TOTAL AERIAL CENSUS OF ELEPHANTS AND OTHER LARGE MAMMALS IN THE TSAVO-MKOMAZI ECOSYSTEM

Shadrack Ngene[1]; Festus Ihwagi[2]; Martha Nzisa[1]; Joseph Mukeka[3]
Steve Njumbi[4]; and Patrick Omondi[3]

[1]Kenya Wildlife Service, Tsavo Conservation Area, P.O. Box 14 Voi, Kenya; [2]Save the Elephants, P.O. Box 54667, Nairobi 00200, Kenya; [3]Kenya Wildlife Service, Biodiversity Research and Monitoring, P.O. Box 40241, Nairobi 00100, Kenya; [4]International Fund for Animal Welfare, P.O. Box 25499, Nairobi 00603, Kenya

Sponsored by the International Fund for Animal Welfare and Kenya Wildlife Service

AUGUST 2011

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ILLUSTRATION

The tusks on the cover page were located from air and recovered from an intact carcass during the aerial census. They weighed 50 and 56kg each, representing the largest pieces of ivory under Kenya Wildlife Service's custody as of the date.

ACKNOWLEDGEMENTS

This work could not have been completed without the input and support of many people. We take this opportunity to thank some of them. We are grateful to Dr. Julius Kipng'etich (Director, KWS) for leading the fund raising for this census and accepting to release the official results on the last day. Dr. Samuel Kasiki (Deputy Director - Biodiversity Research and Monitoring, KWS) provided the necessary administrative support and technical input during the planning and implementation phases of the census. Drs Patrick Omondi (Senior Assistant Director - Species Conservation and Management, KWS) was instrumental in raising funds from the Monitoring of illegal Killing of Elephants (MIKE) programme. The MIKE funds facilitated participation of Ugandan and Tanzania collaborators. We also acknowledge the support we had from Wycliffe Mutero (KWS-GIS unit), who ensured that we received all the necessary shape files for the study area promptly. We also thank Mr. Wycliffe Mutero for providing staff from his unit to support the ground team during the census. They also provided technical support in GIS analysis. Special thanks go to the Head of KWS air-wing, Pilot Major (rtd) Solomon Nyanjui for ensuring that 7 aircrafts were available for the census exercise, including providing aircraft technicians and procuring all the fuel for the census exercise. Many other staff from KWS headquarters contributed to making the aerial census successful in one way or another, including Dr. Samuel Andanje, Elephas Bitok, Paul Udoto, Charles Ooro, Pilot/SW-Mount Kenya Robert Obrien, Pilot/SW-Tsavo West National Park Daniel Woodley, Pilot Oyile, Pilot George Mwangi, Pilot Kennedy Shamalla, Pilot Moses Lelesit and Pilot Muchina. You made us achieve the census goals and gave us words of encouragement, which kept us working hard to complete the exercise successfully.

At Tsavo Conservation Area, we thank Julius Kimani, Yusuf Watol, Christine Boit, Grace Kariuki, Silas Mureithi, Bernard Koruta, Kiplimo Wekesa, Daniel Kassam, Jillo Arero, Dennis Ombuna, Oswald Sangawe, Daniel Chepkwony, Festus Ojwang, Sarah Kasyoki for their logistical support during the census. Without your support, this mega-aerial census could not have been undertaken smoothly. Special thanks go to Julius Kimani (Assistant Director - Tsavo Conservation Area) for his words of wisdom during the aerial census planning and implementation phases. Our deepest appreciation is extended to all the members of Tsavo Conservation Area for their invaluable support during the census.

From other Conservation Areas, we thank the Assistant Directors from Southern, Central Rift, Western, Eastern, Mountain and Northern for releasing front seat observers, rear seat observers and data entry personnel to participate in the aerial census. Let this spirit continue during such mega-exercises in other conservation areas. We acknowledge the precious contribution of Lekishon Kenana, Fredrick Lala, Peter Mwangi, Daniel Muteti, David Kones, Christine Mwinzi, Geoffery Bundotich, Sospeter Kiambi, Stephene Ndambuki. By accepting to fly in Tsavo-Mkomazi ecosystem, you made us collect the data provided in this report. Without you, this data could not have been a reality.

The International Fund for Animal Welfare (IFAW) provided part of the finances used to make this aerial census a success. Special thanks go to James Isiche (IFAW Regional Director) for his valuable

support and advice during the planning and implementation of the census exercise. We also thank Elizabeth Wamba (IFAW, Communications), Isaac Peroh (IFAW Finance & Administration), and Alex Gombe (IFAW, Project Assistant) for their technical and logistical support during the aerial census. To all the IFAW staff, your effort and immense support during all the phases of this mega-census made the exercise a success. May you work tirelessly during other upcoming exercises as you did during the census.

We thank Dr. Iain Douglas-Hamilton, Judith Njuguna, Jerenimo Leperei, Bernard Lesowapir, Jake Wall, and Pilot Andrew Francobe of Save the Elephants for their technical support. To Dr Iain Douglas-Hamilton, your efforts to ensure that an aircraft and STE were available during the census are highly appreciated.

Lastly, other aircrafts were provided by Peter Zannetti of Mwalunganje Wildlife sanctuary and Sheldrick's Wildlife Trust (SWT). Your support is highly appreciated. To Richard Moller (SWT) and Peter Zannetti, we highly appreciate your flying throughout the aerial census.

ABSTRACT

This report updates the status and distribution of live and dead elephants as well as other large mammals in Tsavo-Mkomazi ecosystem. Data was acquired through aerial count undertaken between 7 and 12 February 2011 and review of past aerial count reports and publication. The count covered an area of approximately 48,319 km^2. The area was divided into 44 counting blocks with grids of 1km spacing. Each block was assigned to one aircraft with crew comprising of the pilot, front seat observer, and two rear seat observers in the case of four seater light aircraft and a pilot and an observer for two seat light aircraft. Total counts of elephants, elephant carcasses, buffaloes and other wildlife species was done including cattle and shoats. The distribution of logging sites, settlements, farms, fires, charcoal burning sites, mining areas, water pans and dams were also established during the count. The count lasted for about five days that involved about 252 hours of actual counting time, representing a mean search rate of approximately 191km^2 hr^{-1}.

During the count, handheld GPS units were used to store the species point data and aircraft flight lines. On landing, the stored data stored was downloaded onto desktop computers. ARCGIS 9.3 was used to prepare data summaries. The data summaries were exported and saved as excel spreadsheets in a desktop. The excel data were summarized according to species per block. The block summaries were added together to provide the estimated number of each species counted in the study area. This data was compared with data from past aerial counts to discern the species population trends. Species distribution and hot/cold spot maps were prepared using ARCGIS 9.3. The latter maps were prepared for elephants only as they indicate areas where large groups of elephants occurred. Standard deviation ellipse was used to discern the direction and mean centre of elephants' distribution. The Z-score statistic was used to guide conclusions regarding the species distribution.

A total of 12,573 elephants were counted. Most of these elephants (69%; n = 8,614 individuals) were found inside the protected areas whereas about 31% (n = 3,859 individuals) were counted outside the protected areas. About 50% (n = 6,214), 22% (n = 2,751) and 17% (n = 2,142) of the elephants were in Tsavo East National Park, the Taita Ranches and Tsavo West National Park respectively. Overall, the elephant estimate had increased by 2% since 2008 when the last total aerial count was conducted. A total of 567 carcasses were recorded during the February 2011 census, representing a 4.3% carcass ratio.

Between 2008 and 2011 buffalo increased from about 6514 to about 7402, an increase of about 12%. Most of the buffaloes were in groups ranging from two to about 300 animals. The ecosystem's giraffe population increased by 55% (n = 907 animals) from about 1,148 animals in 1999 to about 2,055 animals in 2011. However, compared with the number of giraffe in 2008, a population decline of about 19% (n = 395 animals) was recorded in three years. The population of common zebra decreased from about 8276 animals in 2008 to about 6726 animals in 2011, a decline of about 23% in three years. The species appeared to be thriving well in Tsavo West National Park, which accommodated about 33% (n = 2,248) and 31% (n = 2,532) of the common zebra counted in the Tsavo-Mkomazi ecosystem in 2011 and 2008 respectively.

During the 2011 Tsavo-Mkomazi census, 38 wild dogs were counted, 66% (n = 25) of which were recorded in Tsavo West National Park. Taita, Mkomazi and northern parts of Tsavo East National Park had 8, 4 and 1 wild dogs respectively. About 11 Hirolas in four different groups were recorded in the southern parts of Tsavo East, around Satao area. Grevy zebra were recorded slightly outside the boundary of southern part of Tsavo East National Park and also slightly to the north of Galana

River in Tsavo East National Park. The Tsavo-Mkomazi ecosystem supported about 281 lesser kudu in early February 2011 with the highest densities recorded in the Taita ranches followed by Tsavo West National Park and northern parts of Tsavo East National Park respectively.

Illegal activities in the area included livestock grazing in the protected areas, logging, charcoal burning, poachers' hideouts, and snares. In 2011, large cattle herds were found in Chyulu West at Njukini, which lies along the south west boarder of the Tsavo West National park, Taita ranches, southernmost tip of Tsavo West National Park and in Mkomazi Natonal Park. Cattle and shoats were recorded inside Tsavo East National Park just south of Tiva River, South Kitui National reserve, and the southern parts of Tsavo West National Park. Charcoal burning and logging were recorded outside the protected areas except South Kitui National Reserve.

We can conclude that in the last three years, the number of elephants in Tsavo-Mkomazi ecosystem increased at a declining rate of about 2%. The number of buffalo in Tsavo West National Park showed a drastic decline. The reasons for this decline are not so far well understood. Further studies are needed to understand this buffalo population. Logging and charcoal burning continue to encroach into wildlife habitats in the Northern parts of Tsavo East National Park. If this is left unchecked, most of wildlife habitat in these areas will continue to be destroyed. Livestock incursions into the protected areas, especially South Kitui National Reserve, Southern parts of Tsavo West National Park, are a threat to the Tsavo-Mkomazi ecosystem. As such, the following is recommended: (i) the existing water pans in the protected areas within the ecosystem need to be de-silted to be able to accumulate water throughout the year. These are to be distributed at a distance of not less that 10km from each other. In addition new water pans and dams needs to be established in the northern parts of Tsavo east national park. These areas have little water resources for wildlife; (ii) to control human encroachment in the northern parts of Tsavo East National Park and South Kitui National Reserve, a 150km electric fence needs to be constructed along the boundary of south Kitui national reserve, from Umbi to about 10km along the eastern boundary of Tsavo East; and, (iii) to control livestock encroachment in the southern parts of Tsavo East and West National Parks and other illegal activities in the ecosystem, the KWS top management (ECOM and board) needs to deliberate on the options provided above and adopt one of the options for implementation.

1.0 GENERAL BACKGROUND

The Tsavo ecosystem is home to Kenya's largest elephant population (Blanc *et al.*, 2007). The elephant population was over 35,000 animals by the end of 1974 (Cobb, 1976) and about 11,733 in 2008 (Omondi *et al.*, 2008). This February 2011 dry season census was conducted one year after the severe drought of 2009 to early 2010 when it was feared that many elephants (*Loxodonta africana*) had succumbed much like happened during the unusually dry conditions in 1970 and 1971 led to elephant mortality of unanticipated magnitude; about 6,000 elephants died in the eastern sector of Tsavo National Park (Corfield, 1973; Cobb, 1976).

The ecosystem has been a subject of detailed sample and total aerial counts since the early 1960's. Recent total counts include Olindo *et al.* (1988), Douglas-Hamilton *et al.* (1994), Kahumbu *et al.* (1999), Omondi *et al.* (2002), Omondi & Bitok (2005) and Omondi *et al.* (2008). Past sample counts include those by Cobb (1976); Leuthold (1976); WCMD (1976); IUCN (1978), and Inamdar (1996). Both the sample and total counts in the 1970s showed remarkably high numbers of elephants, though sample counts appear to have overestimated the numbers by a wide margin; almost twice the total count figures.

The 1988 counts showed a 75% decline in elephant numbers within the protected areas and a further 87% in the adjacent non-protected areas since the 1972 total counts (Olindo *et al.*, 1988). Two major factors are likely to have contributed to this decline: reductions in the carrying capacity of Africa for elephants, resulting from habitat change, and hunting for ivory (Milner-Gulland & Beddington, 1993). Since 1988, there has been a steady increase in elephant numbers in the Tsavos, up from the steep decline in the late 1970s and early 1980s (Kahumbu *et al.*, 1999). The 1988 distribution of recent carcasses confirmed heavy poaching was still rampant especially on the periphery of the parks, and the older carcasses confirmed that poaching took place in the heart of the reserves in the earlier 1980s (Olindo *et al.*, 1988). The distribution of elephants in 1989 confirmed that elephants previously counted along the periphery had moved further inside the parks (Douglas-Hamilton *et al.*, 1994). The proportion of 'recent' carcasses however did not change significantly confirming illegal killing was still taking place through 1988 when the 'recent' carcass ratio peaked at 6.69% (Olindo *et al.*, 1988; Douglas-Hamilton *et al.*, 1994). Despite this, the 1989 count was the first authoritative confirmation that the elephant population was on a recovery course, a trend observed till 2008 (Douglas-Hamilton *et al.*, 1994).

The year 2002 wet season survey was undertaken as part of Kenya Wildlife Service (KWS) and Monitoring of Illegal Killing of Elephants' (MIKE) joint initiatives to establish the status of Tsavo's Elephant population and provide baseline data on poaching. The count revealed that the Tsavo population had increased by 5% since 1999 (8068 to 9284; Kahumbu *et al*., 1999). Fifty percent (n=10) of the recent carcasses were spotted in Galana where poaching pressure was high in the 70's and 80's. The figure could have been an under estimate as the thick vegetation may have obscured some carcasses. The census noted a remarkable increase in livestock in the protected areas from 820 in 1999 to 5190 in 2002.

It is important to caution against direct comparisons of results of past aerial counts due to different methodologies, counting effort, and climatic conditions between the years (Douglas-Hamilton *et al.*, 1994). For instance, this possibly explains the big discrepancies observed between sample and total counts in the 1970's. Over the years, elephant densities varied considerably both across in blocks and through time from as low as 0.002 elephants km^{-2} in Galana to as high as 0.921 elephants km^{-2} in

Tsavo East South (Douglas-Hamilton *et al.* (1994), Kahumbu *et al.* (1999), Omondi *et al.*, (2002), Omondi & Bitok (2005) and Omondi *et al.* (2008). Surface water availability and security is believed to be the major factor influencing elephant distribution. In 2002, a dramatic shift in elephant distribution was observed between Tsavo East North and South, as the former had received more rainfall prior to the count (Omondi *et al.*, (2002). Understanding of these ecosystem use dynamics by elephants and other large mammals is important in their management.

Therefore, it is important to continue with the tri-annual aerial census of elephants and other mammals in Tsavo-Mkomazi ecosystem. The information generated will show distribution of human and livestock encroachment into the protected areas as well as population sizes of different species of large mammals in the ecosystem. This information will be used by park managers and policy makers to make management decisions regarding the management of emerging trends of wildlife populations as well as resolving human and livestock encroachments into the protected areas therein.

2. OBJECTIVES OF THE SURVEY

The goal of the aerial survey was to sustain the long term aerial monitoring of elephants and other large mammals in Tsavo-Mkomazi ecosystem. This consistent monitoring programme began in early 1999 and has been closely and accurately monitoring the status and trends of elephants and other large mammals since then.

The specific objectives of the aerial survey were:

i. To establish the current elephant and other large mammals population size and distribution and compare these results with the results of past aerial counts.
ii. To determine the number and distribution of elephant carcasses.
iii. To understand the distribution of elephants and other large mammals in relation to distribution of water sources.
iv. To map human activities inside and outside the protected areas (e.g., logging, settlements, farming, fires and charcoal burning).
v. To document the distribution and numbers of livestock in relation to elephants and other large mammals in the ecosystem.

3. STUDY AREA

3.1 Location and area

The Tsavo-Mkomazi ecosystem, in East Africa, is an area of about 48,319 km^2 that occupies the lowland savanna (Cobb, 1976). The ecosystem occurs between 2° - 4° S, and 37.5 - 39.5° E. Forty two percent of the ecosystem comprises of the Tsavo East, Tsavo West, and Chyulu National Parks, with the rest consisting of the private ranches and Mkomazi National Park. Created in 1948, the national parks drew international attention in the 1960s because of its 'elephant problem', when large populations of elephants converted over 12,000 km^2 of woodlands and shrub lands into open savannas and grasslands (Napier-Bax & Sheldrick 1963). Mount Kilimanjaro, Pare and part of Usambara ranges mark the South western boundary of this ecosystem. Galana ranch marks the extreme north eastern end. In the heart of the ecosystem lie the Taita hills (Figure 1).

3.2 Rainfall

Mean annual rainfall varies locally between 250 and 500 mm (Leuthold, 1978). Most of it falls in two rainy seasons, in March-May and November-December, but its spatial and temporal distribution is highly irregular (Tyrrell & Coe, 1974). June through October constitutes a long, though relatively cool, dry season which, exacerbated by desiccating winds, is the main period of nutritional stress for herbivores (Leuthold, 1978). During the March-May rainy season, the highest rainfall is received between Taita Hills and Kilimanjaro area, whereas in November-December rainy season, the highest rainfall is recorded to the north and eastern parts and extends beyond the National parks (Tyrrell & Coe, 1974). These two seasons are separated by two dry seasons.

3.2. Geology and Soils

The terrain of Tsavo ecosystem is generally flat and undulating in the south-eastern and northern sections interrupted by granitic hills and inselbergs like Irima, Voi, Mzinga, Maunga and Mudanda rock and other hills of Taita-Taveta that rise above the ground level (Mukeka, 2010). Generally the area lies about 300m-500m above sea level (Mukeka, 2010). Most of this area comprises of rolling peneplain of low relief (Mukeka, 2010). The configuration is strongly influenced by the underlying geology, deviations from a flat surface being an expression of contrasting resistances to erosion of the sandstones, shale's and hard metamorphic rocks(Mukeka, 2010). Towards the north, the plain is eroded to a level of 200-250m by the perennial Galana River, which runs in front of the Yatta plateau, an extensive phenolithic lava flow which forms the most significant landmark of the northern part of Tsavo East National Park (Ayeni, 1974; Mukeka, 2010) .

The soils of the Tsavo Ecosystem show a wide range in depth, colour, drainage condition, structure and chemical and physical properties (Ayeni, 1974; Mukeka, 2010). Extreme differences in texture are not common. The general pattern of the soils is largely determined by the parent material and physiography (Wijgaarden, 1985; Ayeni, 1974). The red sandy soils derived from the basement system and Duruma sandstones are very extensive in Tsavo East National Park (Ayeni, 1974). They are shallow in the Galana, platforms and narrow ridges and are deepest at the base of hills like Irima and the foot of the Yatta plateau (Ayeni, 1974; Mukeka, 2010). The soils are rich in quartz and ferruginous gravel with finer sand cemented by a red lateritic crust (Ayeni, 1974; Wijgaarden, 1985).

Grey acid soils in the form of dark heavy clays accumulate in the flat poorly drained plains and valley bottoms in the central and eastern parts of the park (Ayeni, 1974; Mukeka, 2010). Sands and gravel of the alluvial soils are cross-bedded together along the river loops of the Galana (Ayeni, 1974). These soils are saline as indicated by the saline adapted plants found growing in these areas (Wijgaarden, 1985). Surfaces of the Yatta plateau have shallow soils (Ayeni, 1974; Mukeka, 2010). Other soils like the lateritic ironstones occur in small patches in many parts of the park especially around the foot of the basement system hills while alluvial soils can be found in lower Tiva spreading over distances of one kilometer in the floodplain (Ayeni, 1974; Mukeka, 2010).

3.3 Habitat

The vegetation consists of remnants of formerly extensive *Commiphora-Acacia* woodlands that have been destroyed or at least thinned out by elephants (Cobb, 1976). Densities of trees and shrubs are generally lowest near rivers, except for local patches of riverine forest or fringes of trees along water courses. The preferred habitats of the African elephant are forest edge, woodland, bushland and

wooded or bushed grassland (Laws, 1970). Large portions of the originally dense woodlands, dominated by *Commiphora* and *Acacia* spp., in Tsavo National Park were transformed into more open vegetation types primarily by elephants through destruction of trees and excessive utilization of woody regeneration (Napier-Bax & Sheldrick, 1963; Laws, 1969; Laws, 1970; Yyrrell & Coe, 1974).

