem increased from 12,843 elephants to 12,866 elephants, representing a 14.7% over the last three years (2014-2017). This represents an annual increase of 4.9% over the period. This annual increase is above the expected 4% annual natural growth rate of elephant population. The increase in elephant population is attributed to reduction of poaching in the ecosystem, which is attributed to three factors. First, over the last three years, the Government of Kenya through KWS, Conservation NGOs and the International Community has doubled efforts to curb elephant poaching in Kenya and other elephant range states. Second, change in legislation that increased penalties regarding dealing with elephant trophies has discouraged dealers and poachers from engaging in poaching and dealing with elephant trophies. Third, creation of awareness on the new wildlife conservation and management act 2013 has been undertaken to the prosecution and judiciary departments, which has enhanced prosecution and sentencing on crimes related to poaching and dealing with elephant trophies.

Two other factors may contribute to the increase in elephant, and other wildlife. First, the increased attention paid to training of observer crews and hence, a more rigorous count with improving technique and technology. Furthermore crews were given smaller more manageable areas to count than in previous years which translate into shorter times spent counting. In turn, this allows crews to remain more focused aver the course of the count. Fatigue was also minimized by the fact that more trained observers were available for the count. This allowed crews to rest on alternate days and stay fresh. These factors are hard to quantify but none-the-less will have a positive impact on the total number of wildlife detected. Second, with the noted significant increase in livestock and human activity both inside the national park and surrounding it (e.g., see Figure 16), the count may have benefited from a concentration of wildlife. This may have simplified counting by making the typically more widely distributed wildlife easier to detect. More elephant, and other wildlife,inside the TME area, may well suggest less in areas not counted by this survey. This represents a redistribution of the population as opposed to a net increase.

The increase in elephants was not consistent within the nine counting regions. This was mainly because the change was positive in some counting regions, and negative in others. For example, Tsavo West, Chyulu, Rombo and Mkomazi counting regions experienced a negative population change during the period. A plausible explanation for this trend would be the differences in elephant carcass distribution or movement of elephants to secure regions in the ecosystem. Dead elephants serve as a useful index of elephant mortalityand can subsequently be used to model population status (Douglas-Hamilton and Burrill, 1991).

A high elephant carcass ratio of 8.3% for the entire ecosystem was observed during the 2017 survey compared to previous surveys (Ngene *et al.*, 2013; Kyale *et al.*, 2014). The increase in carcass ratio could be attributed to variability in carcass ratio estimation owing to carcass decay rates in different environmental conditions (Douglas-Hamilton and Hillman 1981). For example, in 2011 and 2014, about 567 and 857 elephant carcasses were counted in the ecosystem (Ngene *et al.*, 2013 and Kyale *et al.*, 2014). There is a cumulative effect of un-decomposed carcasses that is carried over after every three years, which justifies the recording of the 1,167 carcasses during the February 2017 aerial survey as well as better training of crew in carcass identification and categorization. This maybe further justified since there was no significant difference in elephant carcass ratio to population change (P=0.154, df= 9, t=1.553),while comparing the elephant population change for the period 2014 to 2017, and the carcass distribution in the nine counting blocks. However, the high carcass ratio for Mkomazi ecosystem (65.5%) and the corresponding population decline might require further investigation as this carcass ration is higher than the recommended ration of 50% (0.5) PIKE. Also, elephants are highly mobile and their place of death from natural causes is almost a chance event.

Carcass numbers from total counts should be treated as minimum numbers because many carcasses are missed during total counts. Nonetheless, a comparative look at their trends is useful in deciphering long term trends for an ecosystem. Figure 15 shows the longterm trends of carcass ratios in Tsavo ecosystem. The increase in elephant carcass ratio alongside an increase in elephant numbers is possibly due to reduced poaching in the ecosystem.

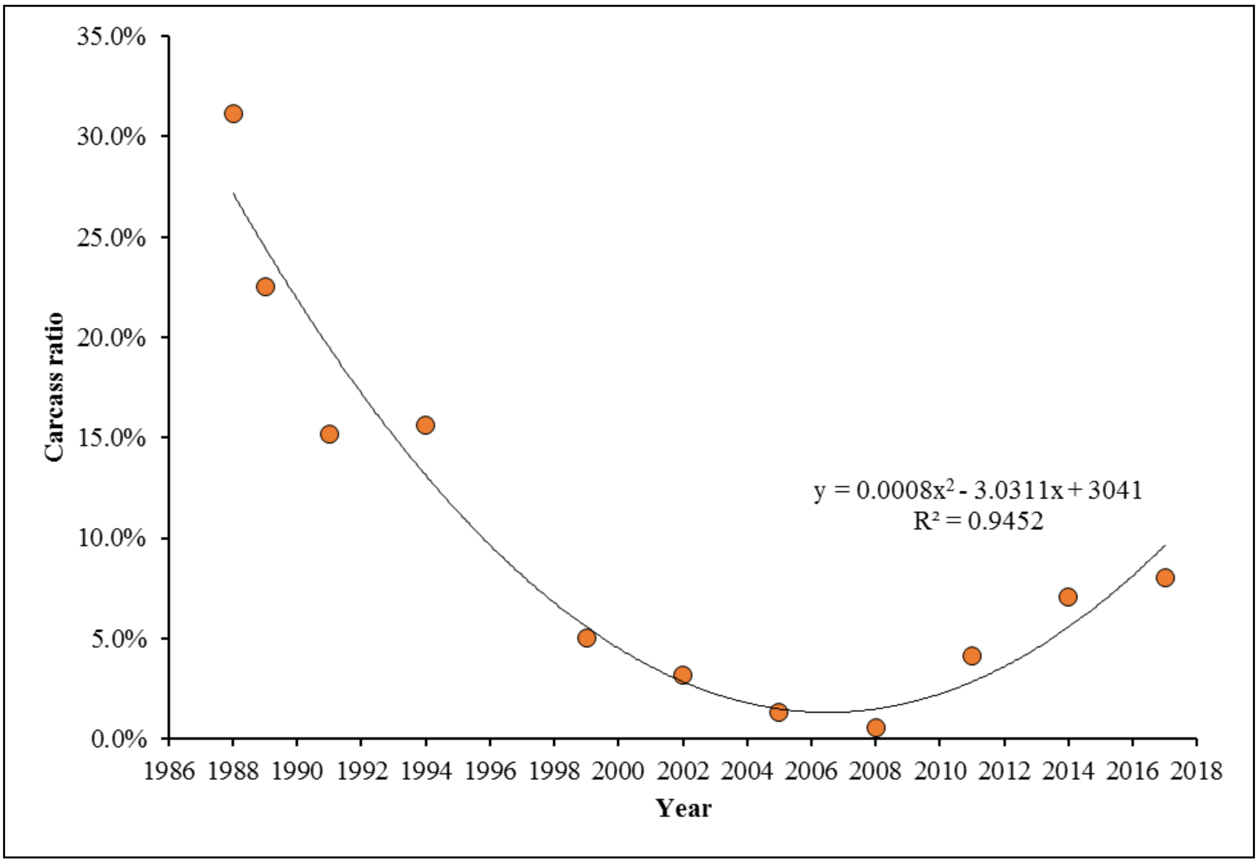

Figure 15: The carcass ratios of elephants in Tsavo conservation area from 1986 to 2017. A steady decrease in carcass ratios was recorded until the year 2008

Although there were few overlaps of elephants and livestock, most of the elephants avoided areas utilized by livestock (Figure 16). This is because elephants are sensitive to human disturbances and are known to ovoid areas with human activities like livestock keeping (Ngene *et al.*, 2013; Ngene *et al.*, 2009).