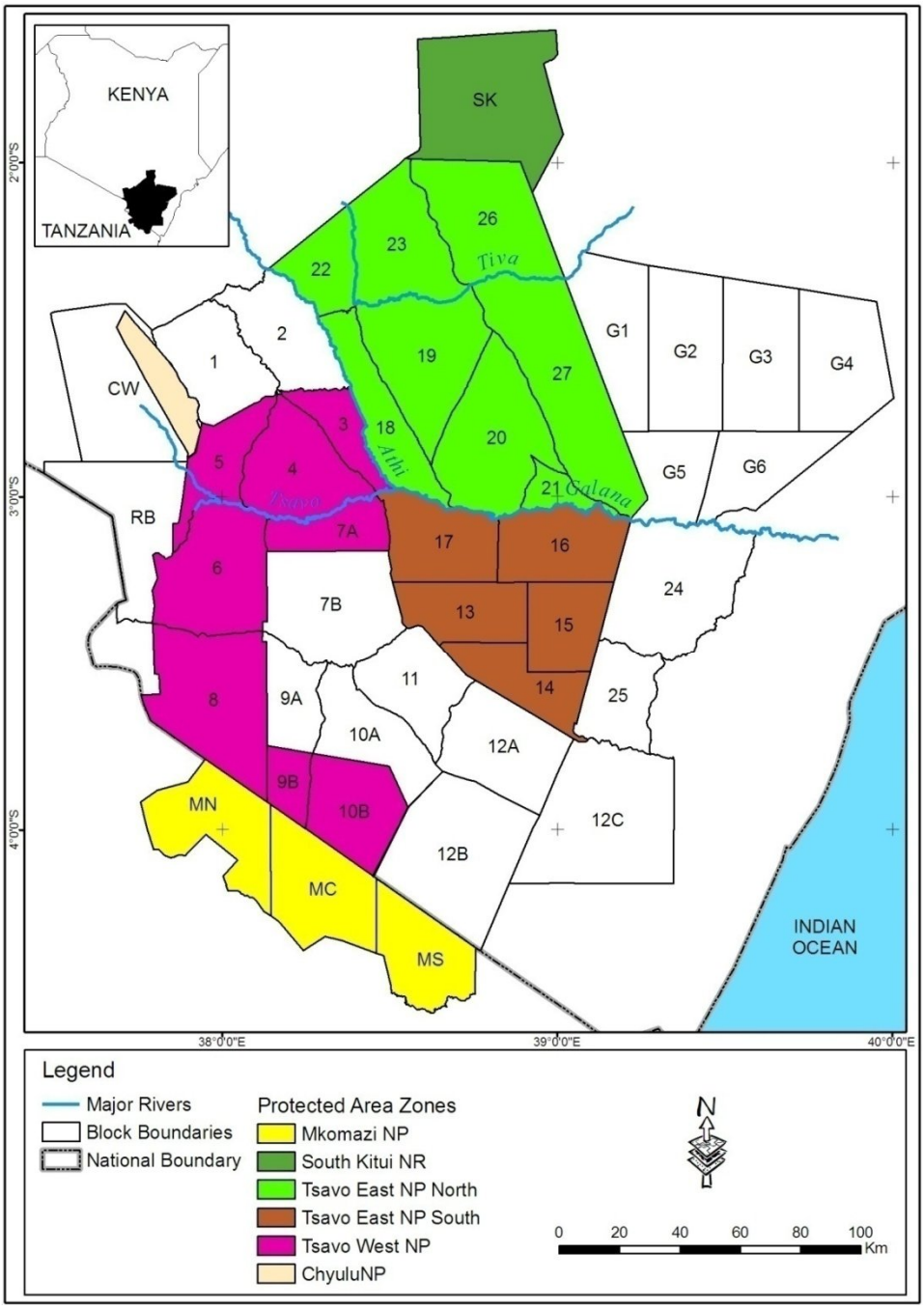


Figure 1: A map showing the counting blocks used during the 7-12 February 2011 aerial count of elephants and other large mammals in the Tsavo-Mkomazi Ecosystem

3.4 Flora

The dominant vegetation is dominated by a mixture of the perennial grasses *Digitaria macroblephara*, *Chloris roxburghiana*, and *Bothriochloa radicans* and the annual legumes *Tephrosia subtriflora* and *Tephrosia villosa* (Belsky *et al.* 1987). The tree component includes *Acacia tortilis*, *Adansonia digitata*, *Delonix elata* and *Melia volkensii* surrounded with distinct patches of under storey species. The grasslands are dominated by the perennial grasses *Cenchris ciliaris*, *C. roxburghiana*, *Digitaria macroblephara* and *Eragrostis caespitosa*. Herbaceous-layer vegetation under tree canopies is dominated by the stoloniferous perennial grass *Cynoden nlemfuen* and *Panicum maximum*. These under storey species, along with *Aneilema johnstonii*, *Coccinia microphylla*, and *Commelina benghalensis*, are replaced at or near the edge of the canopy zone by a more species-rich mixture dominated by *Bothriochloa radicans*, *Chloris roxburghiana*, *Digitaria macroblephara*, and *Eragrostis caespitosa*, among other species. The under storey species also occur away from the trees in association with small shrubs but at lower cover values. Other frequent species (> 5% cover) in the open grasslands include the dicots, *Cassia mimosoides*, *Commelina africana*, *Portulaca oleraceae*, *Solanum incanum*, *Momordica boivinii*, *Heliotropium steudneri*, *Ipomoea obscura* and *Hibiscus micranthus*, and the grasses *Cenchris ciliaris*, *Microchloa kunthii*, *Sporobolus pellucidus*, *Aristida adscensionis*, and *Sporobolus fimbriat* (Belsky *et al.*, 1989).

3.5 Fauna

The major herbivores are elephant (*Loxodonta africana*), African buffalo (*Syncerus caffer*), eland (*Taurotragus oryx pattersonianus*), fringe-eared oryx (*Oryx beisa callotis*), coke's hartebeest (*Acelaphus buselaphus cokii*), burchell's zebra (*Equus burchelli*), impala (*Aepyceros melapus*), giraffe (*giraffe camelopadalis)*, and Grant's gazelle (*Gazella grantii; Cobb*, 1976).

4. METHODS

4.1. Census Blocks design

The aerial count followed the method described by Douglas-Hamilton (1996). Forty four counting blocks, as designed for previous censuses, were adopted for ease of comparing findings. Flight lines, mostly of one kilometer spacing, were designed with the intention of ensuring that all elephant herds and large mammals were sighted and counted (Figure 2). The blocks are defined mostly by recognizable features like roads, rivers, hills and protected area boundaries except for the Voi triangle and blocks 13-17. The blocks were of suitable sizes that could be flown in a day by one or two teams. The average block size was 1098 (SE = ±445 km²; N = 44). The smallest and largest block were about 248 km² (block 21) and 2008 km² (block 12C) respectively (See Appendix 2). In the larger blocks more than one team were deployed to ensure counting was completed within a day in every block.

4.2. Aircraft and crew

Nine fixed wing aircrafts (Cessnas and Huskys) with high wings to give an unobstructed ground view were used on the six day event. The crew comprised of a pilot, one front seat observer (FSO) and in case of four seater aircraft two rear seat observers (RSOs) as well. Flight maps of assigned blocks were provided to each team in the evening to allow each crew plan for the next day. A Geographical Positioning System (GPS) was used for navigation, recording of waypoints and flight

paths. The GPS units were set to Universal Transverse Mercator (UTM) kilometer grids on both north and south axis. The teams took off at dawn ensuring that counting started before the day got hot. Parallel lines whose interval was determined by the front observer and the pilot based on terrain and visibility were flown. Fuel was strategically distributed in the various airstrips in the ecosystem for convenience of refueling from blocks distant from the counting center. In a few blocks, the topography influenced the flight paths as rugged terrain was avoided.

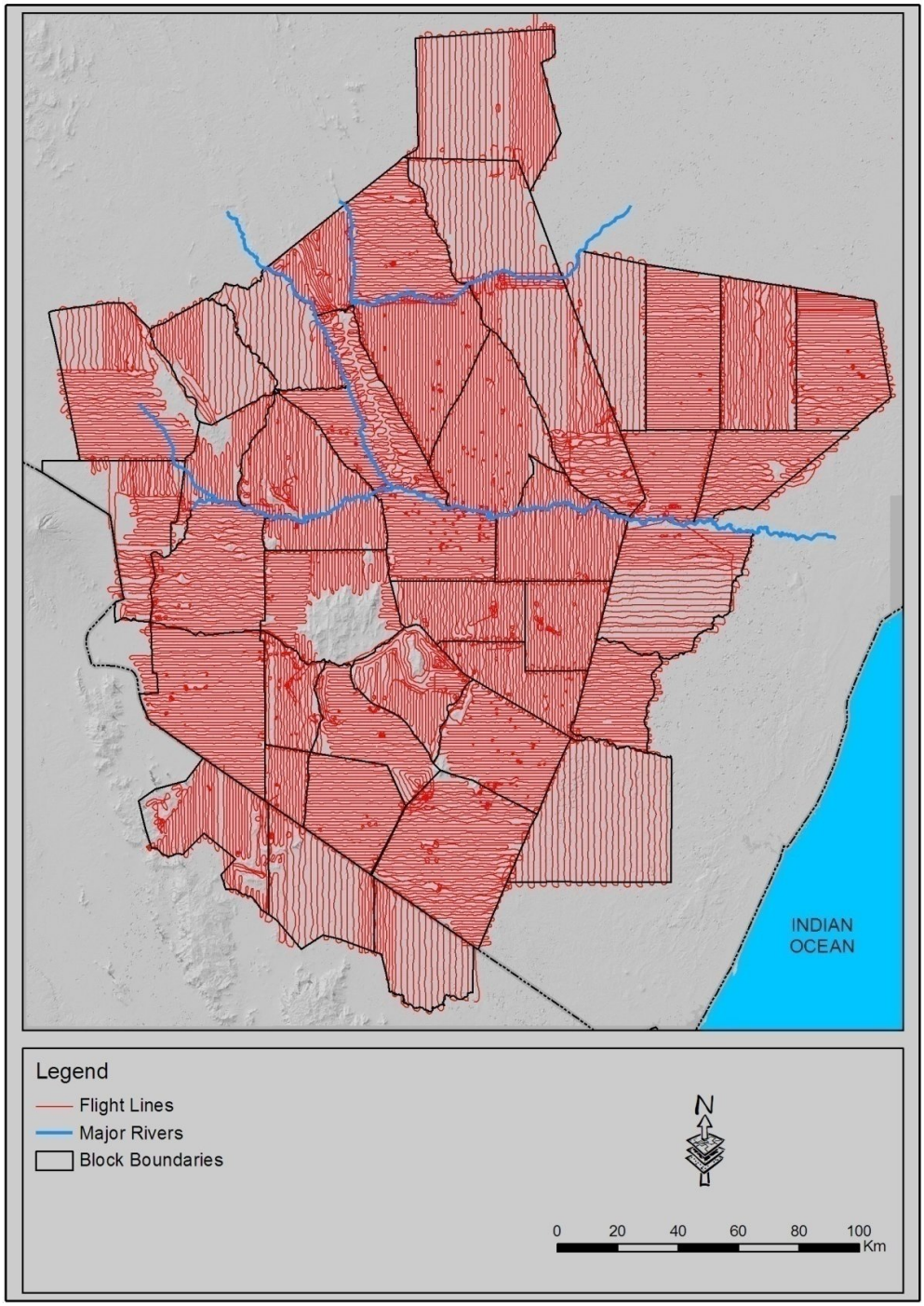


Figure 2: A map showing the flight lines used during the 7-12 February 2011 Tsavo-Mkomazi aerial count.

4.3. Data recording and cleaning

The aerial census took place from 7th to 12th February 2010. Most of the crew members were highly experienced. Test flights were conducted a day before the actual counting commenced to familiarize and/or refresh the crew. Speeds of approximately 130-180 km/hr and heights of about 200-400 feet above ground level were maintained. Blocks separated by rivers were counted simultaneously to minimize double count or omission due to elephants crossing the river. Pilots flew overlaps of approximately 1-2km into the adjacent blocks to ensure that herds moving into the block were not missed by either team. Both dead and live elephants were counted. Where large herds were encountered, the pilots circled to give observers ample time to count. Elephant carcasses were classified as 'fresh', 'recent', 'old' or 'very old', as described by Douglas-Hamilton and Hillman (1981). For analyses, the first and second categories were pooled as "Recent", third and fourth were pooled as "Old". In addition to elephants, estimates of livestock and other large mammal species were made and recorded. Standard codes were used to denote various species (See Appendix 3). FSOs cleaned the data sheets when necessary before handing to the data entry team. Waypoints and tracks were downloaded on to ArcGIS 9.3. The tabulated species data was added onto the ArcGIS software and a spatial join created based on the way point. The file was converted into a shape file for each block. Duplicates in the zones of overlap of adjacent blocks were identified and corrected before merging all datasets into one dataset.

4.4. Data analysis

For regression analysis, data was pooled for areas that were consistently surveyed from 1988 to 2011. These areas included Tsavo East (North), Tsavo East (South), Tsavo West, Mkomazi National Park, Galana, and Taita Ranches. The regression analysis followed the procedures described by Zar (1996). Fourth order polynomial analysis was used to get the line of best fit during the regression analysis (Zar, 1996).

The orientation of the geographic distribution and the centre of the elephant concentration were analyzed for elephants only using the standard deviational ellipse and mean centre (ESRI, 1997; Mitchell, 2009). General distribution patterns (random, dispersed or clustered) and distribution of herd sizes were analyzed for elephants, buffalo, giraffe and zebra. We tested for the general distribution patterns of the four species using the Getis-Ord general G statistic as described by Mitchell (2009). The distribution of different herd sizes were mapped using the Hot-Spot analysis (Getis-Ord Gi* statistic) and implemented using ArcGIS 9.3 (ESRI, 2007; Mitchell, 2009). The results were interpreted as described by Mitchell (2009). The *Z-score* statistics were used to aid interpretation of results as outlined by Mitchell (2009).

To analyze the relationship between elephants distribution and water pans (dry and wet) and rivers, a kernel density of the elephant was created as described by Mitchell (2009) using a search radius of 24 km. A simple density surface for water pans (dry and wet) and distance surface for rivers were created as described by Mitchell (2009). Using spatial analyst tool in ArcGIS 9.3, the raster cell values of the respective surfaces were extracted onto the elephant count point shape-file (ESRI, 2006). Then, the extracted values were exported into Ms-excel spreadsheet to obtain a set of elephant density data against distance to water pans and rivers. A simple correlation analysis was performed using this data as described by Zar (1996). The strength of the correlations was interpreted following guidelines described by Fowler *et al.* (1998).

The proportion of recent to old was calculated as in index of the previous year's mortality, noting that 2009 to early 2010 was marked by a severe drought. In addition to elephants, estimates of other large mammal species and livestock were made and recorded. Standard codes were used to denote various species (See appendix 3). FSOs cleaned the data sheets when necessary before handing them over to the data entry team.

5. RESULTS

5.1 Census effort, status and trends of elephants

The entire count lasted for five and halve days, comprising approximately 252 hours of actual counting time. This represents a mean search rate of 191km^2 per hour in a counting area of about 48,319 km^2. The ecosystem supports about 12,573 representing a modest increase of about 2% in the last three years (Table 1). About 69% (n = 8,614) and 31% (n = 3,859) of the elephants were counted inside and outside the parks, whereas about 50% (n = 6,214), 22% (n = 2,751) and 17% (n = 2,142) of the elephants were in Tsavo East National Park, the Taita Ranches and Tsavo West National Parks respectively (Table 1).The number of elephants increased from about 6,399 in 1988 to about 12,573 in 2011, representing about 96% increase in thirteen years. A fourth order polynomial regression analysis on trend of elephant numbers from 1988 to 2011 showed an increase in elephant population during the period (R^2 = 0.99; n = 9; Figure 3).

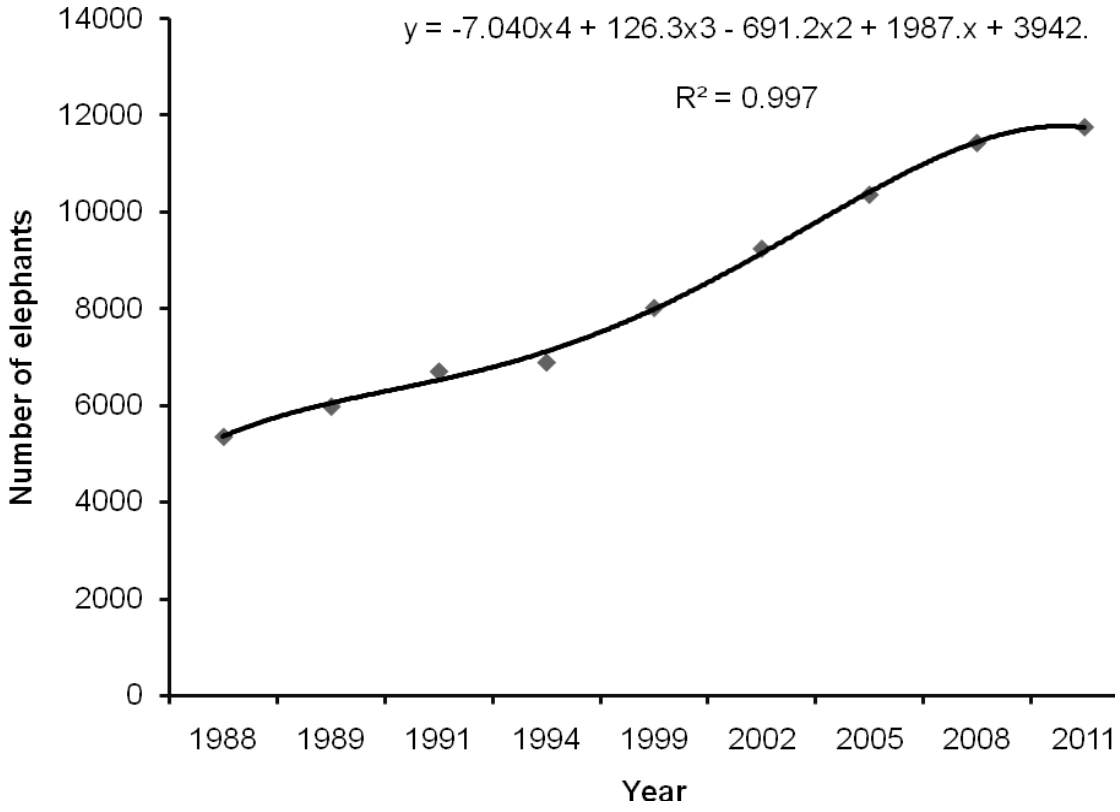


Figure 3: Total count estimates of Tsavo-Mkomazi elephants from 1988 to 2011.

Table 1: Number of elephants counted in Tsavo-Mkomazi ecosystem from 1962-2011

	Years															
	2011	2008	2005	2002	1999	1994	1991	1989	1988	1978*	1973	1972	1970*	1969*	1965*	1962
Tsavo East (N)	2094	4118	2499	4089	1337	399	450	134	770	220	9011	6435	0	6619	8,056	4,073
Tsavo East (S)	4120	3731	3896	2087	3221	2733	3436	3020	2283	2469	3955	6633	6008	5709	4,744	1358
Tsavo West	2142	2161	2626	2168	2119	3132	1233	2106	1274	1938	9208	4328	6592	8134	2,238	1394
Chyulu NP	135	131	-	-	-	-	-	-	-	-	-	-	-	-		-
South Kitui NR	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
Mkomazi NP	256	8	41	63	77	302	131	11	93	667		2067	-	-	-	-
Galana	398	308	11	14	27	46	50	74	90	1076	500	4379	-	2964	-	3540
Taita	2751	1108	1292	828	1245	287	1413	642	853	79	-	1235	-	500	-	-
Rombo	0	0	31	2	12	446	-	193	-	-	-	-	-	-	-	-
Other blocks	509	130	1	35	30	26	50	46	-	-	-	300	100	-	-	-
Outside	168	38	1376		1391	1107	1644	966	1036	-	-	-	-	-	-	-
Total (parks)	8614	10149	9062	8344	6754	6566	5250	5271	4420	5294	22174	19463	12600	20462	15038	6825
Total (non parks)	3959	1584	2680	940	2693	1466	3157	1728	1979	1155	500	5914	100	3464	-	3540
Total	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 2011, 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).

.

5.2 The distribution and density of elephants

As in the other past counts, majority of the elephant herds were counted in Tsavo East National Park, within about 45km north and south of Galana River (Figure 4). High densities were recorded in the southern sector of Tsavo East National Park (Figure 5).

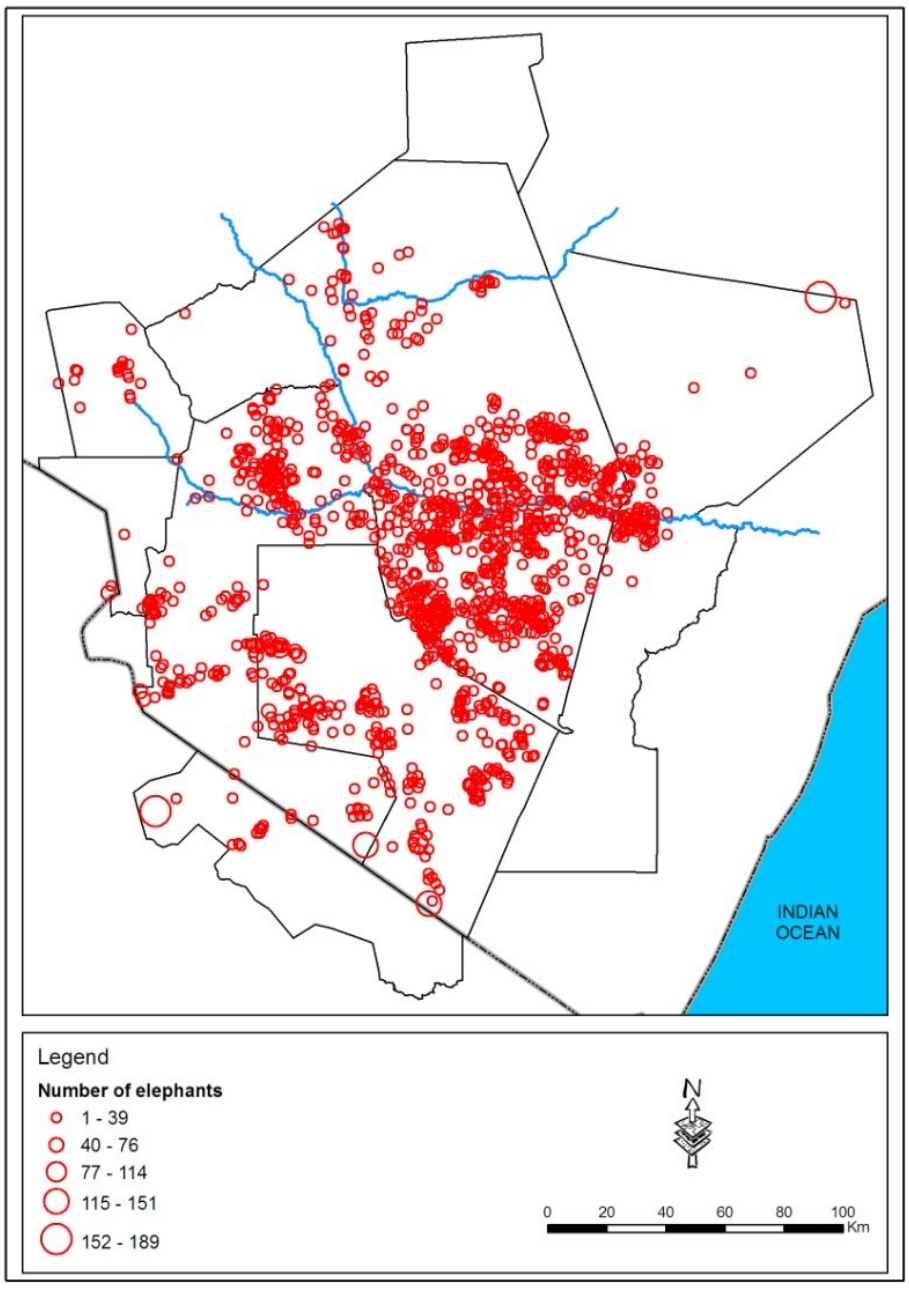


Figure 4: Map showing the distribution of different herds of elephants in Tsavo-Mkomazi Ecosystem. No elephants were counted in South Kitui National Reserve.

The elephants exhibited a highly clustered distribution (Z score = 5.36; P = 0.01; Critical value = 2.58. The mean centre of the distribution was within the Ndara plains in Tsavo East National Park, South of Galana River (Figure 6). The elephants occurred as individuals or in groups with herd sizes ranging from two (2) to one eight nine (189) with a mean herd size of 9 ±12 elephants. The larger herds of elephants were found in the Taita Ranches, southern parts of Tsavo West National Park (Njukini and Jipe area) and north Mkomazi National Park (Figure 7). The smallest herds of elephants were counted north of Galana River in Tsavo East National Park (5B). High densities of elephants occurred close to wet water pans whereas low densities were recorded near dry water pans (wet water pans: r = 0.90; n = 1,408; P < 0.05; dry water pans: r = 0.19; n = 1,408; P < 0.05; Figure 8). There was a weak negative relationship between elephant density and distance to water pans (r = 0.37; n = 1408; P < 0.05).

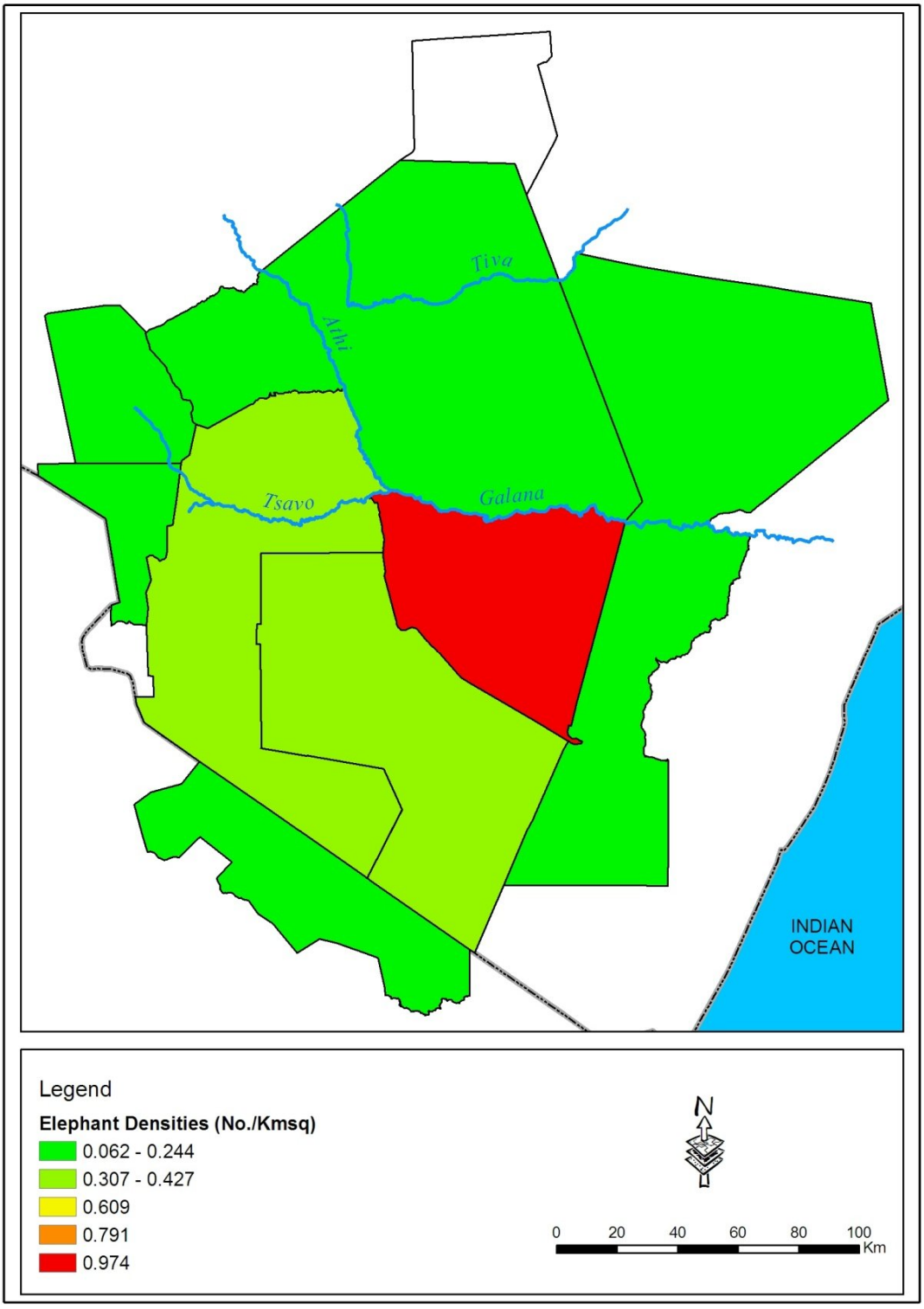


Figure 5: The density of elephants in Tsavo-Mkomazi Ecosystem (7-12 February 2011). High densities of about 1 elephant per km^{-2} were recorded in the Tsavo East National Park (South of Galana River)

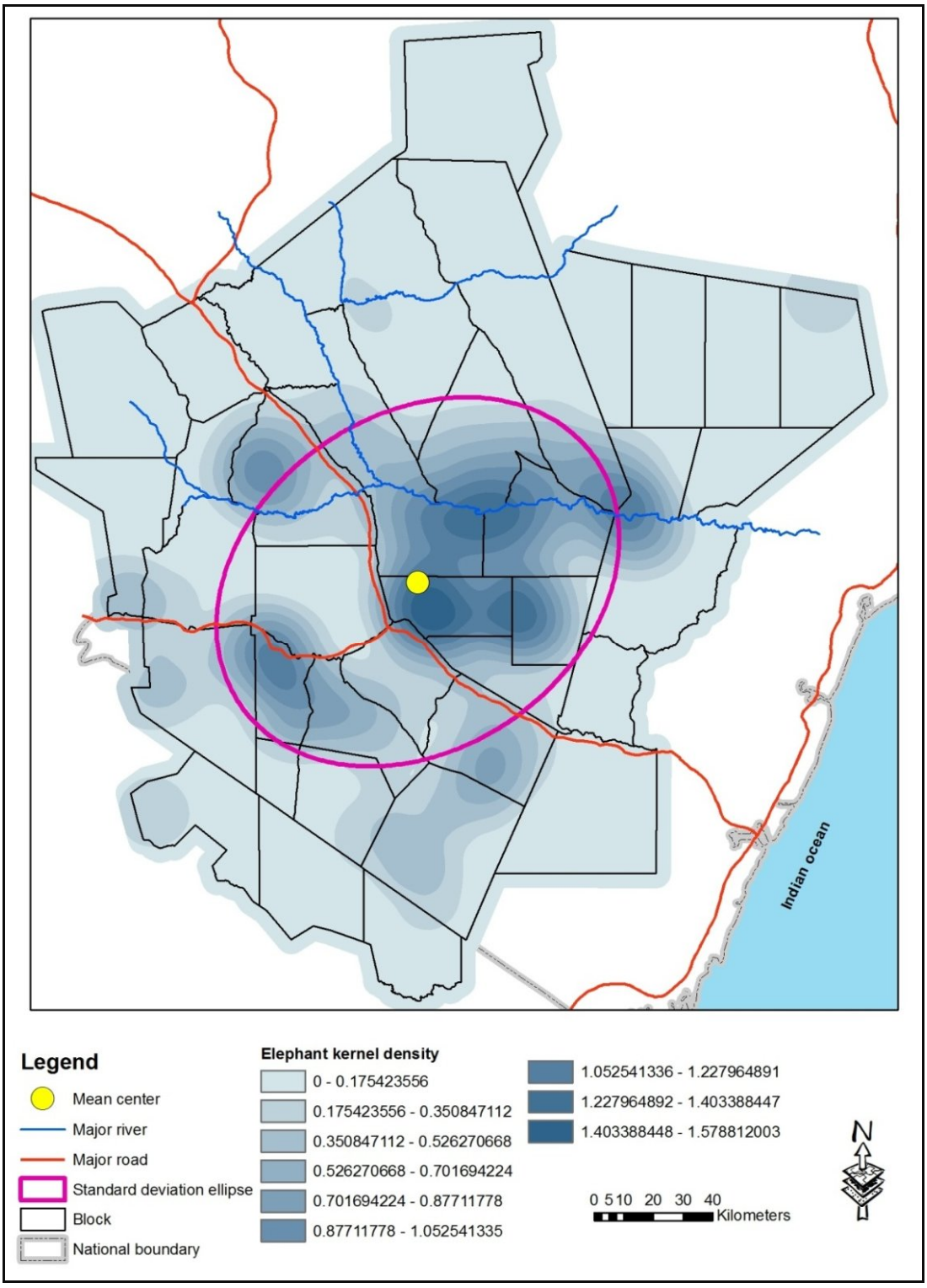


Figure 6: The kernel density of elephants in Tsavo-Mkomazi Ecosystem, mean centre and standard deviational ellipses based on data collected from 7-12 February 2011

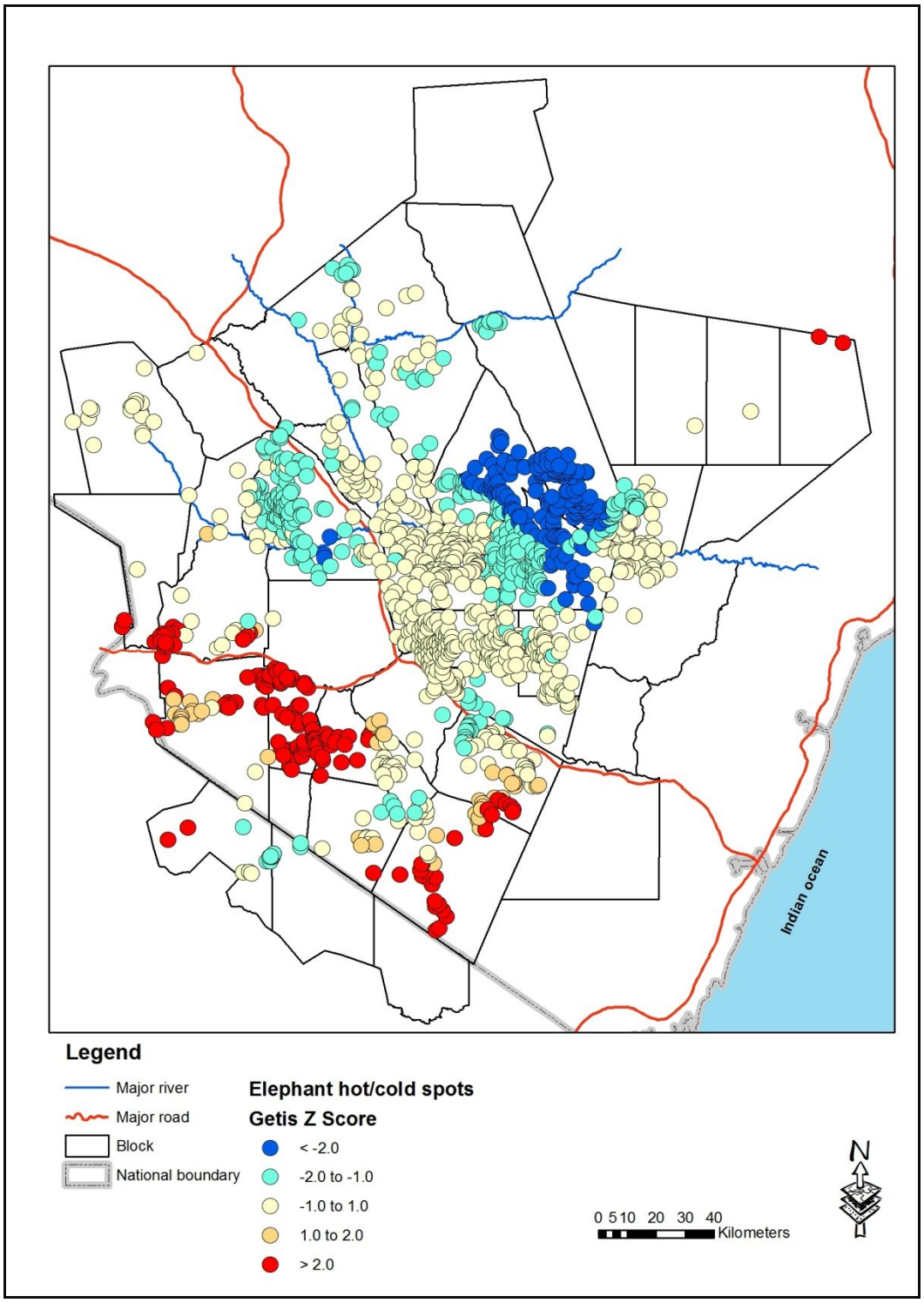


Figure 7: A hot-spot analysis of the locations with different sizes of elephant herds in the Tsavo-Mkomazi ecosystem. Large herds of elephants (>2.0 animals) were recorded in the Taita Ranches, northern parts Mkomazi National Park and southern parts of Tsavo West National Park

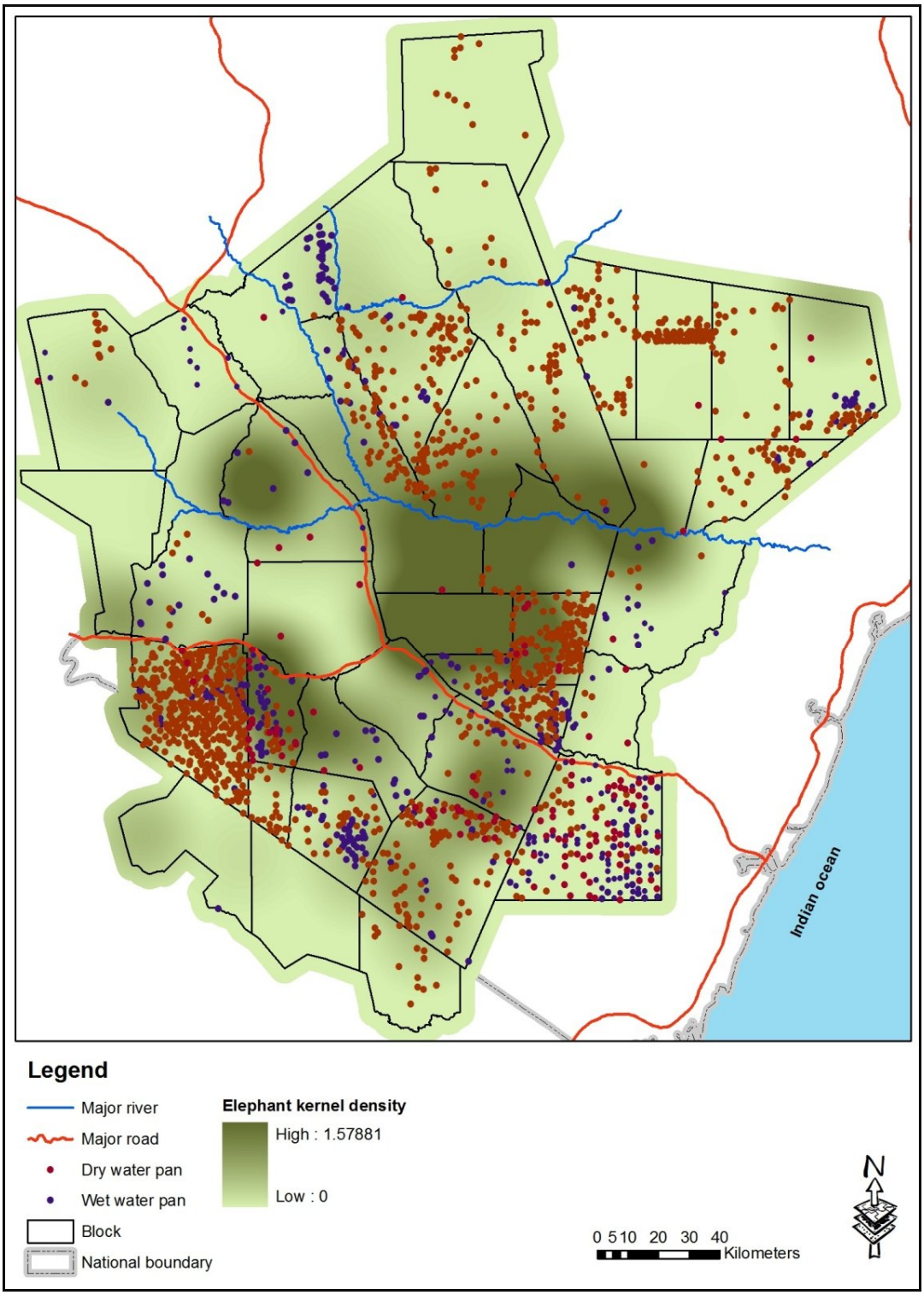


Figure 8: The density of elephants against the distribution of dry and wet water pans in Tsavo-Mkomazi ecosystem (early February 2011)

5.3 Elephant carcasses and carcass ratio

A total of 567 carcasses were recorded during the February 2011 census. Table 2 below provides a summary of the number of elephant carcasses counted during the aerial census including the carcass ratio. Recent carcasses in 2011 were forty eight whereas in 2008 they were only eight, which represents an increase of about 600%. The carcass ratio also increased from 0.6% in 2008 to 4.3% in 2011. High carcass density (about 0.031-0.037km^2) were recorded in Tsavo East National Park, South of Galana River (Figure 9), whereas modest (about 0.02km^2) and lowest (0.001-0.008km^2) carcass densities were recorded in Tsavo East National Park, North of Galana River and Tsavo West National Parks; and, the rest of the remaining areas (Figure 9). Figure 10 provides a summary of the general distribution of the elephant carcasses according to age classes in the Tsavo-Mkomazi ecosystem.