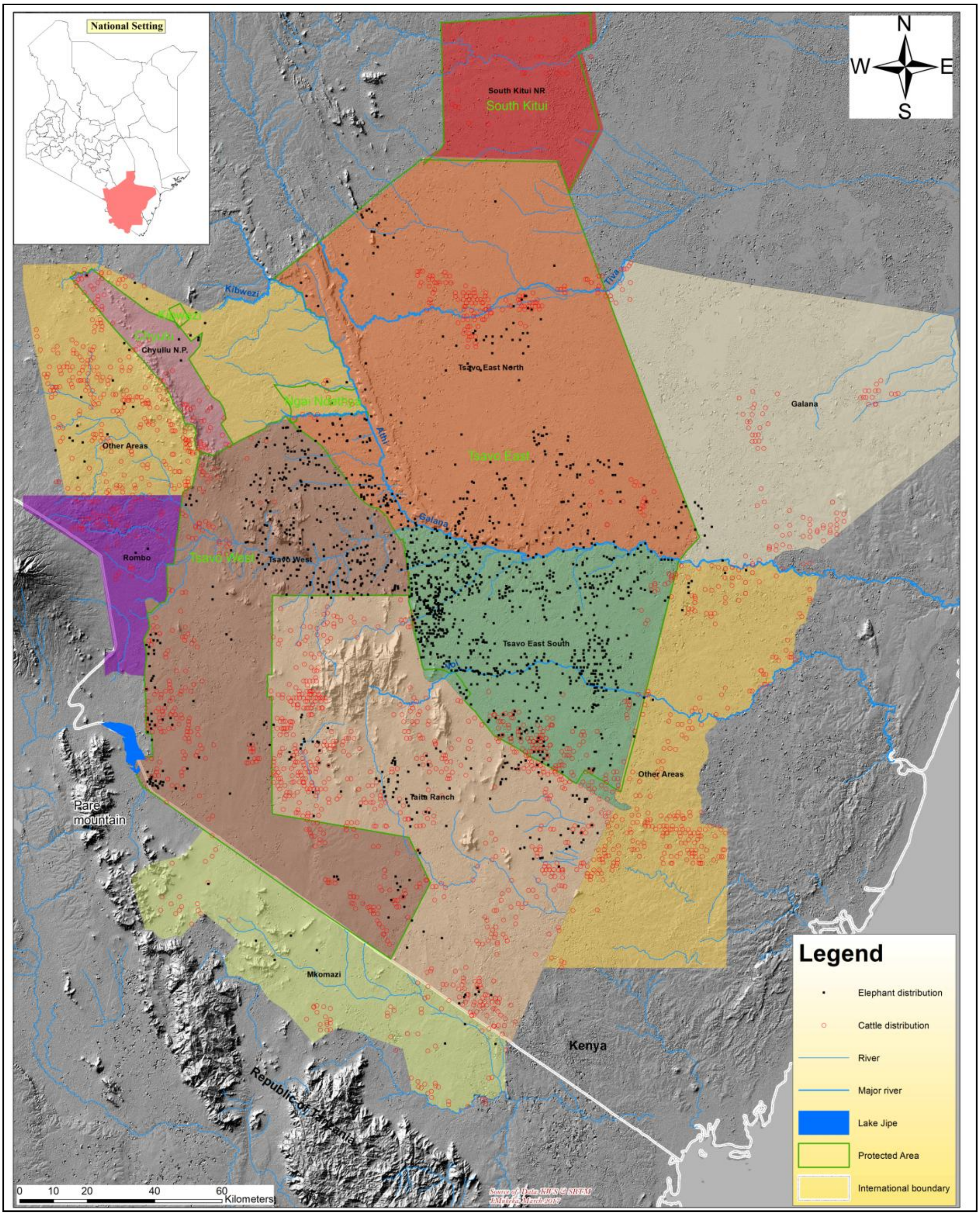

Figure 16: The distribution of elephants and cattle in Tsavo-Mkomazi ecosystem (February 2017)

5.2 Buffalo

Within the three-year period, a 46% population increase was recorded in the entire ecosystem which translates to an annual percent increase of about 15%. This can be attributed to population growth or variation in seasonality. However, this rate may be misleading considering that during 2014 census; the area was a bit wet compared to the dry spell experienced in most of the parts in the ecosystem in 2017. This contributes to either underestimate or overestimate. In wet periods, grazers are sparsely distributed and thus easy to estimate compared to dry period when the species aggregate in watering points and estimating their numbers may be exaggerated (Ottichilo, 1999). It is worth mentioning that 78.83% of the buffalo were counted inside protected areas.

Though the population showed an increase in the last three years, the overall trend shows insignificant decline since 1988. The same trend has been evident in other populations of the African buffalo (IUCN SSC Antelope Specialist Group, 2008). The decline may be due to declining of the preferred habitat either due to human activities and livestock (IUCN SSC Antelope Specialist Group, 2008). Tsavo-Mkomazi in the recent past has suffered from large herds of livestock influx like other African parks. This increases demand for pasture and water which in most cases is limited in such arid and semi-arid ecosystems. The drought on the other hand has been more unpredictable and irregular than before, which has also increased pressure on the limited resources especially for grazers.

It is notable that some regions in the ecosystem have recorded increase in buffalo numbers compared to those counted in 2014. Regions of TENPN, TENPS, Rombo and Taita experienced more than 63.4% increase between 2014 and 2017. Critical scrutiny of the data revealed that buffalos were distributed in areas with no livestock and with abundant water. This means therefore, such areas have plenty of pasture due to reduced competition from livestock, and water is available. The opposite is shown in the Galana, MNP and other blocks, where water is scarce, large concentrations of livestock sighted and illegal human activities observed. In such areas, competition is high and in case of a long dry spell, huge deaths of buffalo may occur affecting the growth rate. In TWNP, the population seem to be stable (decline of about 3% in three years). There are high chances the northern side of TWNP experienced an increase due to no livestock influxand availability of water but southern part may have experienced decline due to livestock influx and water stress except areas near Lake Jipe. The same trends have occurred since 1988. In the same time periods, Galana region has experienced a significant decline in buffalo population. In the Galana, high pressure is been received from increasing livestock numbers and human activities. On the contrary, Taita region has experienced significant increase in population between 2005 and 2017. The contribution is from the population around Taita sanctuary and Rukinga/Taita ranch where water is available and pasture is plenty due to controlled livestock numbers.

No buffalo were sighted during the survey in SKNR and CHNP. CHNP has permanent water springs, dense mountain forest and forest glades which are ideal for buffalo. The aerial census method might not be ideal for this area due to the terrain and also the dense mountain forest which in most cases may not allow for good aerial view and thus hinders aerial counting (Doughlas-Hamilton, 1996).

In the 317 observations, about 82% were buffalo in groups were either family or bachelor herds. Even the lone ones were near the herds. Though the largest herd size was 485, the average group size was of about 27 buffalo. Large groups can only be supported by high quality of the habitat they are in (Nowak, 1991; Kingdon, 1997). In most cases, temporary aggregations can be experienced in wet seasons. The average herd sizes for various regions were not the same meaning certain regions had large herd sizes while others were not. The results therefore show certain regions are rich in resources compared to others. TENPN, TENPS and Taita regions had large herd sizes depicting the availability of pasture, water and to some extent low competition from livestock. TWNP and MNP had least herd sizes.

The buffalo density in the ecosystem was 0.18 buffalo per square kilometre and for regions, it ranged from <0.001 to 0.84. High densities were recorded in areas with good habitats. TENPS still the favourite having a 0.84 buffalo per square kilometre. Apart from TENPS been an open grassland, it is served with permanent water points which include wind powered boreholes, tourist facilities with waterholes, rivers and water pipeline.

Soil drainage played a big role in determining buffalo distribution, where extremely slow drained soils were preferred than rapidly drained soils. Extremely slow drained soils are able to retain water for some time as well as rich in soil nutrients. In arid and semi-arid areas like the Tsavo-Mkomazi ecosystem, such soils are critical to support rich and nutritious plants that support the large herds of buffalo. In addition, poorly drained soils in shallow depressions have tendencies to accumulate rain runoffs and thus available for the water dependant species like buffalo during the dry spells. Residing around such areas is eminent. The soil texture plays a minimal role in buffalo distribution in Tsavo-Mkomazi. The three main soil texture types where buffalo were present in the regions were loamy, clayey and very clayey. The characteristics are almost similar and thus all equally preferred.

Buffalo in Tsavo-Mkomazi might have developed immune over time and thus tryponosomiasis infection is not a big deal. Though, tryponosomiasis menace has not been reported in the near past, translocated species like hirola have shown avoidance to such tsetse infested areas (Kimitei *et al.*, 2015).

The SGR had an impact within the 15 kilometres radius on the distribution of the buffalo. Because of the construction, the noise of the heavy machinery and use of rock-crackers might have forced buffalo to keep distance. The number was less within 5 km but increased at 5-10 kilometres but later reduced up to 15 kilometres. Secondly, the raising and fencing of the SGR might have blocked the buffalo movement. Until they get used to the crossing points, these groups may be lining up around the SGR for some time. Supplemented water points showed minimal effect on distribution of buffalo. Probably the water points are few or water was available in the areas they were since rains had been received earlier in December 2016. However, distance to rivers had significance within 10 km but not thereafter. Areas beyond might have been served with surface water after the rains but within rivers, there are high chances of heavy runoffs and thus collection in pans is minimal unless dammed or scooped.

The buffalo preferred open plain areas. The plains are rich in grass and also some of the depressions on the plains hold water collected from run offs after rains. The plains in most cases receive runoff that comes with humus thus contain soils rich for grass and tree growth. It emerged that, buffalo in the ecosystem were located close to roads. Most of the parks roads are used for game drives as well as firebreaks. However, the same roads have cut off drains that drain runoff water out of the road. The water drained out of the road in most cases irrigates the plains and create good pasture for grazers. Mostly, the roads are created in open areas to boost game drives which is a coincidence, they are areas occupied by many grazers including buffalo.

5.3 Giraffe

There was a 49.53% population increase in the number of Giraffe in Tsavo-Mkomazi ecosystem in the year 2017 compared to 2014. The tremendous increase was recorded in the Tsavo east and west National parks and this increase was due to protection and security the Giraffes obtained in the park. The Taita ranches also showed increase in numbers. Currently KWS has security bases patrolling over the ranches and providing security to the wildlife. Cases of poaching have been controlled in the park and Taita ranches thus wildlife can forage peacefully hence increase in number. The population declined in South Kitui National Reserve and Rombo areas. This can be attributed to competition between the Giraffes and livestock in these areas. In South Kitui region there is a lot of charcoal burning and most target trees species used for charcoal is the food for Giraffes and this might have contributed to population decline in the area.

5.4 Human activities

The Tsavo-Mkomazi ecosystem climate is suitable for livestock keeping and therefore hosts large numbers of livestock. According to Bailey (2005) livestock grazing distribution is influenced by both a-biotic and biotic factors (Butt and Turner, 2012). These livestock in the ecosystem have grazing patterns which are determined by availability of water and graze material. The livestock does not belong to the local community but come as far as north eastern. Influx of livestock in the ecosystem is as a result of the Taita ranches being declared as a disease free zone (Ngene *et al.*, 2013). In the pretext of watering the livestock in Galana River, some of it ends up in the park. This is a major threat to the fragile Tsavo ecosystem as the livestock competes for forage with wildlife which further results to overgrazing followed by soil erosion and associated degradation of the habitat. Efforts to tame livestock incursion menace in Tsavos have not yielded positive results as the problem still continues unabated.

Strict livestock control measures needs to be enforced at the Tsavos by the KWS management to ensure the problem of livestock incursions is contained at manageable levels. A zero tolerance level to corruption should be explored as the persistent problem of livestock incursions is associated with the vice.

The results of the 2017 census show that charcoal burning is a real threat in the ecosystem. Charcoal burning in this area targets indigenous trees that produce the best charcoal to fetch a good price in the market. Indigenous trees take decades to be ready for harvesting and therefore the uncontrolled felling of such trees, coupled with increasing clearing tracts of land for cultivation is inevitably going to cause habitat degradation and loss. The density and distribution of charcoal kilns in the areas buffering the protected areas point to a worrying trend and the need for substantive measures to be put in place to abate this. The increase in cultivated areas around the protected areas of Tsavo will increase the edge effect and blockage of critical movement routes that sustain the ecological integrity of the ecosystem. Studies show that edge effects can have serious impacts on species diversity and composition, community dynamics and ecosystem functioning (Laurance *et al.*, 2007). The ecosystem southern fringes in the counties of Taita Taveta, Kwale and Kilifi, the scale of charcoal burning just from a casual examination is unsustainable and alternative livelihoods for the communities need to be identified.