Table 2: Number of elephants and elephant carcasses counted in Tsavo-Mkomazi ecosystem from 1988 to 2011. Old carcasses are calculated by subtracting total dead from recent dead. The old carcasses include very old and old carcasses whereas recent cases include fresh and recent carcasses

Year	Elephants	Recent dead	Total dead	Carcass Ratio (dead / dead plus live)	Standard Natural Mortality @ 4%	Carcass Ratio Recent
1988	5,363	162	2,421	31.1%	215	2.9%
1989	6,033	115	1,752	22.5%	241	1.9%
1991	6,763	4	1,210	15.2%	271	0.1%
1994	7,371	1	1,362	15.6%	295	0.0%
1999	8,068	6	427	5.0%	323	0.1%
2002	9,284	14	302	3.2%	371	0.2%
2005	10,397	6	138	1.3%	416	0.1%
2008	11,696	4	68	0.6%	468	0.0%
2011	12,573	48	567	4.3%	497	0.4%

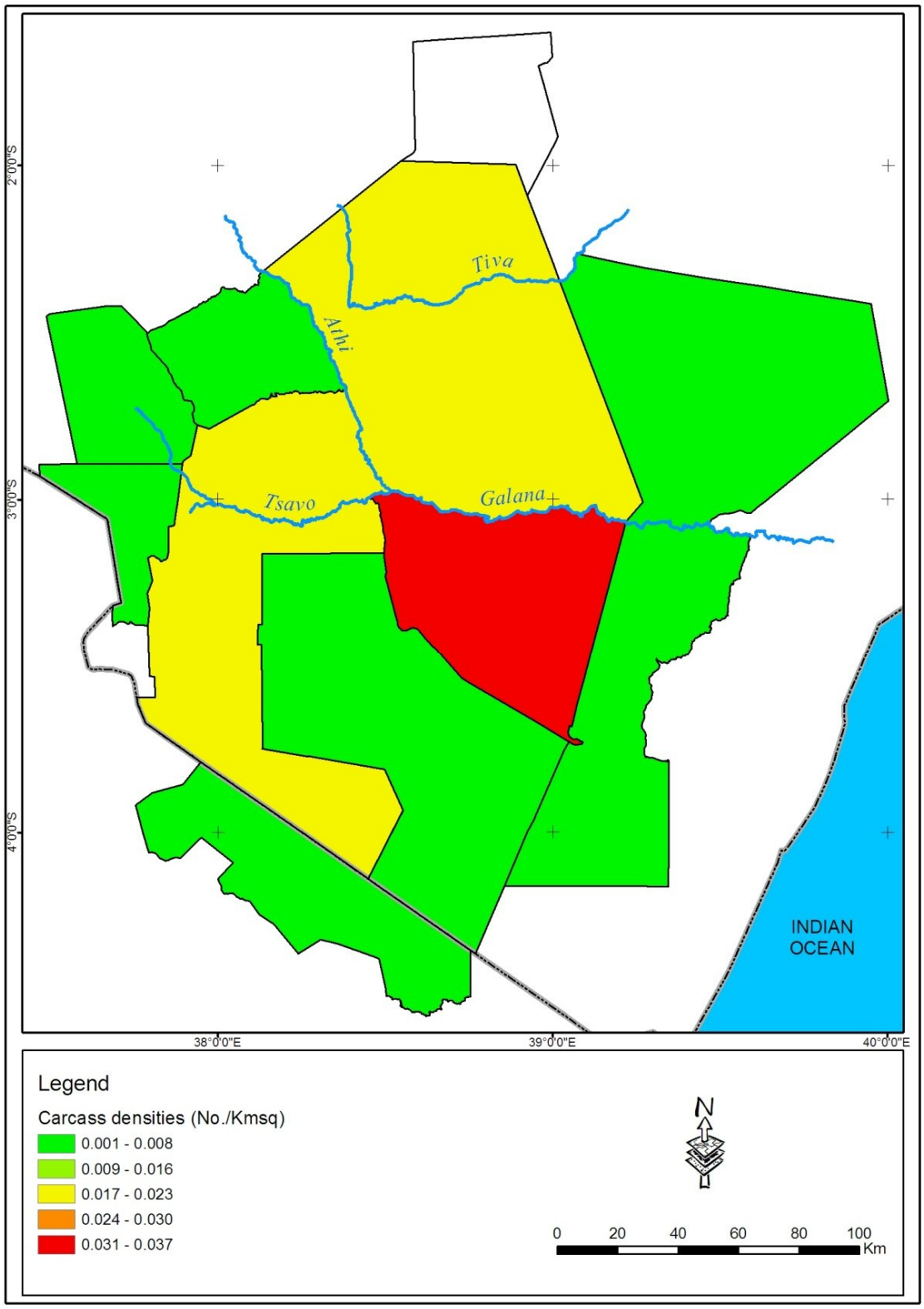


Figure 5: The density of elephant carcasses in Tsavo-Mkomazi ecosystem (Early February 2011)

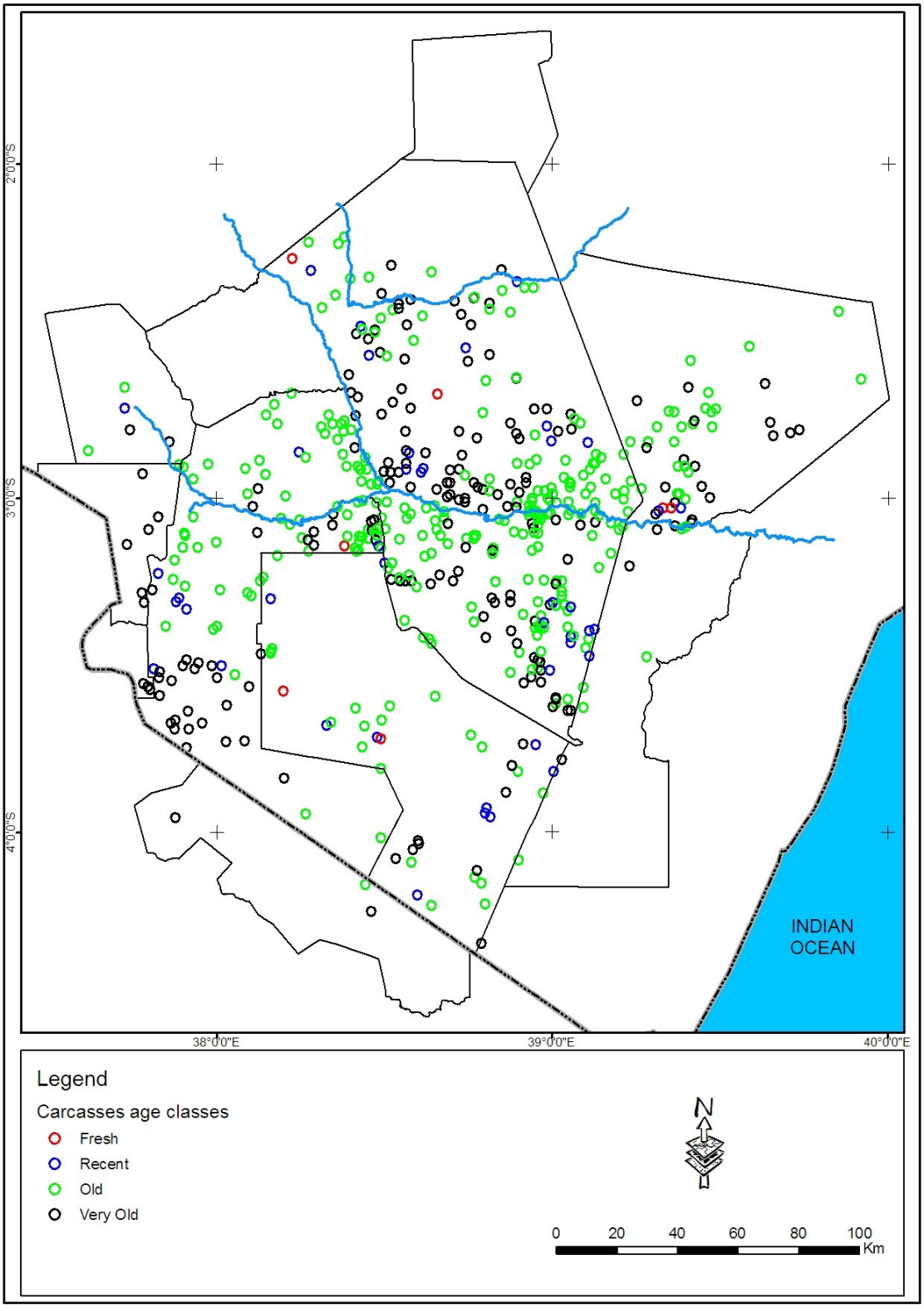


Figure 6: Map showing the spatial distribution of elephant carcasses according to different age classes in early February 2011. Most of the carcasses were old and very old

5.4 The status and distribution of buffalo

The buffalo population trend over the 23 years considered in the study site indicates that the species population has been fluctuating ($R^2 = 0.58$; $P < 0.05$; Table 3). The species indicates a general upward trend in both Tsavo East National Park (North; $R^2 = 1$; $P < 0.05$) and Tsavo East National Park (South; $R^2 = 0.88$; $P < 0.05$; Table 3). In Northern and southern parts of Tsavo East National Park, the buffaloes population increased by 91% and 57% between 2002 and 2011 (Table 3). In Tsavo West National Park, the species sharply declined by 343% between 2002 and 2011 ($R^2 = 0.77$; $P < 0.05$; Table 3). Most of the buffaloes were counted along the Galana, Tsavo and Voi Rivers respectively (Figure 11). High densities occurred in Tsavo East National Park, South of Galana River (Figure 12)

Table 3: The number of buffalo counted in the Tsavo-Mkomazi ecosystem in 7-12 February 2011

	Years								
Locations	2011	2008	2005	2002	1999	1994	1991	1989	1988
Tsavo East NP(N)	2613	1376	1274	1361	592	2127	1155	972	528
Tsavo East NP(S)	3142	2229	2325	1999	2295	3039	2817	2038	1084
Tsavo West NP	641	1945	4907	2839	1779	5676	2878	5808	2279
Chyulu NP	0	71	-	-	-	-	-	-	-
Galana	44	45	235	162	142	3	842	389	667
Taita	797	583	442	590	573	733	1393	590	1019
Mkomazi NP	121	73	182	380	302	95	781	229	245
Other Blocks	44	192	6	16	258	125	340	12	38
Total	7402	6514	9371	7347	5941	11798	10206	10038	5860

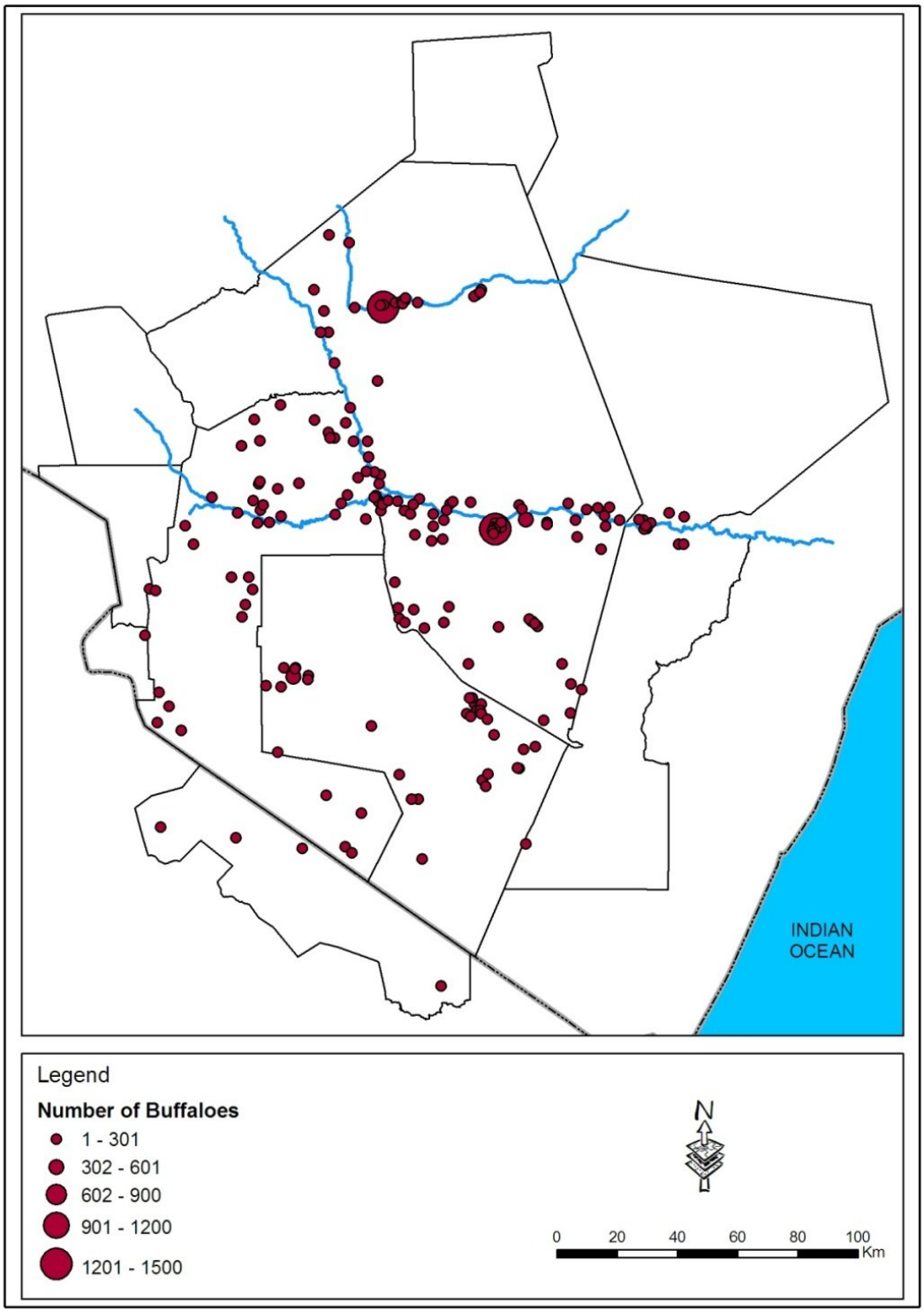


Figure 7: A map showing the distribution of different sizes of buffalo herds in the Tsavo-Mkomazi ecosystem in early February 2011. Large herds of buffalos (>1200 animals) were recorded along Galana and Tiva Rivers respectively.

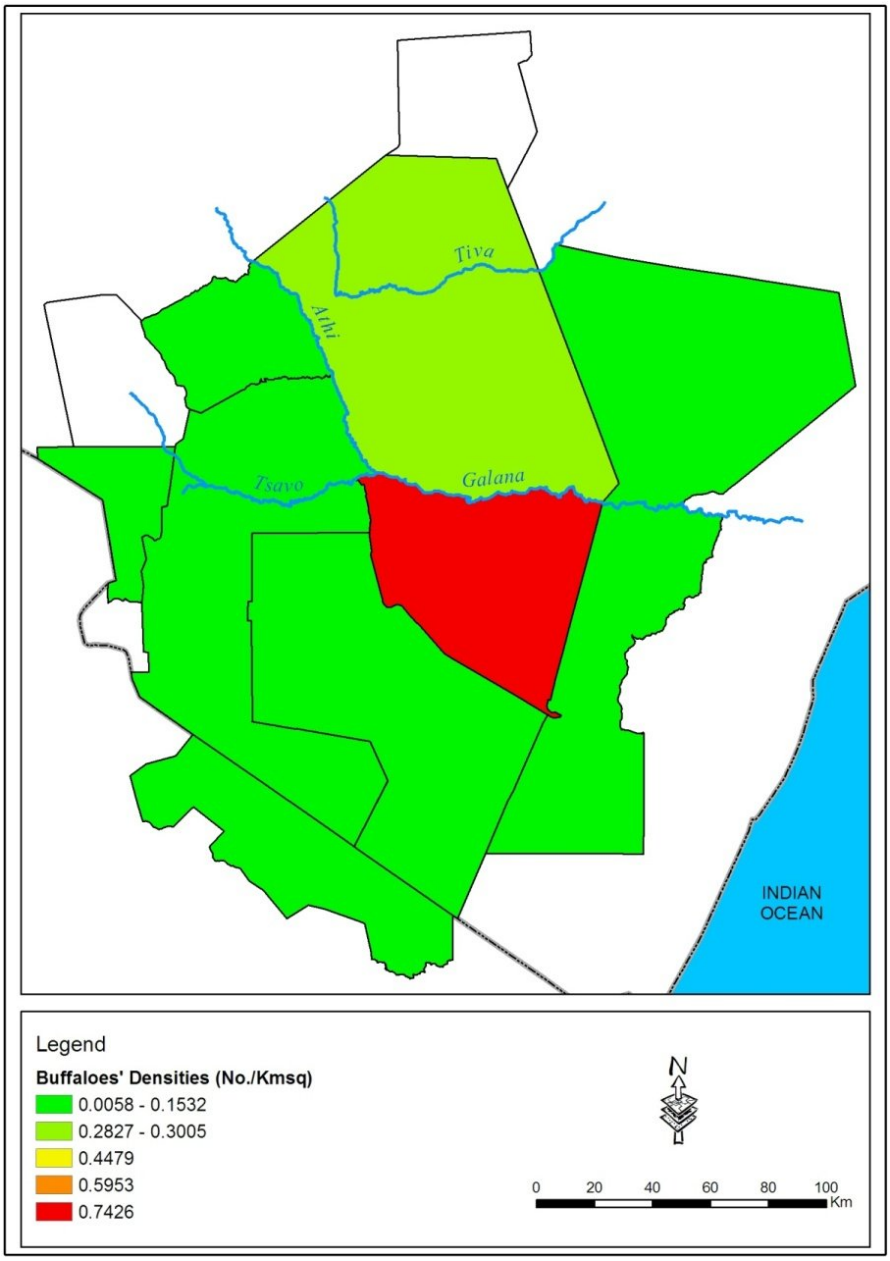


Figure 8: The density of buffalo in Tsavo-Mkomazi ecosystem in early February 2011. A high density of buffaloes (0.7 animals per km^{-2}) was recorded in Tsavo East National Park, South of Galana River.

5.5 Status, density and distribution of giraffe

The ecosystem supported a population of about 2,055 giraffes in early February 2011 (Table 4). The giraffe population in the ecosystem increased from 1,148 animals in 1999 to 2,055 animals in 2011 representing an increase of about 55% (n = 907 animals). However, compared with the number of giraffes in 2008, a population decline of about 19% (n = 395 animals) was recorded in three years. The highest decline of about 60% (n = 254 animals) and 45% (n = 242) was recorded in Tsavo East National Park (North) and Chyulu National Park respectively (Table 4). During the four census periods, Tsavo West National Park recorded the highest number of giraffes whereas South Kitui

National Reserve had the least number of giraffes (Table 4). Large groups of giraffe were recorded in Chyulu West, southern parts of Tsavo West National Park, and northern part of Mkomazi National Park (Figure 13).

Table 4: The number of giraffe counted in the Tsavo-Mkomazi ecosystem in 7-12 February 2011. Data on giraffe for 2002 is missing.

	2011	2008	2005	2002	1999
Tsavo East NP (N)	170	424	281	-	133
Tsavo East NP (S)	222	257	261	-	222
Tsavo West NP	691	678	568	-	272
Chyulu NP	292	534	-	-	-
Mkomazi NP	120	116	62	-	82
South Kitui NR	6	3	-	-	-
Galana	93	95	153	-	171
Taita	282	193	148	-	147
Other Blocks	178	148	111	-	121
Outside	1	2	0	-	-
Total (Parks)	1501	2012	1172	-	709
Total (Non-parks)	554	438	412	-	439
Totals	2055	2450	1584	-	1148

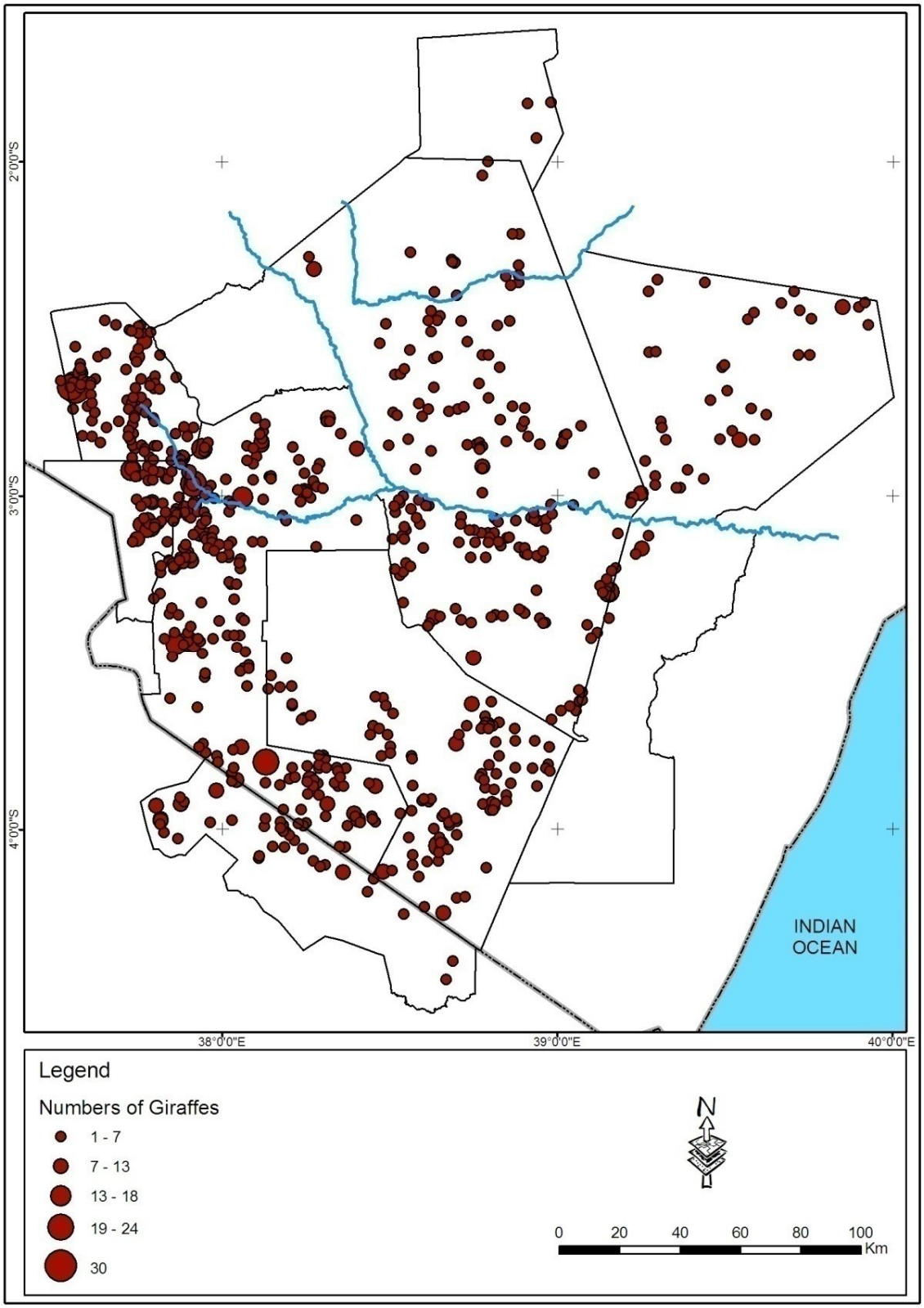


Figure 9: A map showing the distribution of different sizes of giraffe herds in the Tsavo-Mkomazi ecosystem in early February 2011. Large herds of giraffe (> 30 animals) were recorded along Chyulu West and parts of Tsavo West respectively.

5.6 The status, density and distribution of common zebra

Table 5 below summarizes the number of common zebra counted in 2011 and 2008. The parks hosted about 71% (n = 4,782) of the common Zebra in the ecosystem. The species appears to be thriving well in Tsavo West National Park based on the 2011 and 2008 dry season large mammal census (Table 5). Tsavo West National Park accounted for about 33% (n = 2,248) of the common zebra counted in the Tsavo-Mkomazi ecosystem in 2011. However, in West Chyulu, which includes Chyulu National Park, the population of common zebra declined by 222% (n = 1978) between 2008 and 2011 (Table 5). Figure 14 shows the distribution of the common zebra in February 2011. They concentrated on the eastern parts of Galana River, western parts of Chyulu, and various parts of Tsavo West National Park (Figure 14).

Table 5: The number of common zebra counted in the Tsavo-Mkomazi ecosystem in 7-12 February 2011

	2011	2008
Tsavo East National park (North)	494	317
Tsavo East National Park (South)	955	885
Tsavo West National Park	2248	2532
Chyulu National Park	890	2868
South Kitui National Reserve	0	0
Mkomazi National Park	195	231
Galana	124	134
Taita	960	532
Other Blocks	835	745
Outside	25	32
Total (Parks)	4782	6833
Total (Non parks)	1944	1443
Total	6726	8276

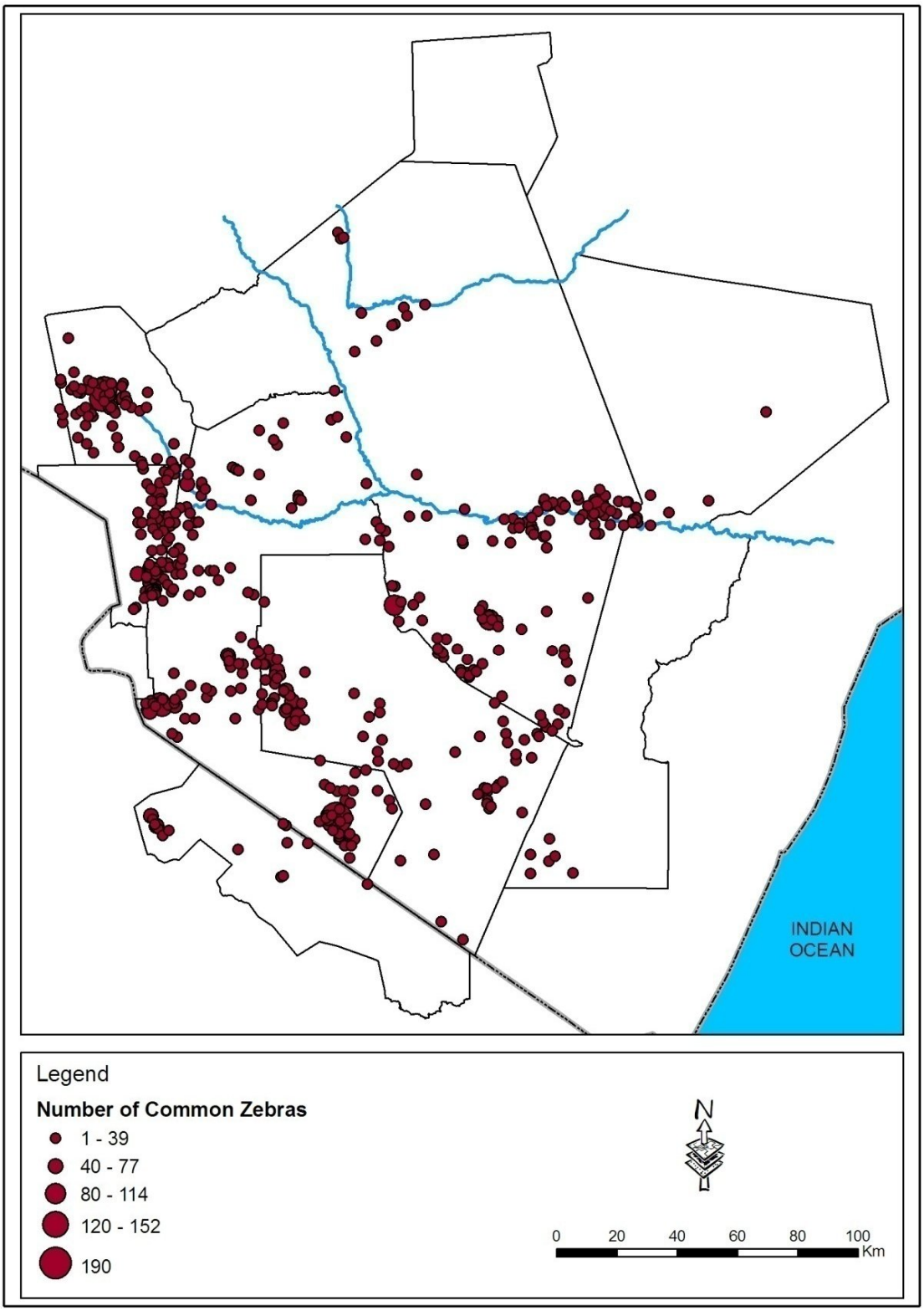


Figure 10: A map showing the distribution of different sizes of zebra herds in the Tsavo-Mkomazi ecosystem in early February 2011. Large herds of common zebra (> 190 animals) were recorded along Chyulu West and parts of Tsavo West respectively

5.7 The status, density and distribution of lesser kudu

The Tsavo-Mkomazi ecosystem supported about 281 lesser kudu in early February 2011. These were found Tsavo East North (n = 64), Tsavo East South (n = 11), Tsavo West National park (n = 68), Chyulu West including Chyulu National Park (n = 10), Galana (n = 9), Mkomazi National Park (n = 14), Taita Ranches (n = 102), South Kitui National Reserve (n = 2) and other areas (n = 1). Figure 15 below summarizes the distribution of the lesser kudu in the ecosystem. Most of the animals were counted in the Taita ranches followed by Tsavo West National Park and northern parts of Tsavo East National Park respectively (Figure 15).

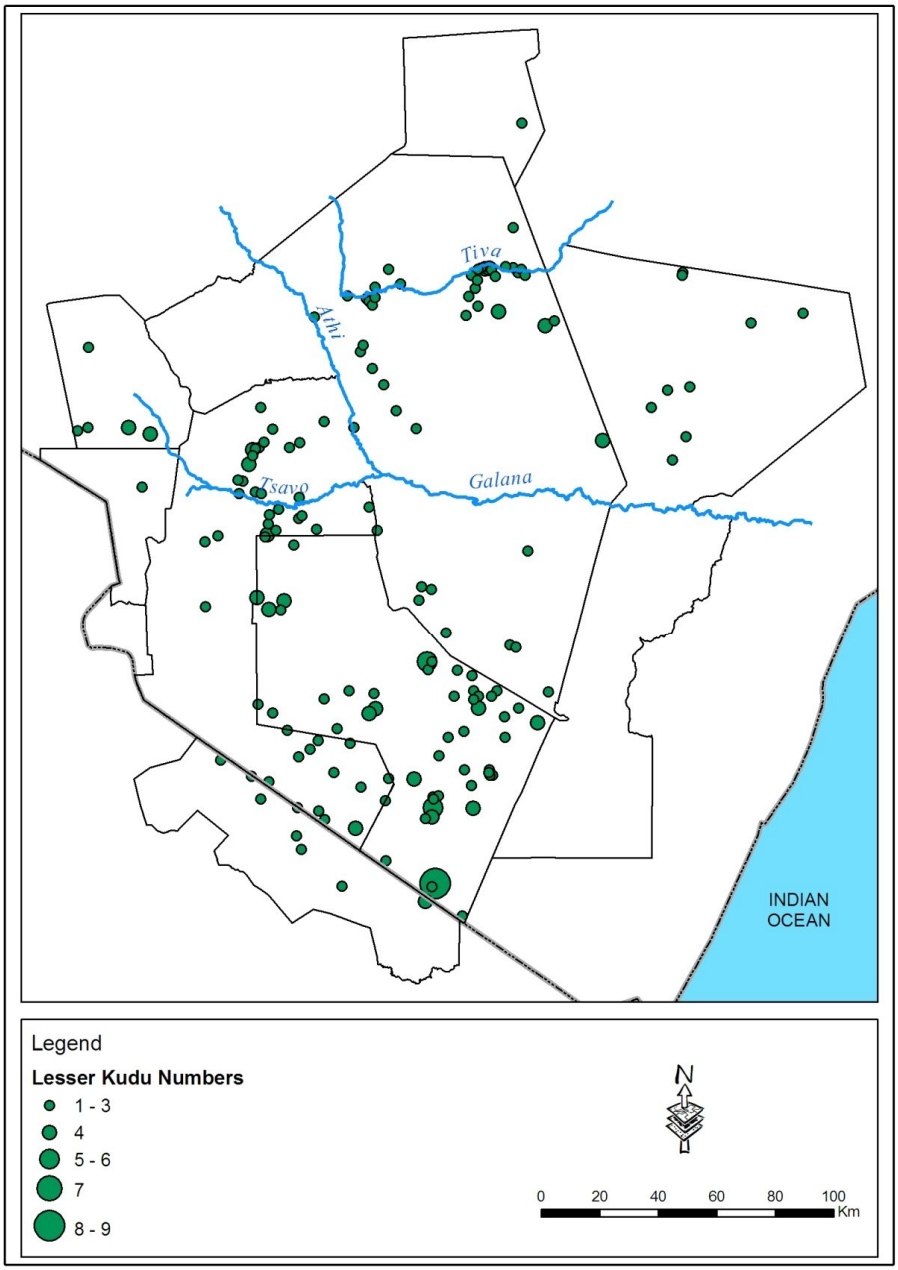


Figure 11: A map showing the distribution of different sizes of lesser kudu herds in the Tsavo-Mkomazi ecosystem in early February 2011. Large herds of lesser kudu (> 5 animals) were recorded in Taita ranches.

5.8 The status and distribution of cattle and shoats

In 2011, large cattle herds were found in Chyulu West around Njukini area, which lies along the south west boarder of the Chyulu National park, Taita ranches and southernmost tip of Tsavo West National Park and in Mkomazi National Park (Figure 22). Cattle were recorded inside Tsavo East National Park just south of Tiva River.

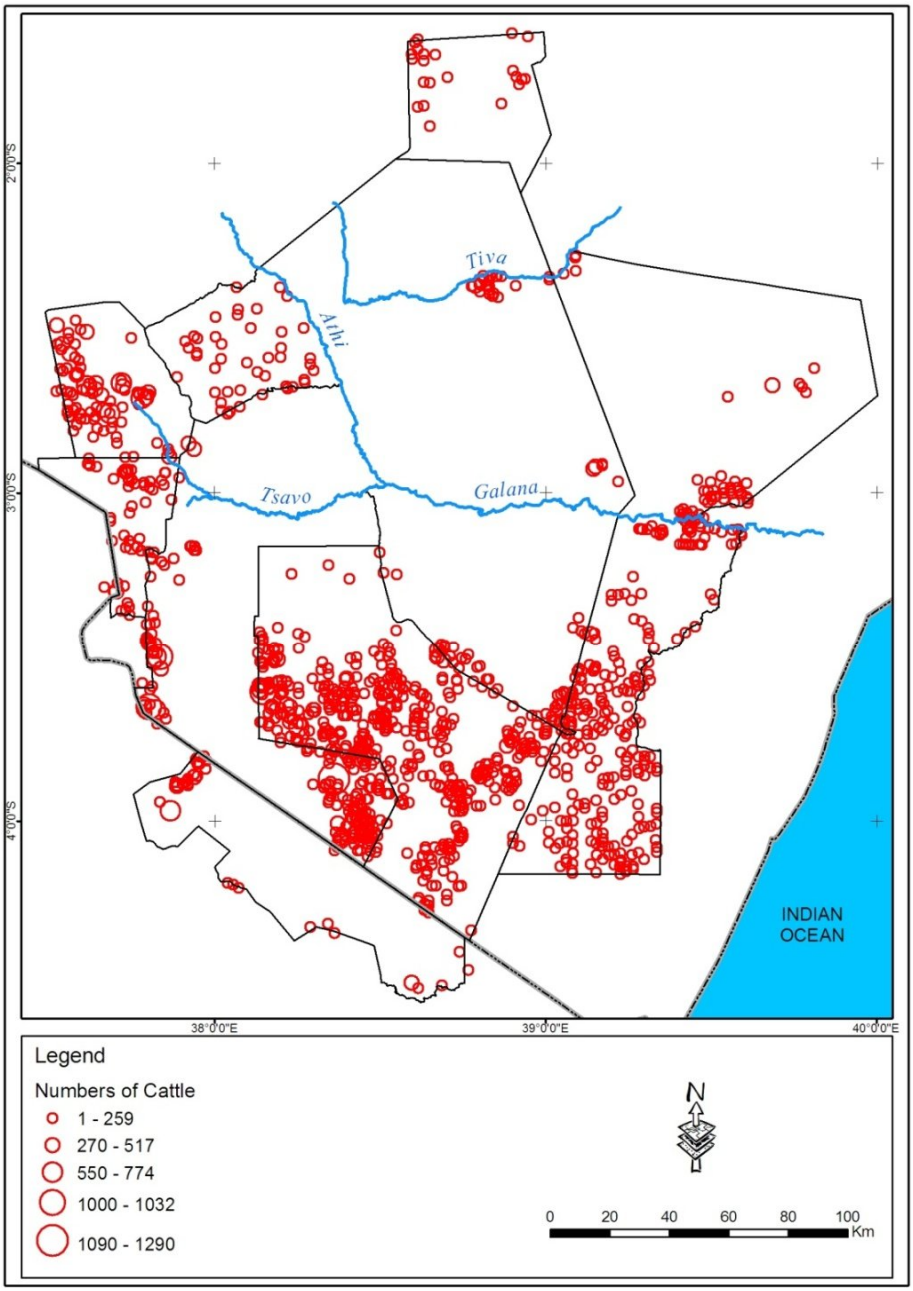


Figure 12: Numbers and distribution of cattle in Tsavo-Mkomazi ecosystem (early February 2011)

Few livestock were counted in the park s (Figure 16). Other areas where we counted livestock included South Kitui National Reserve, galena ranch, West of Chyulu, and north of Tsavo West National Park (Figure 16 and Figure 17).