6.0 CONCLUSIONS

Between 2014 and 2017, the population of elephants in Tsavo-Mkomazi ecosystem increased by 14.7%. This represents an annual increase of 4.9%. However, the increase was only in Tsavo ecosystem as in Mkomazi National Park, the population decreased by 61%. Three (3) and twenty seven (27) fresh and recent carcasses (Tsavo and Mkomazi respectively) were recorded during the aerial survey. The carcass ratios are increasing since the year 2008. Poaching levels in Africa have been on the decline since the year 2011, but they are still above the naturally sustainable level of 54% PIKE (Proportion of Illegally Killed Elephants). The increase in carcass numbers may not necessarily reflect an increase in poaching levels alone, but it should be taken as an indicator that there is still some considerable level of poaching, albeit minimal compared to the levels of poaching during the period 2010 to 2012. It is anticipated that with continued anti-poaching activities, the carcass ratios would decrease in the future. Noting that the percentage of recent carcasses is much lower than expected natural mortality (i.e., 2.4% versus 4%) it is apparent that many carcasses were missed. It would be prudent to recalculate carcass ratio based on carcasses derived from a sample count.

The population of buffalo was 8,623 which is about 46% increase compared to 5,912 buffalo recorded in the same ecosystem in 2014. The population of buffalo in Tsavo ecosystem increased by about 52% whereas that in Mkomazi National Park decreased by 68%.The 2017 Tsavo-Mkomazi census indicated that the ecosystem supports 4323 giraffe.

Buffalo play a big role in shaping the plains but also as prey for large predators. It is therefore necessary to put in place strategies to improve their population growth and distribution. One of the factors contributing to their distribution is water. Holistic management of water in Tsavo-Mkomazi will add value to the habitats currently not occupied by buffalo.

Giraffe plays a big role in the ecosystem and it is also food for carnivores like lions. Protecting and conserving the Giraffes will ensure continuity of food web in Tsavo ecosystem. The results of 2017 indicate an increase in human activities within and around the protected areas. Charcoal burning and increase in number of livestock in the ecosystem poses a threat to the wildlife habitat.

7.0 RECOMMENDATIONS

1. There is need to ascertain the number of buffalo in CHNP as it was not captured in the census, though a herd of 5 was counted just adjacent. In addition, a dry season count could be necessary to understand the dynamics.
2. More patrols and research should be focused in the areas where buffalo population have declined to assess the route cause for these declines.
3. Development of zonation in community land is critical so as to allow introduction of suitable land use and management strategies based on the zones. Area around Taita sanctuary is a good example which has boosted the buffalo population in the region.
4. Active management in pasture to be introduced taking advantage of the available road networks. Harvest of runoff in the roads and used to irrigate nearby areas will improve on the pasture for grazers.
5. There is need to manage these threats to acceptable levels by engaging relevant agencies and County Governments.
6. There is need for further investigation on elephant poaching threat at the different sections, specifically Mkomazi, Galana and Tsavo east North, where a high carcass ratio was encountered.

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ANNEXES

Annex 1: Training Results

To provide an understanding of how well the survey crews were performing and an indication of the accuracy of the count, data was reviewed in two ways. First, prior to the survey several test flights were undertaken in four seat aircraft which had been set up to test inter observer variability as described in the methods above. During this so called "*Front Seat: Back Seat*" test, the Left-Hand Rear Seat Observer (LRSO) also collected data. The LRSO was then compared to the RRSO to test whether one observer was undercounting animals.

In addition to this, survey standards for flight parameters were evaluated during training and at regular intervals during the count. Quantitative parameters such as aircraft speed, altitude within a digital elevation model, adjusted for height above ground and heading obtained from GPS track log data, were plotted and reviewed with survey crews to ensure that survey standards were being met.

Second, all observers were tested on a count simulation using Wildlife Counts ™ software. These results were used to individually assess whether an individual could operate under the pressure of a timed exercise and how accurate group size estimation was. This was particularly relevant for the large herds of wildfire and livestock encountered.

Front Seat& Back Seat Test

The average group size and species detection reliability based on matched observations during flight tests was 70% (range 39% to 91%)at the start of the count. We used an adaption of mark-recapture methodology, the Chapman Estimator, to predict variance between observer pairs. The Chapman estimator was used because of low sample sizes and hence numbers of matched sightings. Matched pairs of sightings were verified by location (using GIS models), species observed and number of animals estimated from raw data.

The average inter-crew (RSOL vs. RSOR) variability for the number of groups of animals seen between the selected cohort of observer crews was 30%(SD±15%, n=20).

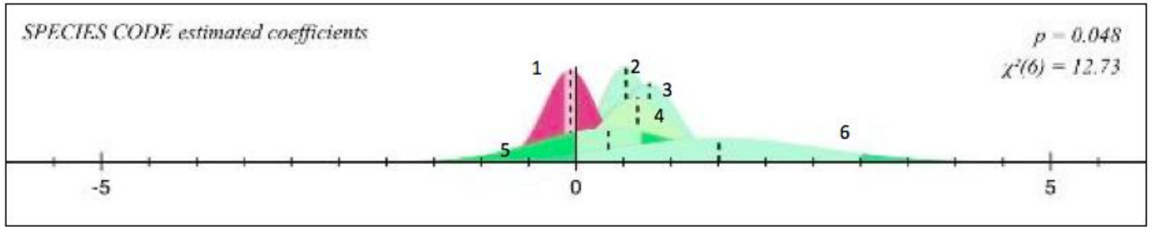


Figure 1: Observer variability of species detection. 1: Elephant, 2: Giraffe, 3: Camels, 4: Donkeys, 5: Cattle, 6: Shoats.

Figure 1. shows normalized plot of *Front Seat & Back Seat* observer variability. The model to detect significant differences between observers uses covariates: 'flight number', 'estimated number of animals' and 'species' as factors. Variability is significantly influenced by large herds of animals that are not circled (livestock). 6 Targets were detected during the test (elephant: p=0.882, giraffe: p=0.094 cattle: p=0.042, shoats: p=0.014,donkeys: p=0.142 and camels: p=0.642 – no buffalo were detected during test flights). There was no difference between detections of different wildlife species by observers following each other on matched transects with a 30-min separation (time = 4 hours total, X^2 = 11.782, p = 0.048, df = 5, n observers = 20).

No data was removed from the count owing to observer variability because a total count is a simple cumulative total estimate calculated from all observations. For this reason, the results represent a "minimum total count". These results form a baseline from which future serves can be gauged and improved. They also fall within similar tolerances for SRF counts undertaken for elephant count in East Africa during the Great Elephant census (Chase et al. 2016).