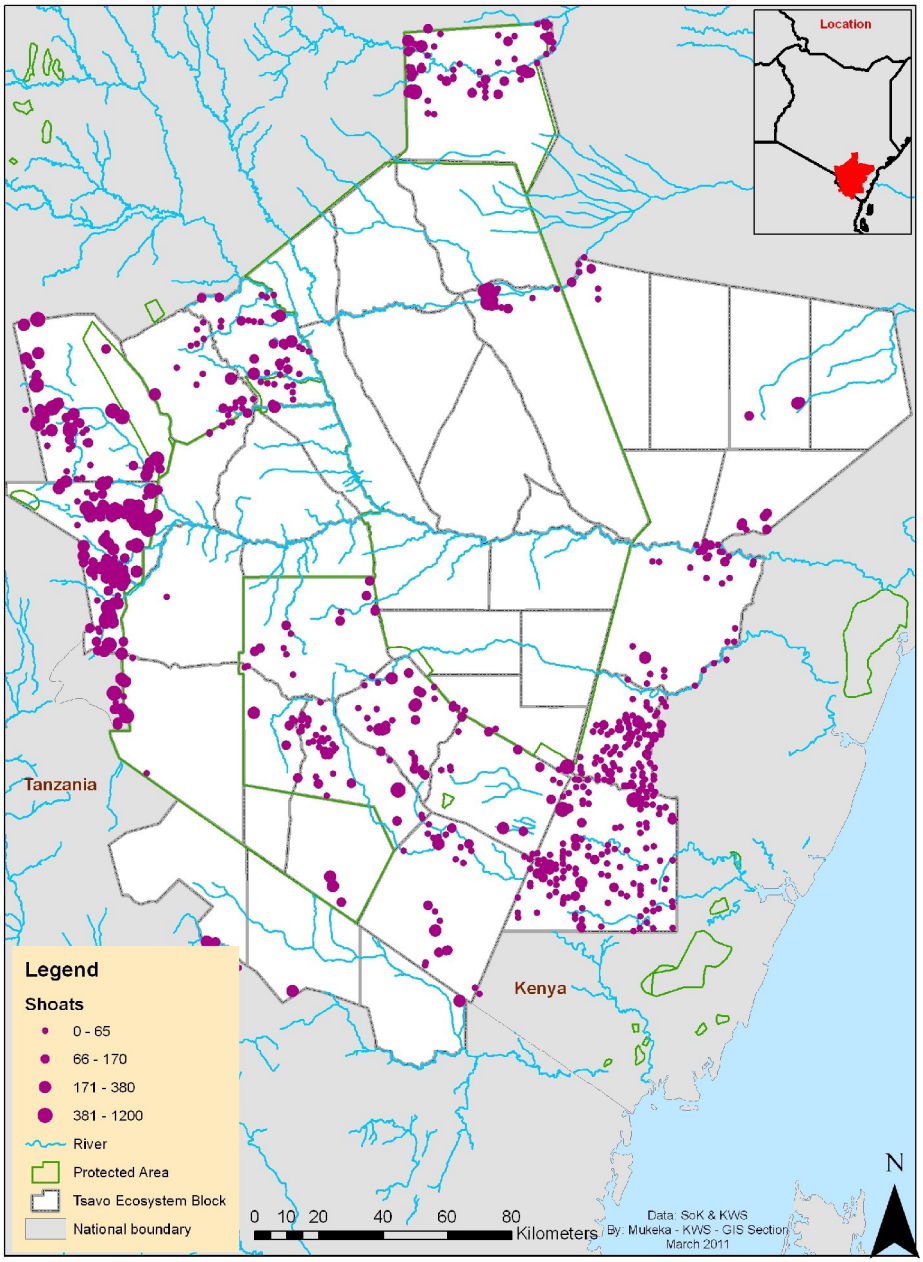


Figure 13: Numbers and distribution of shoats in Tsavo-Mkomazi ecosystem (early February 2011)

5.9 The distribution and density of other species

The other wildlife species opportunistically counted during the 2011 census included wild dogs, lions, crocodiles, hippos, and ostriches Grevy's zebra, hirola, bushbucks, duikers, wildebeest, impala, warthogs, jackal, hyenas, hartebeest, grant's gazelle, thomson's gazelles, gerenuk, oryx and waterbuck. Figures 18-21 shows the distribution of the other species counted in the ecosystem in early February 2011.

The wild dog is critically endangered with about 5000 animals remaining in the wild (Woodroffe and Ginsberg, 1999). During the 2011 Tsavo – Mkomazi census, 38 wild dogs were counted, 66% (n = 25) of which were recorded in Tsavo West. Taita, Mkomazi and Tsavo East North had 8, 4 and 1 respectively (Figure 18). These were nonetheless opportunistic sightings considering that they are relatively harder to see from air. The methodology used for the large mammal aerial census is not suitable for determining small wildlife species trends hence the results are only indicative of their presence in Tsavo Conservation Area.

Hirola is listed as critically endangered in the IUCN Red List (2010). This species is endemic to north –east Kenya and south –west Somalia which is mainly the historical range. The individuals counted in Tsavo East comprise those that were translocated to safeguard the species that was fast declining due to habitat loss, poaching, drought and competition with livestock. In the 2008 Tsavo Ecosystem elephant census 25 and 4 individuals were counted in Tsavo East South and North respectively (Figure 19). The 11 individuals counted in the 2011 census were only found in Tsavo East South.

In 2011, 233 wildebeest were counted in Tsavo West, up from 48 counted in 2008. This huge difference would most likely be attributed to counting biases other than natural increase. In Chyulu 33 wildebeest were counted in 2011 while in 2008, the number recorded was 803. These results may indicate a possible migration of the species in the south-western side of Tsavo West and Chyulu. Figure 19 shows the current distribution in the Ziwani area of Tsavo West and West Chyulu.

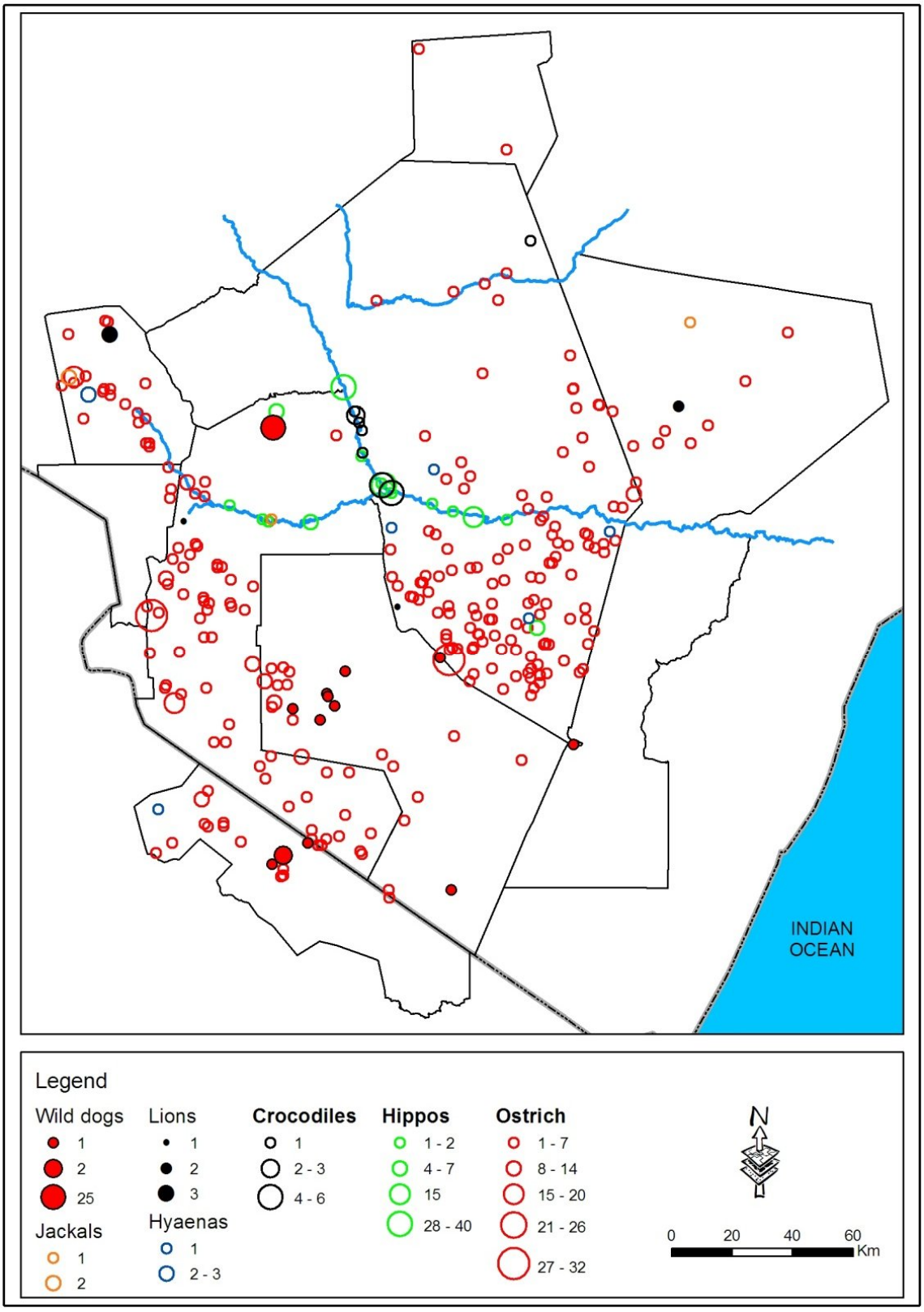


Figure 18: The distribution of Wild dogs, Lions, Jackals, Hyenas, Crocodiles, Hippopotamuses and ostriches (early February 2011)

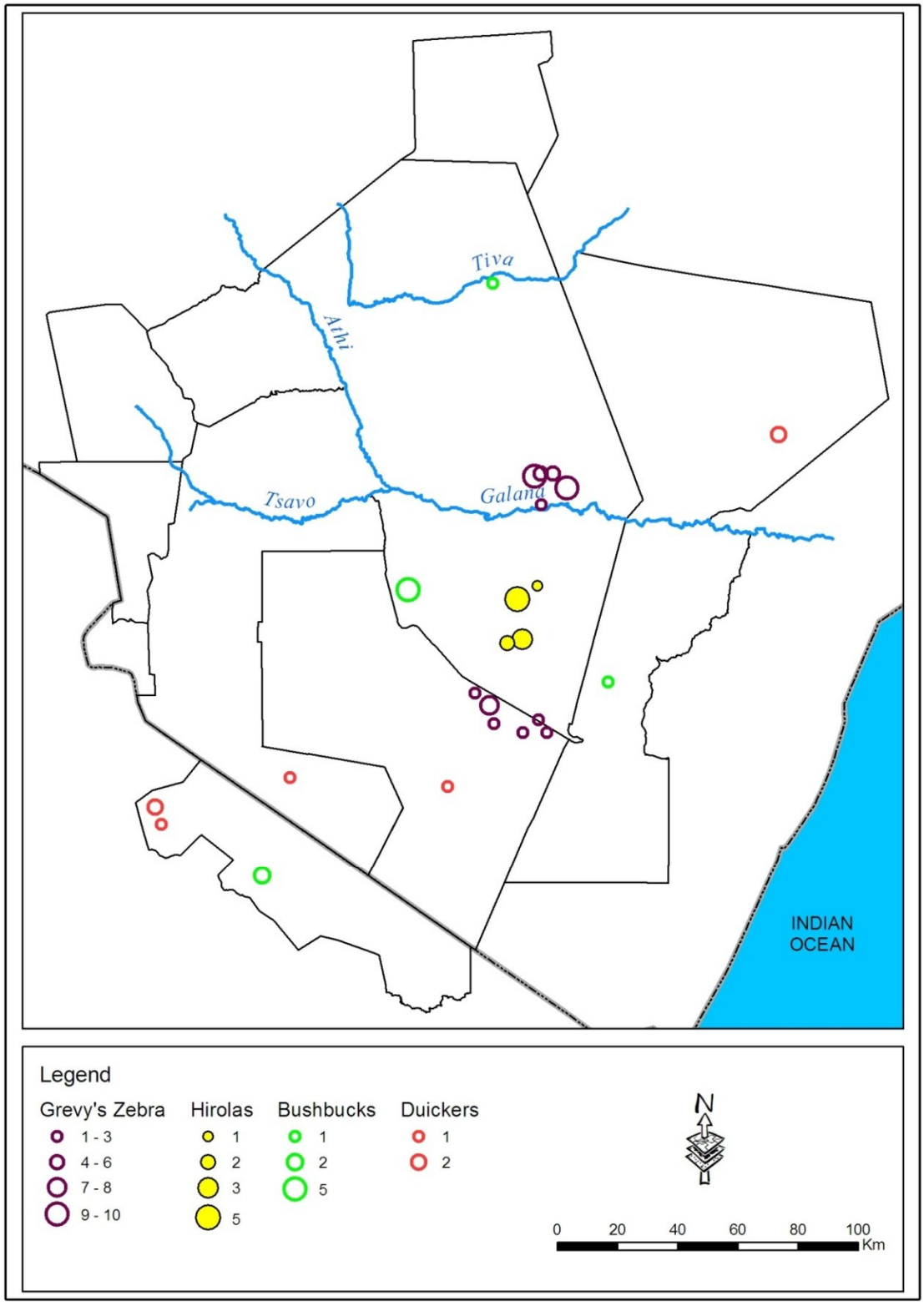


Figure 19: Numbers and distribution of Grevy's Zebra, Hirolas, Bushbucks and Duickers. About 11 hirola in 4 different groups were recorded in the southern parts of Tsavo East, around Satao area. Grevy zebra were recorded slightly outside the boundary of southern part of Tsavo East NP and also slightly to the north of Galana River in Tsavo East NP. Data is for early February 2011.

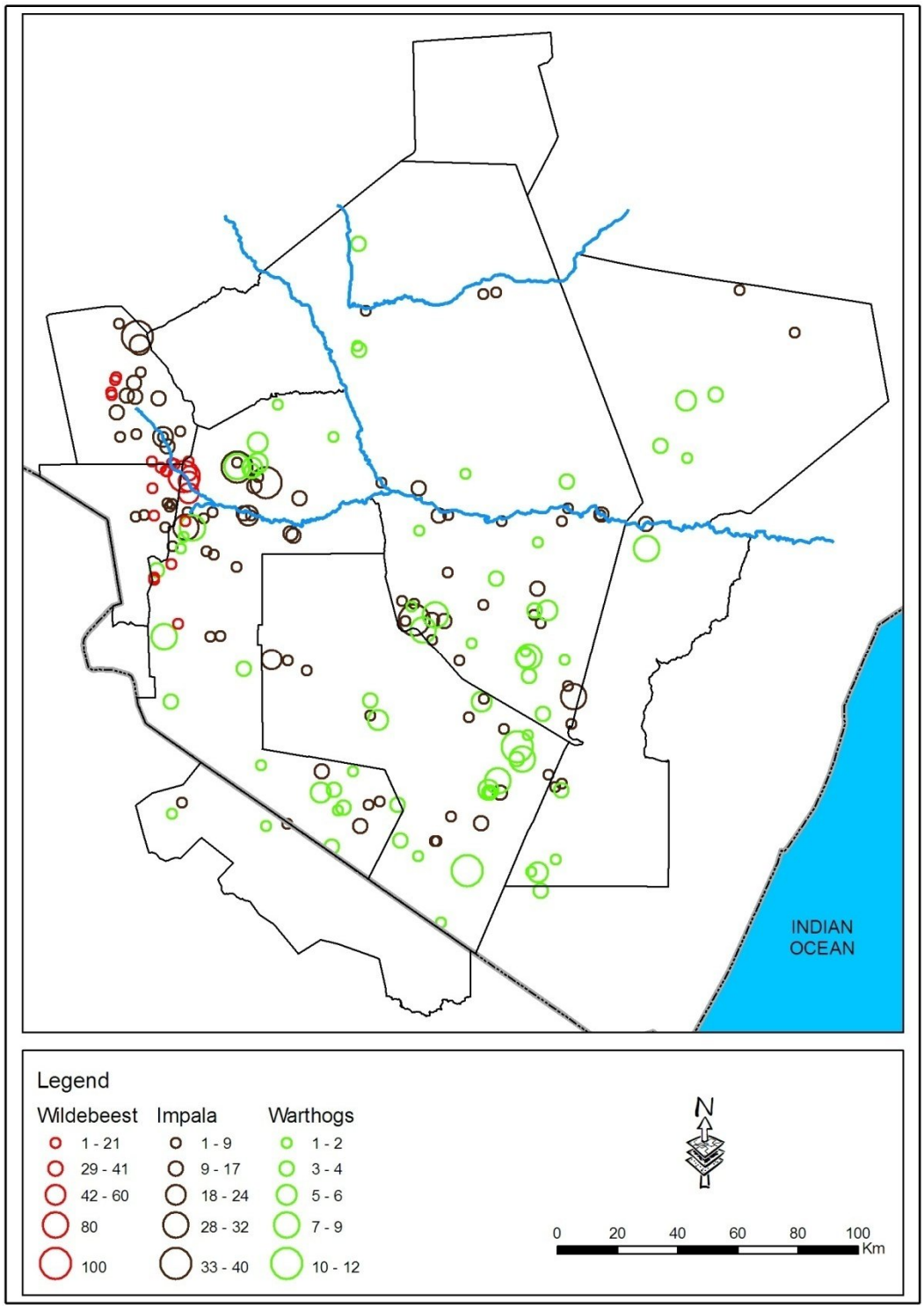


Figure 20: Numbers and distribution of wildebeest, impala and warthogs (early February 2011). Wildebeests were recorded in the north-western part of the ecosystem. They are believed to be migrants using the larger Tsavo-Amboseli ecosystem

The early February 2011 census indicated an even distribution of grant gazelles and hartebeests within the ecosystem, while Thompson gazelles were only counted in West Chyulu and Tsavo East

South (Figure 21). Varying group sizes of Gerenuks, oryx and waterbuck were recorded in the study area, however, large waterbucks group sizes (n=120) were sighted in West Chyulu (Figure 22).

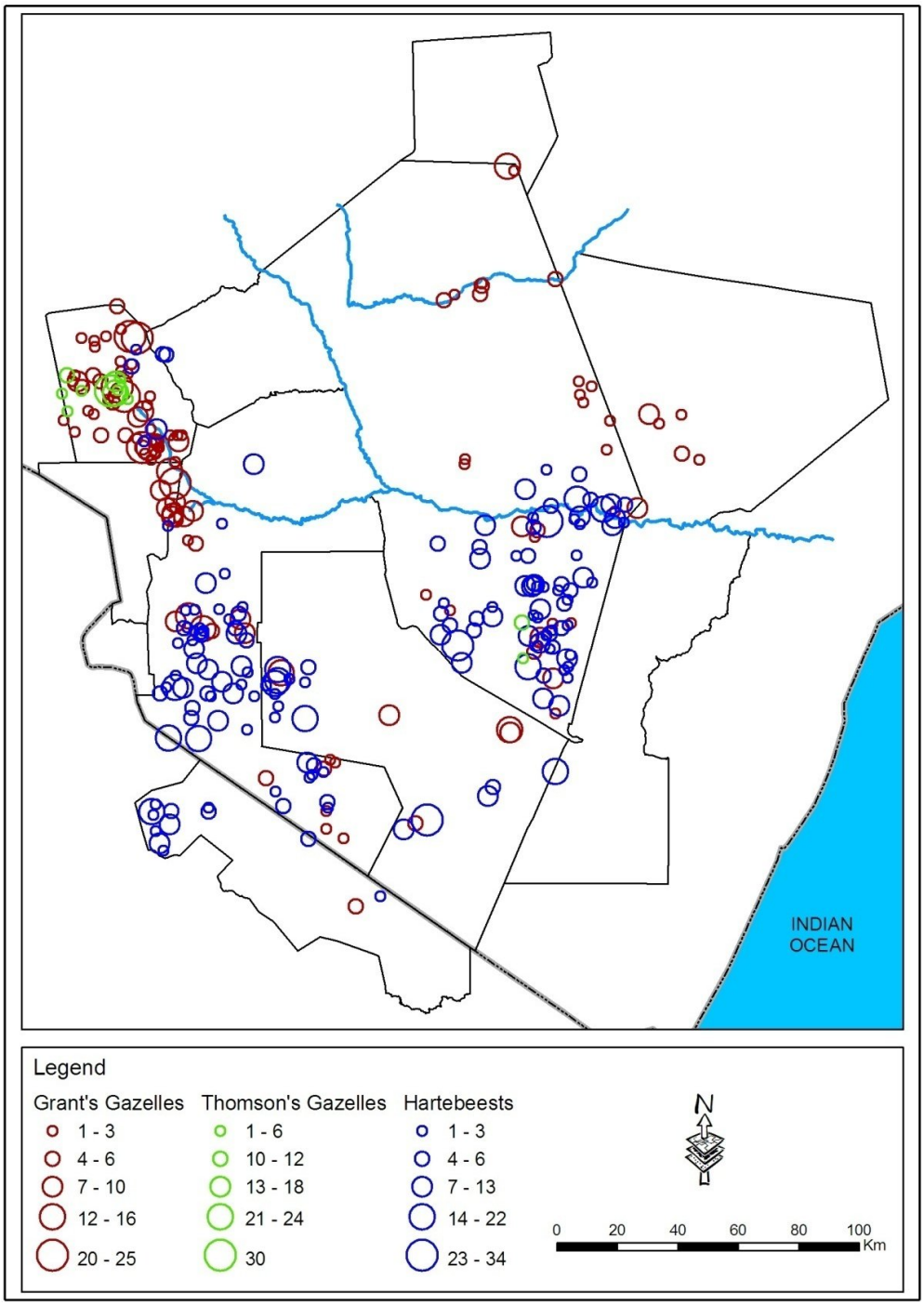


Figure 21: Numbers and distribution of Grant's gazelle, Thomson's gazelle, and hartebeest (early February 2011).

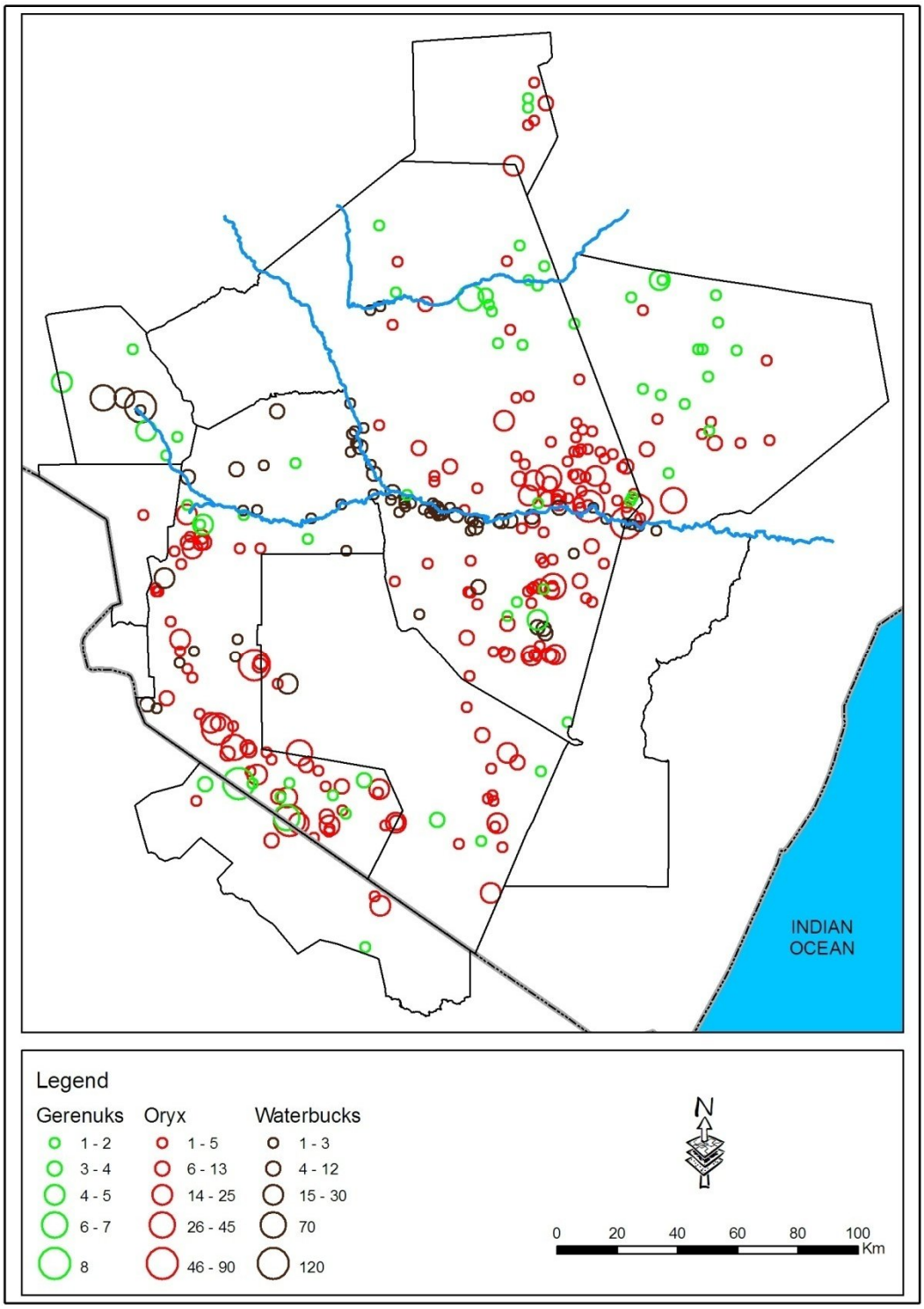


Figure 22: Numbers and distribution of Gerenuk, Oryx and Waterbuck (early February 2011)

5.10 Distribution of settlements and mining activities

Settlements were put into two classes, permanent settlements (Figure 23) and temporary settlements (Figure 24). Temporary settlements comprised of occupied manyatas, occupied and abandoned bomas, the latter of which dotted the whole landscape especially Tsavo West NP, Mkomazi NP and western part of Tsavo East NP (figure 24). Scattered occupied bomas were more in Tsavo West NP and South Kitui NR (figure 24). Block 12c had the highest concentration of occupied bomas.

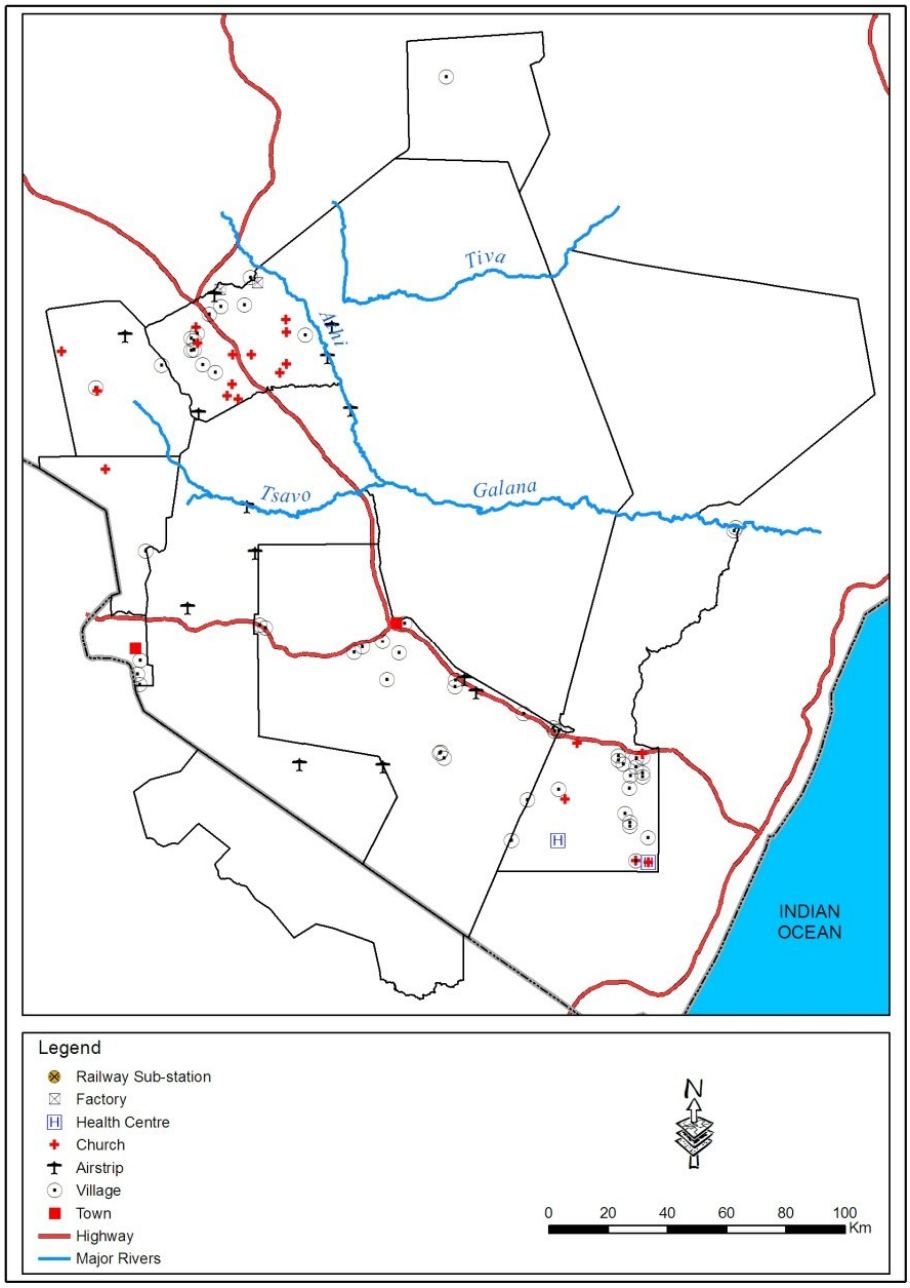


Figure 23: Permanent features recorded during the early February 2011 aerial survey

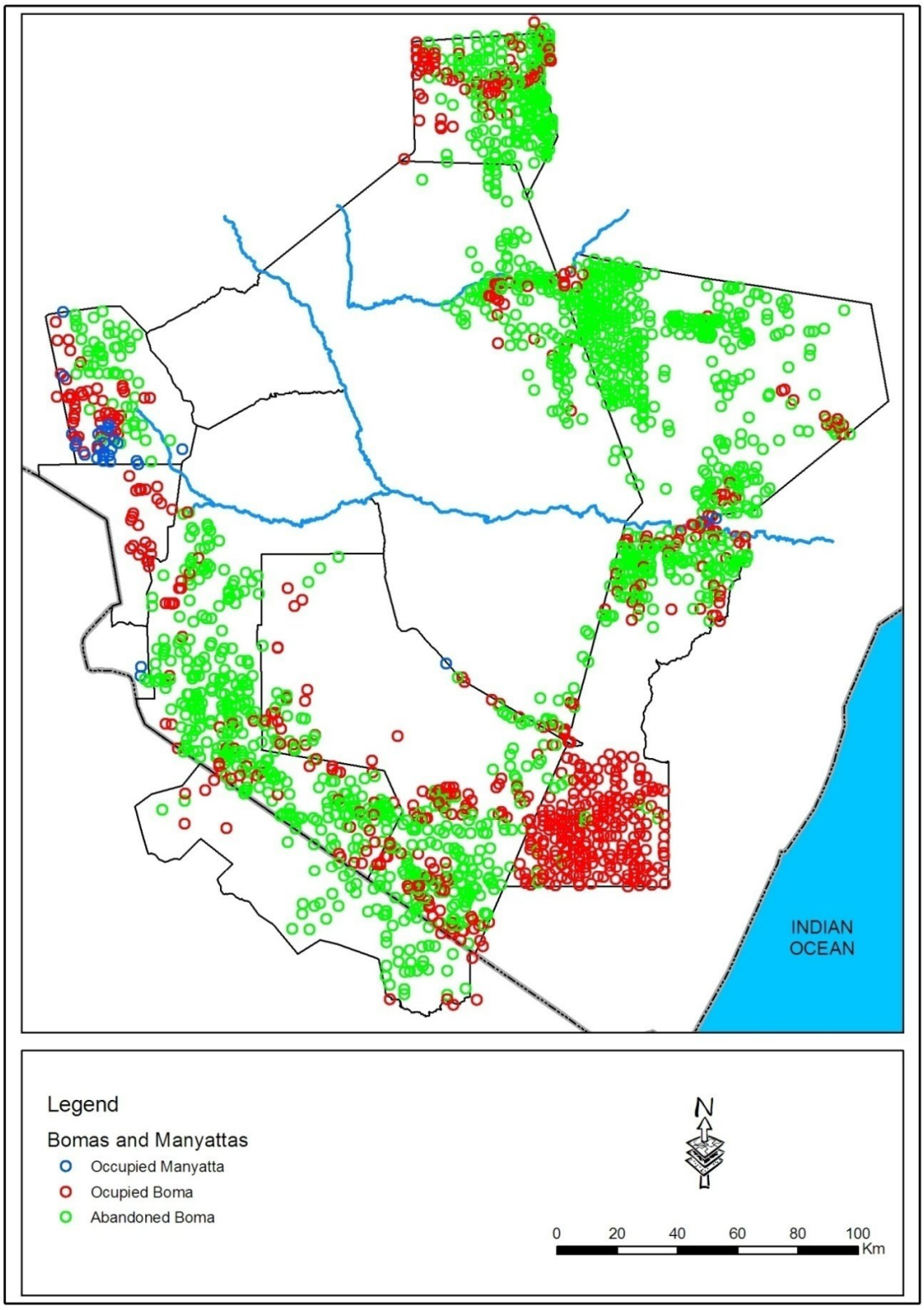


Figure 24: Temporary settlements comprising the Manyattas, occupied and abandoned livestock bomas (early February 2011). The Manyatta are traditional huts inhabited by pastoralists whereas the bomas are holding grounds for livestock. The bomas are usually fenced with *Acacia* branches to secure the livestock at night.

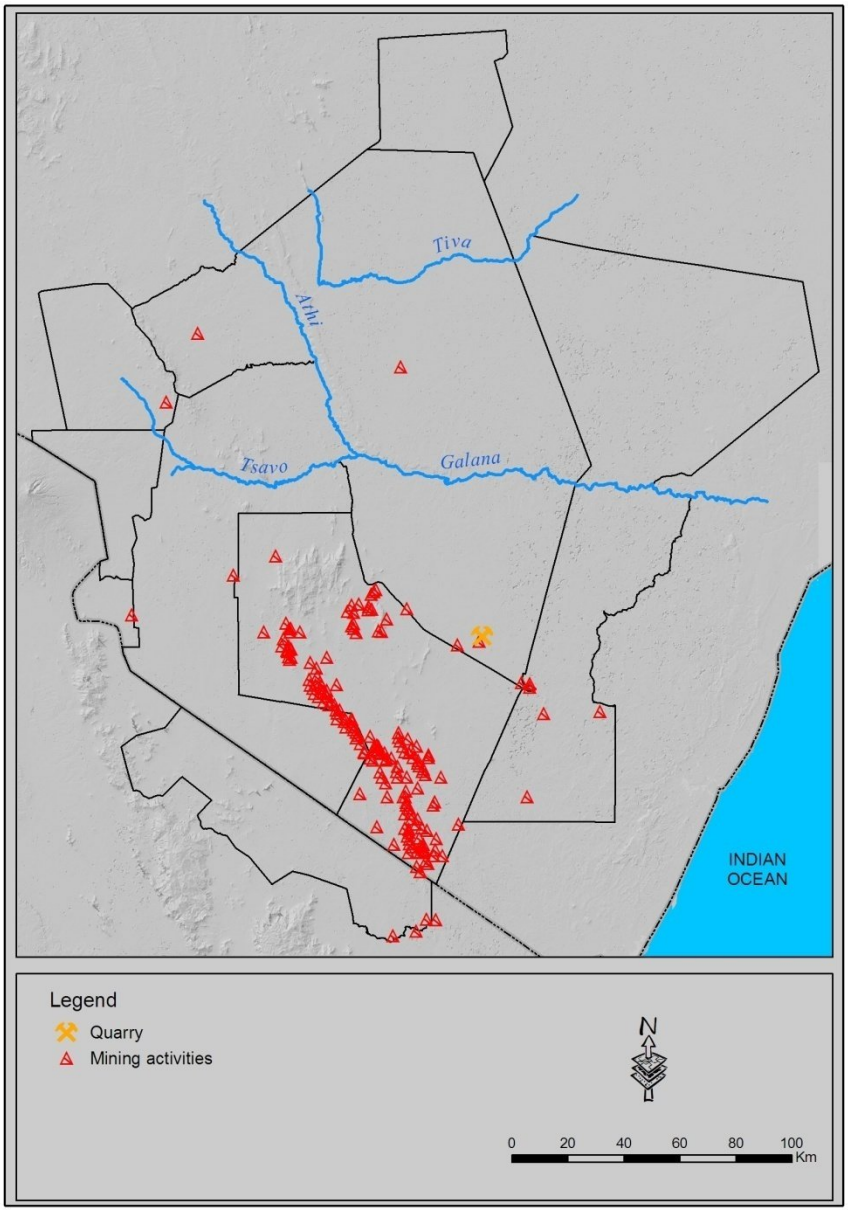


Figure 25: Precious stones mining locations and one stone quarry recorded within the conservation area during the census

Figure 25 shows intensive mining activities in the south-eastern side of Tsavo West National Park. Block 12B in Tsavo West National Park was the area with the highest number of mining activities in the protected areas. These activities have resulted to environmental degradation and loss of habitat for wildlife. Interestingly Block 12 in the park and the adjacent Blocks 10A, 9A and 7B in Taita had high elephant concentrations. Further study is required to investigate whether elephants are attracted to area because of a preferred habitat, water from the mines or there could be other factors.

5.11 Illegal activities

Within the protected areas, charcoal burning and logging were recorded on the western side of South Kitui National Reserve and the north western boundary of the northern part of Tsavo East (Figure 26).A poachers hide out was also recorded at the central part between Galana and Tiva Rivers in Tsavo East National Park. Charcoal burning and logging was extensively common in the Taita Ranches and other areas outside the protected areas (Figure 26).

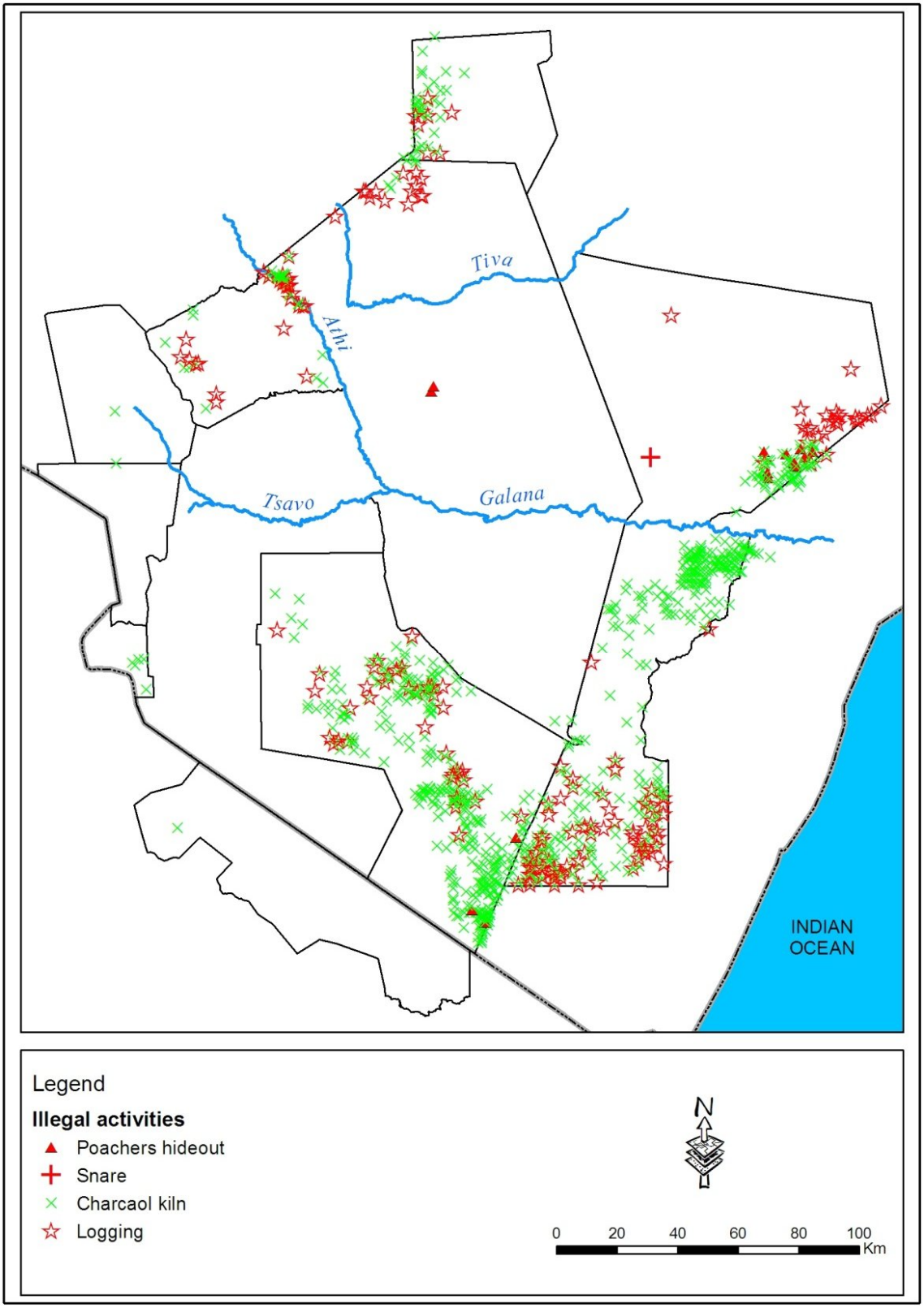


Figure 25: Various illegal activities recorded in TCA and neighboring areas (early February 2011)