Wildlife Counts ™ Results

Table 1 presents the summarised results of simulated group size estimate test using the Wildlife Counts ™ software. This data was incorporated into a panel discussion for selection of the final survey crew. As far as possible crew were selected on merit. The Average error on the simulated group size estimate was calculated on a random sample of group sizes between 5 and 180 animals over 5 iterations. The test was only run once the candidate was confident that their practice runs were achieving the best accuracy they could deliver. In general, the accuracy was high, reaching a mean of less than 1% undercount error (-0.77% SD±10.49)

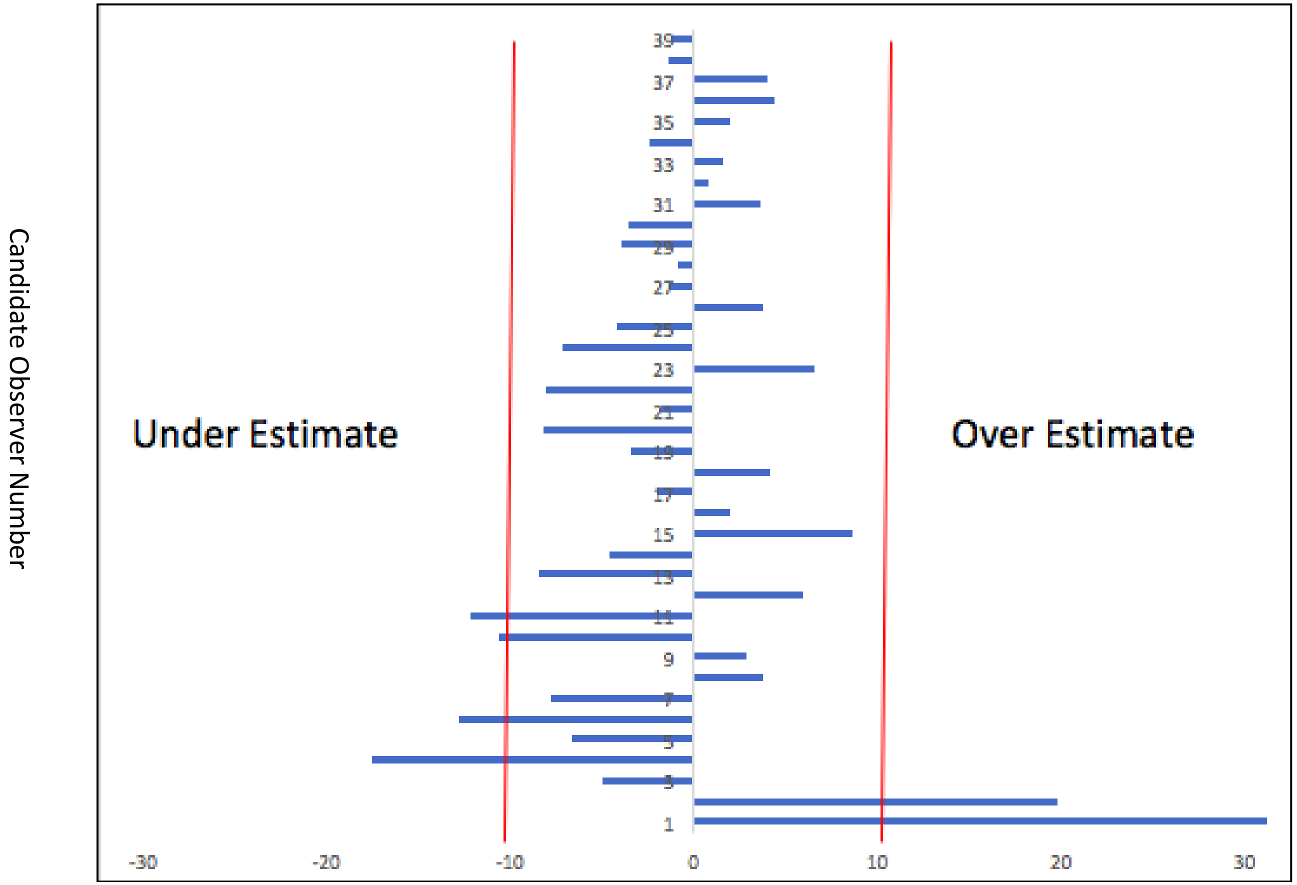


Figure 2: Simulated group size estimation results for 39 trainee candidates using Wildlife Counts ™ software. This is particularly relevant to the estimation of livestock numbers.The red lines indicate one standard deviation of the mean percent error for 5 iterations of the test.

Observer	It1				It2				It3				It4				It5				Average Error	SD±
	Est	Act	Err%	Er2	Est	Act	Err%	Er2	Est	Act	Err%	Er2	Est	Act	Err%	Er2	Est	Act	Err%	Er2		
Observer 1	78	74	5	5	68	53	28	28	68	7	-12	12	128	96	33	33	186	92	102	102	**31.2**	**36**
Observer 2	23	14	64	64	62	68	-9	9	87	112	-22	22	280	173	62	62	87	84	4	4	**19.8**	**32.2**
Observer 3	40	30	33	33	102	128	-20	20	140	169	-17	17	160	135	19	19	45	75	-40	40	**-5**	**25.8**
Observer 4	65	7	-10	10	130	155	-16	16	85	108	-21	21	35	33	6	6	55	104	-47	47	**-17.6**	**20**
Observer 5	10	13	-23	23	50	74	-32	32	20	21	-5	5	160	131	22	22	60	57	5	5	**-6.6**	**17.4**
Observer 6	65	75	-13	13	120	123	-2	2	75	131	-43	43	25	26	-4	4	50	51	-2	2	**-12.8**	**12.8**
Observer 7	145	160	-9	9	48	47	2	2	92	13	-32	32	26	29	-10	10	56	51	10	10	**-7.8**	**12.6**
Observer 8	250	251	0	0	201	163	23	23	280	270	4	4	200	176	14	14	98	126	-22	22	**3.8**	**12.6**
Observer 9	60	70	-14	14	52	45	16	16	21	20	5	5	102	87	17	17	140	156	-10	10	**2.8**	**12.4**
Observer 10	11	11	0	0	131	129	2	2	60	59	2	2	125	153	-18	18	45	74	-39	39	**-10.6**	**12.2**
Observer 11	148	160	-7	7	85	101	-16	16	120	157	-24	24	85	90	-6	6	45	49	-8	8	**-12.2**	**12.2**
Observer 12	145	130	12	12	11	11	0	0	50	41	22	22	22	20	10	10	130	151	-14	14	**6**	**11.6**
Observer 13	30	39	-23	23	95	98	-3	3	90	105	-14	14	18	17	6	6	125	136	-8	8	**-8.4**	**10.8**
Observer 14	50	47	6	6	11	12	-8	8	75	79	-5	5	128	171	-25	25	12	11	9	9	**-4.6**	**10.6**
Observer 15	75	75	0	0	160	123	30	30	130	131	-1	1	25	26	-4	4	60	51	18	18	**8.6**	**10.6**
Observer 16	36	30	20	20	93	117	-21	21	80	78	3	3	6	6	0	0	77	71	8	8	**2**	**10.4**
Observer 17	67	70	-4	4	54	35	20	20	20	20	0	0	81	87	-7	7	127	156	-19	19	**-2**	**10**
Observer 18	60	70	-14	14	58	45	29	29	20	20	0	0	90	87	3	3	160	156	3	3	**4.2**	**9.8**
Observer 19	15	14	7	7	54	68	-21	21	121	112	8	8	162	173	-6	6	80	84	-5	5	**-3.4**	**9.4**
Observer 20	32	31	3	3	146	156	-6	6	55	57	-4	4	123	177	-29	29	80	84	-5	5	**-8.2**	**9.4**
Observer 21	25	28	-11	11	100	91	10	10	80	85	-6	6	70	66	6	6	80	87	-8	8	**-1.8**	**8.2**
Observer 22	14	14	0	0	60	68	-12	12	110	122	-2	2	150	173	-13	13	80	84	-13	13	**-8**	**8**
Observer 23	77	74	4	4	102	104	-2	2	160	148	8	8	48	39	23	23	10	10	0	0	**6.6**	**7.4**
Observer 24	68	71	-4	4	10	10	0	0	75	94	-20	20	125	142	-12	12	38	38	0	0	**-7.2**	**7.2**
Observer 25	90	93	-3	3	75	89	-16	16	6	6	0	0	120	112	7	7	60	66	-9	9	**-4.2**	**7**

Observer	It1				It2				It3				It4				It5				Average Error	SD±
	Est	Act	Err%	Er2	Est	Act	Err%	Er2	Est	Act	Err%	Er2	Est	Act	Err%	Er2	Est	Act	Err%	Er2		
Observer 26	100	104	-4	4	140	129	9	9	130	131	-1	1	55	56	-2	2	105	90	17	17	**3.8**	**6.6**
Observer 27	72	75	-4	4	139	123	13	13	110	131	-16	16	26	26	0	0	51	51	0	0	**-1.4**	**6.6**
Observer 28	31	30	3	3	56	68	-18	18	145	134	8	8	7	7	0	0	62	60	3	3	**-0.8**	**6.4**
Observer 29	130	142	-8	8	90	85	6	6	27	28	-4	4	52	52	0	0	43	50	-14	14	**-4**	**6.4**
Observer 30	14	14	0	0	73	68	7	7	105	112	-6	6	160	173	-8	8	75	84	-11	11	**-3.6**	**6.4**
Observer 31	82	75	9	9	123	120	-2	2	140	131	7	7	25	26	-4	4	55	51	8	8	**3.6**	**6**
Observer 32	40	42	-5	5	22	24	-8	8	10	9	11	11	25	24	4	4	120	118	2	2	**0.8**	**6**
Observer 33	48	51	-6	6	63	65	-3	3	10	10	0	0	103	91	13	13	122	117	4	4	**1.6**	**5.2**
Observer 34	38	39	-3	3	147	148	-1	1	90	104	-13	13	78	74	5	5					**-2.4**	**4.4**
Observer 35	115	111	4	4	100	96	4	4	50	53	-6	6	27	25	8	8	90	90	0	0	**2**	**4.4**
Observer 36	121	119	2	2	144	139	4	4	22	21	5	5	56	55	2	2	84	77	9	9	**4.4**	**4.4**
Observer 37	113	111	2	2	87	96	-9	-9	54	53	2	2	26	25	4	4	109	90	21	21	**4**	**4**
Observer 38	5	5	0	0	7	7	0	0	47	54	-13	13	24	24	0	0	18	17	6	6	**-1.4**	**3.8**
Observer 39	21	21	0	0	53	55	-4	4	77	77	0	0	113	111	2	2	92	96	-4	4	**-1.2**	**2**
Total Error																					**-0.77**	**10.49**

Table 1: Results of the Wildlife Counts (TM) simulations.

Eye Test Results

Visual acuity tolerance was capped at 20:40 vision. Several experienced candidates demonstrated poorer vision (range 20:50 – 20:100) and were not included as observers in the survey. Despite these results none of the experienced observer crew presented wearing corrective lenses. Good vision is a basic requirement of an aerial survey which relies on spotting targets with often fleeting glimpses of partial obscured animals. This is the first-time vision has been tested in a survey in Kenya. Those with lower eyesight were referred to professional optometrists to verify and obtain prescription lenses if required. They were also encouraged to return for future counts.

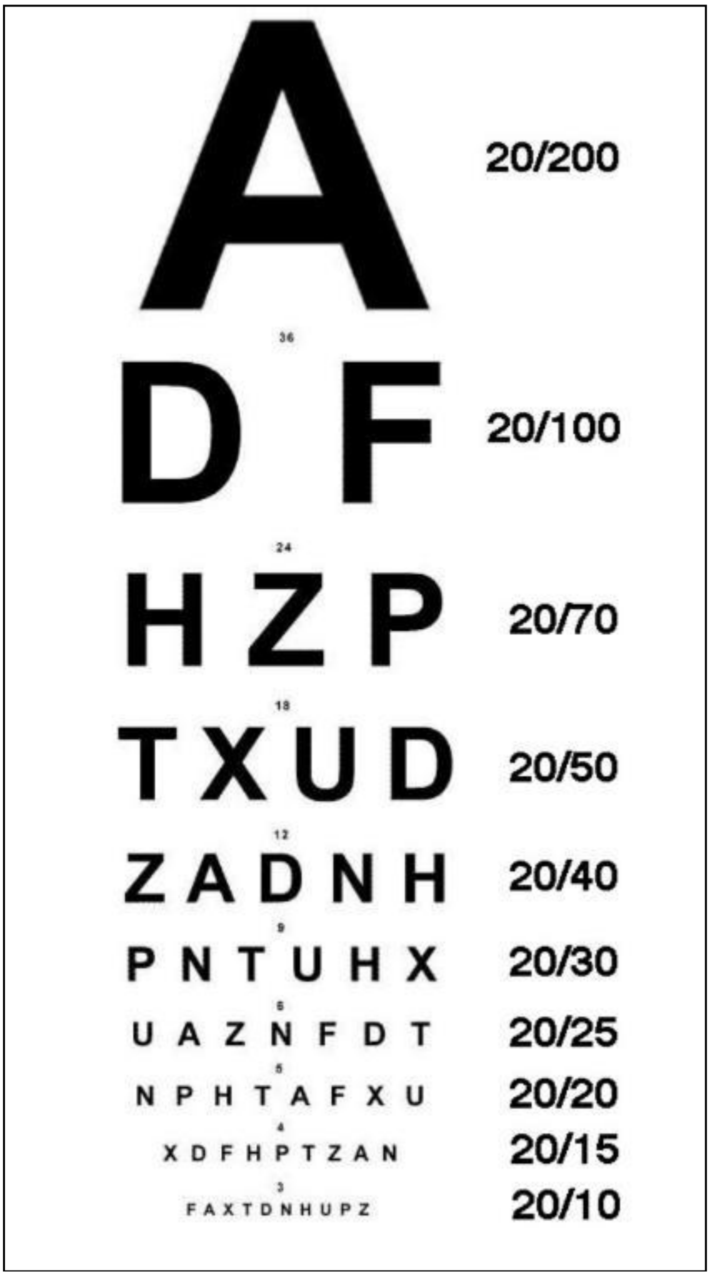
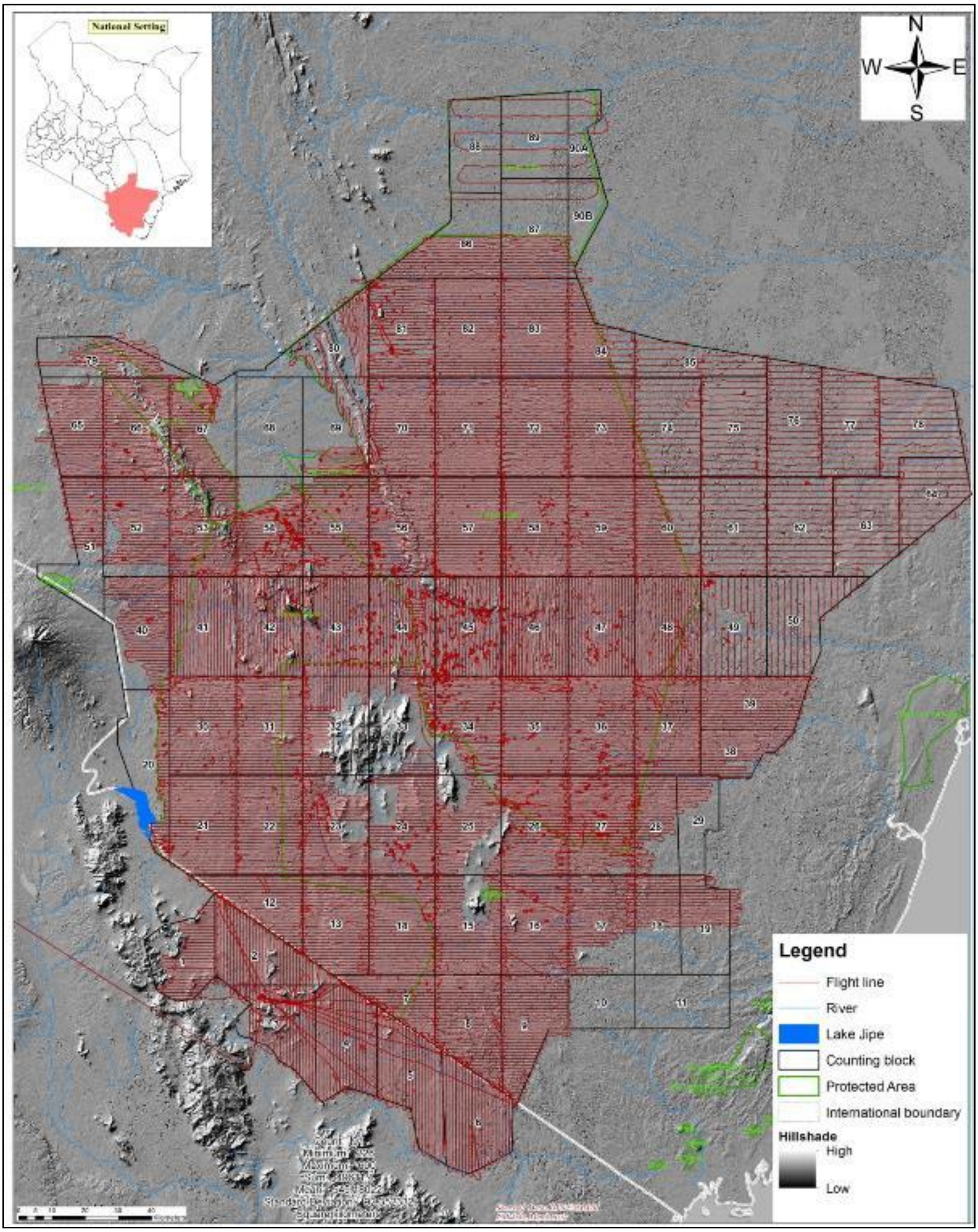


Figure 3: Snellen Chart for testing visual acuity.

Observer Assessment

Observer selection was not a purely quantitative process. Results obtained from the quantitative tests using wildlife counts and inter-observer variability was combined with qualitative information such as the level of experience of the candidate. For example, where eyesight may have been scored lower, but within range, for one candidate over another, their group size estimates and inter observer variability might have combined with several years of aerial survey experience to cause them to be selected over another candidate with somewhat better eyesight.

Annex 2: Map showing flight lines 2017



Annex 3: Total time during the actual aerial survey and the search effort (km^2/hr; February 2017)

Date	AUX	BAU	BWX	DTP	KWC	STE	STP	TTZ
2017-02-16	176	449	181	315	288	320	276	634
2017-02-17	268	434	258	288	179	333	424	221
2017-02-18	136	270	327	296	233	167	323	331
2017-02-19		108	454	374	135		327	94
2017-02-20	289	398	457	456	178	948	335	150
2017-02-21	249	74			160	306	171	310
2017-02-22	464	298		411	227	577	336	464
2017-02-23	296	185		436	300		193	392
2017-02-24	175	161		262	313		274	430
2017-02-25	134	119		129	170		102	152
Total Time (Min)	2187	2496	1677	2967	2183	2651	2761	3178
Total Time (Hrs:Min)	**36.45**	**41.6**	**27.95**	**49.45**	**36.3833**	**44.1833**	**46.0167**	**52.9667**

Total count time = 335 hrs
Search effort = Total census area/total count time = 148.1km^2/hr

Annex 4: Total transit time during the Tsavo-Mkomazi aerial survey (February 2017)

Date	**AUX**	**BAU**	**BWX**	**DTP**	**KWC**	**STE**	**STP**	**TTZ**
2017-02-16	89	109	63	79	136	103	170	92
2017-02-17	49	87	174	180	28	64	46	81
2017-02-18	15	59	49	126	104	63	73	102
2017-02-19		223	185	123	170		137	46
2017-02-20	77	71	101	52	83	112	104	142
2017-02-21	131	482			154	95	184	145
2017-02-22	45	70		120	87	80	155	130
2017-02-23	170	60		44	139		71	163
2017-02-24	296	24		148	152		237	243
2017-02-25	71	79		96	84		118	215
Total Time (min)	943	1264	572	968	1137	517	1295	1359
Total Time (Hrs:Min)	15.7	21.1	9.5	16.1	18.9	8.6	21.6	22.7

Total transit time in hours 134.25

Annex 5: List of participants

No.	Name	Organization	Responsibility
1.	Agnes Laboso	KWS-Air Wing	Aircraft Attendant
2.	Alex Mwazo	KWS -TENP	Rear Seat Observer
3.	Benedict Ndambuki	Tsavo Elephant Research	Rear Seat Observer
4.	Bernard Ochieng	KWS-SHNP	Rear Seat Observer
5.	Bernard Okwoga	KWS-Marsabit	Rear Seat Observer
6.	Bill Eldridge	Marwell Wildlife	Trainer
7.	Cedrick Khayale	KWS-TWNP	Front Seat Observers
8.	Christine Mwende	Tsavo Trust	GIS and Data entry
9.	Christopher Muithya	KWS-Air Wing	Aircraft Engineer
10.	Clarine Kigori	Marwell Wildlife	GIS and Data entry
11.	Cpl Jillo	KWS-TENP	Rear Seat Observer
12.	Dancan Mwenda	KWS-SCA	Rear Seat Observer
13.	Danvas Osoro	KWS-Air Wing	Aircraft Attendant
14.	David Kimanzi	Save the Elephants	GIS and Data entry
15.	Denis Kibara	KWS-TENP	Rear Seat Observer
16.	Edwin Mwasi	KWS-TENP	Rear Seat Observer
17.	Elizabeth Muthoni	KWS-HQs	Media communications
18.	Erustus Kanga	KWS-HQs	Logistics - Team Leader
19.	Esther Serem	Save the Elephants	Rear Seat Observer
20.	Evans Mkalla	International Fund for Animal Welfare	Official Opening
21.	Festus Ihwangi	Save the Elephants	Trainer
22.	Frank Pope	Save the Elephants	Trainer/Pilot
23.	Fredrick Lala	KWS-TCA	Logistics
24.	Fridah Mwikamba	KWS-TCA	GIS and Data entry
25.	George Osuri	KWS-TCA	Official Opening/ Closing
26.	Gerald Gichuki	KWS-TCA	Rear Seat Observer
27.	Geraldine Mjomba	KWS-TCA	GIS and Data entry
28.	Grace Waiguchu	KWS-HQ	GIS and Data entry
29.	Gwili Gibbons	Mount Kenya Trust	Front Seat Observers
30.	Horris Wanyama	KWS-TWNP	Rear Seat Observer
31.	Ian Lemiyian	Lewa Wildlife Conservancy	Rear Seat Observer
32.	Jackquline Nyagah	International Fund for Animal Welfare	Official Opening
33.	James Isiche	International Fund for Animal Welfare	Official Opening
34.	Jamie Manuel	Private	Front Seat Observers
35.	Jeniffer Olang	KWS-HQs	Support Services
36.	Joesph Kyalo	Tsavo Trust	Rear Seat Observer
37.	John Wambua	KWS-TENP	Official Opening
38.	Joseph Bump	University of Minesota, USA	Visiting Scholar
39.	Joseph Mukeka	KWS-HQ	Trainer
40.	Josh Outram	Tsavo Trust	Pilot
41.	Joss Craig	Lewa Wilderness	Rear Seat Observer
42.	Kabete Julius	KWS-CRCA	Rear Seat Observer
43.	Kennedy Ochieng	KWS-TWNP	Official Opening/ Closing
44.	Kennedy Shamalla	KWS-MCA	Pilot
45.	Kenneth Kimitei	African Wildlife Foundation	Front Seat Observers
46.	Margaret Mwakima	State Department of Natural Resources	Official Closing
47.	Kitili Mbathi	KWS-HQs	Official Closing
48.	Lekishon Kenana	KWS-HQ	Front Seat Observer

No.	Name	Organization	Responsibility
49.	Lilian Apollo	KWS-TCA	GIS and Data entry
50.	Lizbeth Mate	Marwell Wildlife	GIS and Data entry
51.	Luke Rukaria	KWS-Meru	Rear Seat Observer
52.	Marc Dupis-Desormeaux	Lewa Wildlife Conservancy	Rear Seat Observer
53.	Martha Nzisa	KWS-TENP	Rear Seat Observer
54.	Martin Mulama	WWF-K	Official Opening
55.	Michael Koskei	Save the Elephants	GIS and Data entry
56.	Mohammed Awer	WWF-K	Official Opening
57.	Monica Chege	KWS-HQ	Rear Seat Observer
58.	Moses Maloba	KWS-HQ	GIS and Data entry
59.	Nelson Mwangi	Save the Elephants	Data entry
60.	Neville Sheldrick	David Sheldrick Wildlife Trust	Pilot
61.	Nick Trent	David Sheldrick Wildlife Trust	Pilots/Pilots' Logistics
62.	Obed Mule	KWS-HQs	Media communications
63.	Paul Gathitu	KWS-HQs	Media
64.	Paul KipKoech	KWS-TCA	Security
65.	Peter Hongo	KWS-HQ	GIS and Data entry
66.	Peter Kimani	KWS-SCA	Rear Seat Observer
67.	Rashid Abdul	African Wildlife Foundation	Photography
68.	Richard Moller	Tsavo Trust	Pilot
69.	Rod Evans	Private	Pilot
70.	Rose Mayienda	African Wildlife Foundation	GIS and Data entry
71.	Sammy Muya	KWS-TCA	GIS and Data entry
72.	Samson Sanare	KWS-Air Wing	Aircraft Technician
73.	Sgt Boniface Oyugi	KWS-TWNP	Rear Seat Observer
74.	Shadrack Ngene	KWS-HQs	Deputy Team Leader
75.	Simon Wachira	KWS-Meru	Rear Seat Observer
76.	Sospeter Kiambi	KWS-HQ	Front Seat Observers
77.	Sten Potgeiter	Private	Pilot
78.	Stephen Ndambuki	KWS-CRCA	Front Seat Observers
79.	Stephen Nyaga	KWS-TWNP	Front Seat Observers
80.	Steve Njumbi	International Fund for Animal Welfare	Official Opening
81.	Sylvester Matheka	KWS-TCA	GIS and Data entry
82.	Tiarapa	KWS	Front Seat Observers
83.	Vasco Nyaga	KWS-Mara	Rear Seat Observer
84.	Vincent Nzau	County Government of Kitui	Rear Seat Observer
85.	Wa Njeri	KWS-Meru	Rear Seat Observer
86.	Zeke Davidson	Marwell Wildlife	Trainer