6.0 DISCUSSIONS

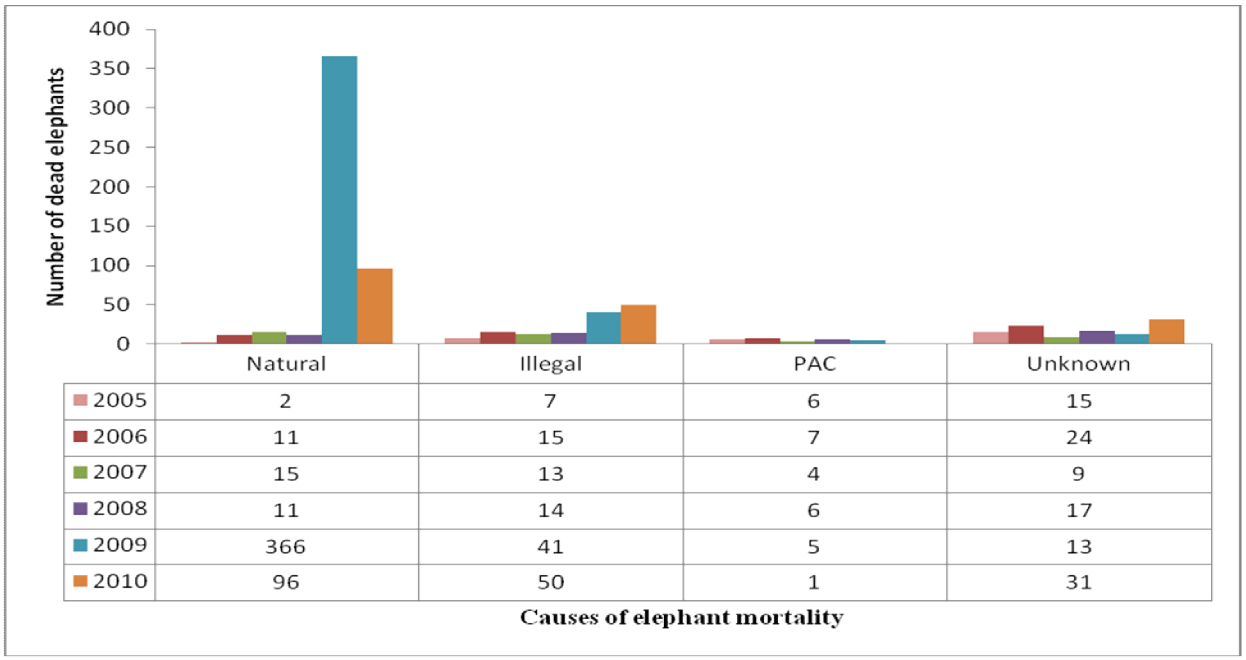
6.1 Elephant number, density and distribution

The 2011 aerial census results revealed that the population of elephants in the Tsavo-Mkomazi ecosystem increased at a decreasing rate of 2% in three years. The decreasing rate of increase is attributed to natural mortality. Natural mortality occurs because of drought or disease outbreak (Estes, 1991). Increase of elephant deaths due to natural causes was recorded between 2008 and 2010 (KWS-TCA database, 2011; figure 26). The elephants dying of natural mortality always have their tusks on the carcass. Data available at Kenya Wildlife Service indicates that natural cause of elephant deaths was high between 2008 and 2010 (84%; n = 674) than from 2005 to 2007 (16%; n = 131; KWS-TCA database, 2011). Specifically, the 2009 and early 2010 droughts were responsible for these natural deaths, with more deaths in 2009 (83%; n = 366) and 2010 (52%; n = 96) than other previous years (Figure 26). Out of the 674 elephant carcasses reported in the study area between 2008 and 2010, 86% (n = 576), 1% (n =9), and 13% (n = 89) of the carcasses had the two tusks recovered, one tusk recovered, and no tusk recovered respectively (KWS-TCA database, 2011). Also, most of the carcasses were classified as old (91%; n = 517), a category for elephants that have died more than one year previously (Douglas-Hamilton, 1996). This period coincides with the period when the study site experienced a drought. The drought led to scarcity of forage and water culminating to starvation of many elephants. Most of the old carcasses were recorded in Tsavo East and northern parts of Tsavo West National Parks as these areas lacked water during the 2009 drought. Elephants are water dependent animals (Ngene *et al.*, 2009), therefore many of them could have died during the period due to lack of water. Alternatively, the search effort during the 2011 aerial count was low compared to other years. This could have resulted to less number being counted than in previous years.

Search efforts during aerial counts determine the number of large mammals counted during the exercise (Douglas-Hamilton, 1994). This report uses the term search effort to refer to the area (km^2) covered by the aerial count crew in one hour (km^2/hour; Douglas-Hamilton *et al.*, 1994). High and low search efforts results to higher and lower numbers of the large mammals being counted (Douglas-Hamilton *et al.*, 1994). The 2011 aerial census recorded a search effort of 191km^2/hour, which was higher than for previous aerial census (1988, 321km^2/hour; 1989, 276km^2/hour; 1991, 247km^2/hour; 1994, 210km^2/hour; 2002, 242km^2/hour; 2005, 224 km^2/hour; 2008, 213km^2/hour; Douglas-Hamilton *et al.*, 1994; Omondi and Bitok, 2008). It is therefore possible that the high number of elephants counted in 2011 is not because of actual population increase but more efforts being made to search and count the elephants. The number of elephants increases with increase of search effort (figure 27).

High density of elephants was recorded in the southern part of Tsavo East National Park. The area was also the mean centre where many groups of elephants were counted. This area happens to have two permanent rivers (Galana and Voi) and many water pans, which are lacking in other parts of the ecosystem. High densities of elephants were recorded about 1-15 km from the rivers of water points. Since elephants are water dependent animals (Estes, 1991), their density is expected to be high in areas within 10-15 km from water points (Ngene *et al.*, 2009). Analogous findings were made for elephants in Marsabit National Park and Reserve (Ngene *et al.*, 2009), Samburu National Reserve in Kenya (Thouless, 1995), Maasai Mara Game Reserve in Kenya (Khaemba & Stein, 2000), Maputo Elephants Reserve in Mozambique (Boer, *et al.*, 2000),

Serengeti National Park in Tanzania (McNaughton, 1990), the Kunene region in northwest Namibia (Leggett, 2006), the northern Namib Desert (Viljoen, 1989), and northern Kenya (Leeuw *et al.*, 2001).



	Natural	Illegal	PAC	Unknown
2005	2	7	6	15
2006	11	15	7	24
2007	15	13	4	9
2008	11	14	6	17
2009	366	41	5	13
2010	96	50	1	31

Figure 26: The number of dead elephants against causes of elephant mortality in Tsavo Conservation Area from 2008 to 2010. Others include deaths due to train accidents, sickness, and lion predation. PAC = Problem Animal Control.

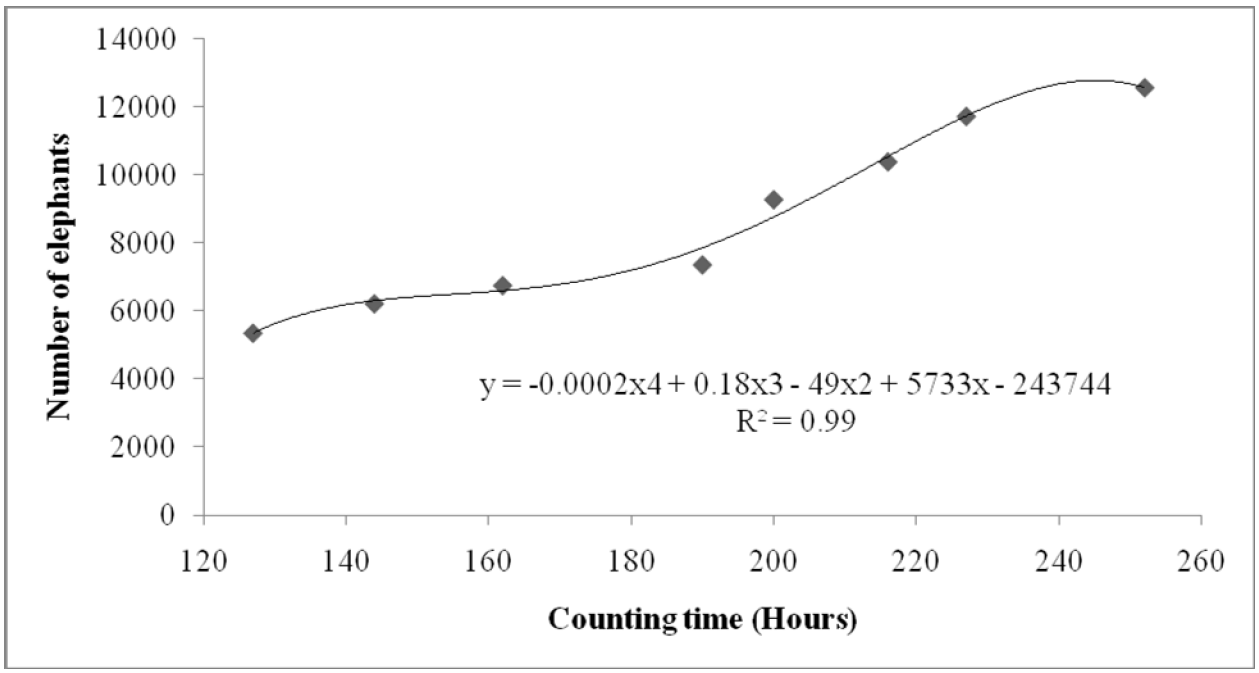


Figure 27: The number of elephants counted in Tsavo-Mkomazi ecosystem against the total counting hours. Data is for the year 1988, 1989, 1991, 1994, 2002, 2005, 2008, and 2011. .

Large herds of elephants were recorded outside the protected areas (Taita and Galana ranches). Possibly, insecurity leading to incidences of poaching of elephants is forcing the elephants to congregate in large numbers outside the protected areas whereas inside our secure protected areas, the groups are small. Similar results have been reported in Meru National Park (

6.2 Elephant carcasses and carcass ratios

Despite an increase in the number of carcasses since the 2008 census (Figure 28), the population is on the increase. The carcass ratio calculated using recent carcasses only is very low (0.4%). This further compels us to believe that most of the carcasses are attributed to the 2009 drought. Under conditions of low rainfall as experienced in the preceding years, the rate of carcass disintegration is minimal (Douglas-Hamilton, 1981). As a result, more carcasses would be cited during aerial census. Just like in the 1970-1971 dry season census (Corfield, 1973), most of the carcasses were recorded in Tsavo East along Galana River, where elephant densities are apparently highest in the ecosystem. Visibility during the 2011 survey was good as it was at the height of the dry season with limited vegetation.

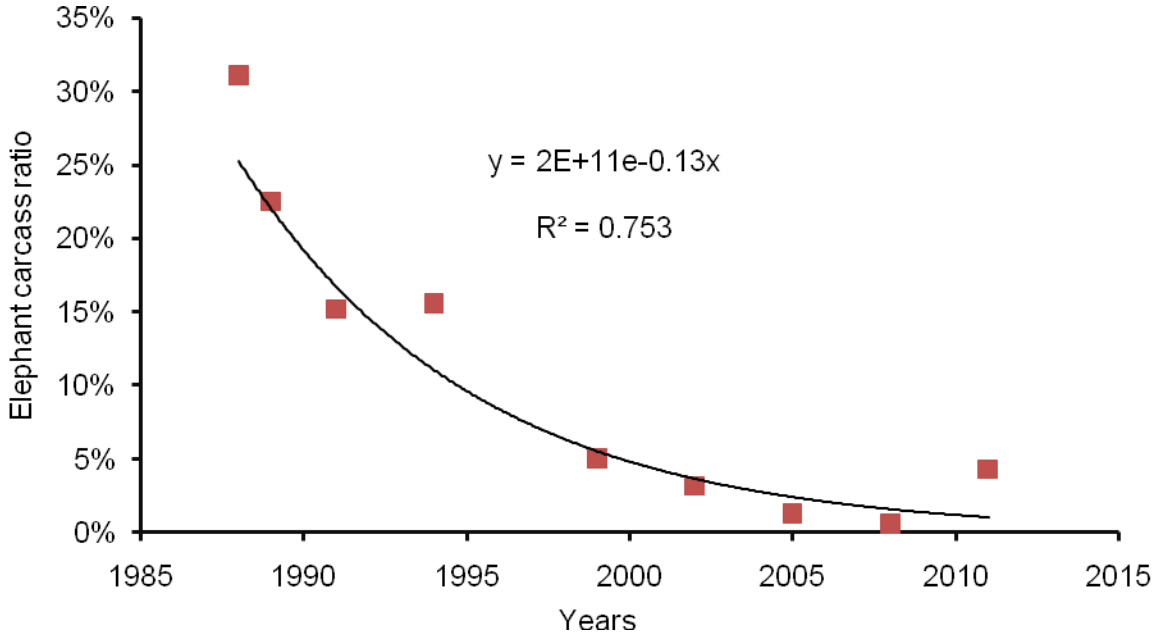


Figure 28: Trends of elephant carcass ratio in the Tsavo-Mkomazi ecosystem from 1985 to 2011.

6.3 Buffalo numbers, density and distribution

Buffaloes did not occur on the eastern part of the area between Tiva and Galana Rivers. Two reasons are advanced for this observation; first, this area has no water making it inhabitable by the water dependent buffaloes; secondly, the area has more dense vegetation, which is unsuitable habitat for buffaloes. The high population of buffaloes in the years 1994, 1991, 1989 and 1988 may be attributed to the wet season period during which the census was conducted. The wet season is the peak breeding season for the species while in the years 1999 to 2011census was conducted in the short dry season.

6.4 Hartebeest, Grant's gazelle and Thomson's gazelle

Higher concentrations of hartebeest (*Alcelaphus buselaphus*) are found in the Tsavo East and Tsavo West National Parks (Figure 29). Over the last three censuses conducted in 2005, 2008 and 2011, the abundances of Hartebeests has changed with Tsavo East South and North hosting more numbers progressively, contrary to Tsavo West where numbers have been on the decline. Hartebeests feed mainly on grass and is also known to compete with cattle for graze material, which could explain the low numbers in areas where there is cattle grazing. Notably, in the three censuses carried out in the ecosystem no individuals of the species were encountered in South Kitui National Reserve where livestock grazing is high. Grant Gazelles were evenly distributed in the entire ecosystem, compared to Thompson Gazelles which were clustered in two pockets in West Chyulu and Tsavo East South.

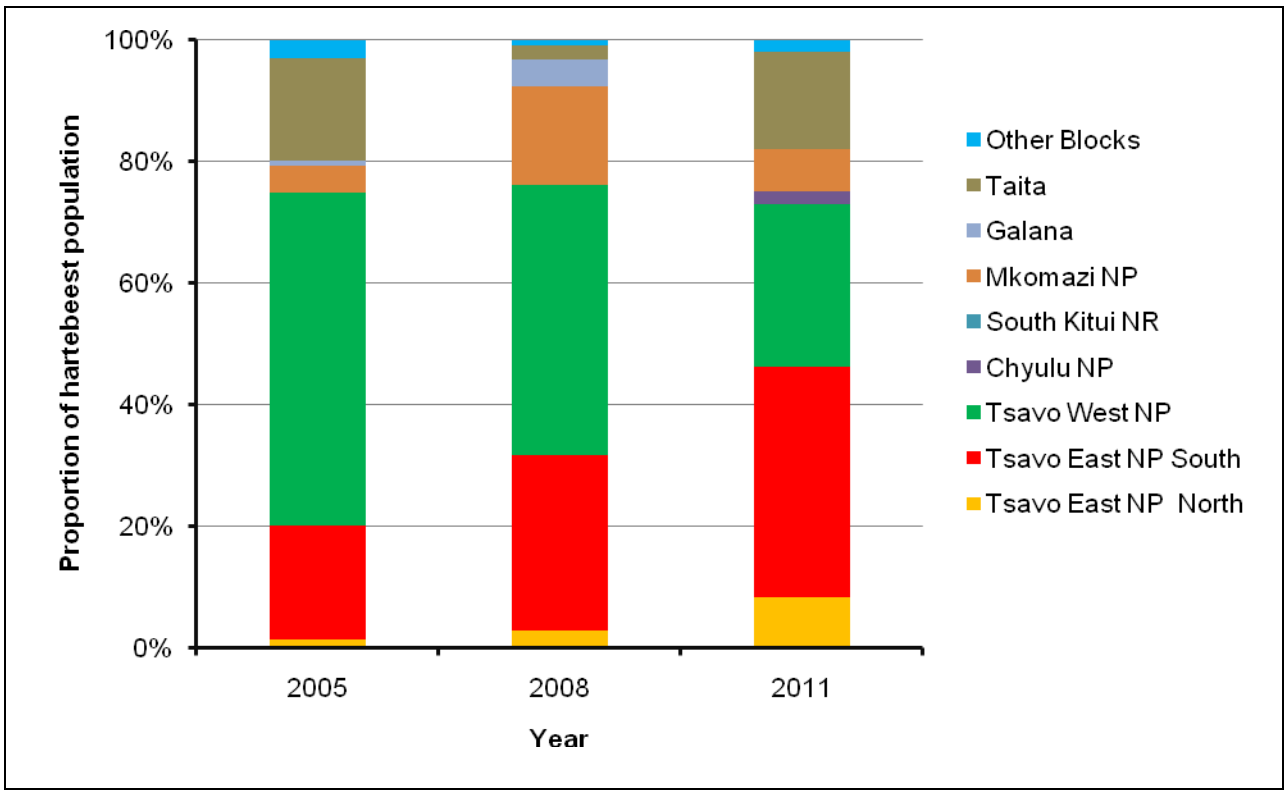


Figure 29: Proportions of hartebeest populations resident in various zones of the conservation areas during the censuses conducted in 2005, 2008 and 2011

6.5 Livestock

Livestock incursion is a serious threat to the Tsavo Ecosystem's health. Increase in livestock numbers in the ecosystem therefore negates its ability to support increasing elephant numbers and other wildlife. Cattle threat was most significant in and around Tsavo West National Park particularly Njukini area and the area bordering the Taita Ranches. The Maasai who are pastoralists live to the west of Tsavo National Park while the Taita area which has been earmarked for livestock development as disease free zone is infiltrated by Somali herdsmen. These two communities keep large numbers of livestock and the erratic nature of rainfall in the Tsavo Ecosystem leads to scarce resources. Tsavo East National Park did not report many instances of livestock inside, however the

spotting of livestock along the Tiva River indicates that water is an important pull factor in this otherwise water deficient area. It was evident that elephant hotspots overlapped cattle hotspots signifying sharing of common resources during the dry season.

Goats and other small browsers impact negatively on herbaceous vegetations and seedlings of most woody vegetation as they browse intensively. Whereas shoats' impact on the ecosystem may not be apparently noticeable like that of cattle, sustained regeneration of vegetation is affected. Donkeys and Camels are used as transportation means when fetching water and ferrying heavy luggage e.g. charcoal and building materials harvested from the PAs. Dogs are a potential sign of poachers as they are used to track wild game. All these are challenges to efforts toward conservation.

In search of water and pasture, livestock encroachment into the protected areas is forcing wildlife to share resources with livestock and human beings. Consequently, this leads to increase in human-wildlife conflict in adjacent protected areas and degradation of the protected area leading to habitat modification. This increases chances of invasive species colonization. In addition, risks of zoonotic diseases are increased.

6.6 Settlements and mining

Informal settlements signified by bomas and manyattas indicate that some of problems faced by conservation managers in the Tsavo Ecosystem are not from within the immediate area. These temporary structures closely related to livestock numbers have been known to increase during droughts. The negative impact of bomas and manyattas cannot be overemphasized. Clearing and burning of patches to put up these temporary structures is haphazard and leaves behind fragmented habitats which may not be suitable for wildlife in the long-term.

Permanent structures indicate areas where the land use practices are also to endure for a long time. The future for wildlife in these areas seems uncertain. Sewage and waste disposal in these areas is a serious threat to the health of the wildlife habitats as the water systems become polluted. Water is an essential requirement for a healthy wildlife population. Any effect on the quality of the water consumed by wildlife has adverse effects on the wildlife population dynamics therein.

Mining was concentrated inside and around the southern part of Tsavo West National Park. While efforts to separate illegal versus legal mining were not made, mining defaces landscapes by leaving behind gaping holes. These are potential sites for poachers, unplanned water sources and vegetation changes.

6.7 Illegal activities

Logging and charcoal burning are two illegal activities that seriously impact trees. Specifically, these two threats were recorded inside South Kitui National Reserve and northern parts of Tsavo East Nation Park that borders this reserve. In search of hard wood *Melia volkensii* (Kamba: Mukau) for fencing posts and calving sculptures, the Akamba community living around this area are responsible for this destruction. The Taita ranches and more so those ranches closer to the Mombasa-Nairobi highway were seriously affected by charcoal burning and logging. Charcoal is a bulky product and ease of transportation is vital for this business to boom. Interestingly, Tsavo West N.P is devoid of these illegal activities.

In order to manage the problem of logging and charcoal burning in the protected areas, four options are advanced. First, the status quo as it is today can be maintained. The consequence of maintaining the status quo situation is an expansion of the area under logging and charcoal burning leading to shrinking of wildlife habitats. In addition, the population of wildlife will decline due to increase of subsistence poaching. Subsistence poaching will increase as the loggers and charcoal burners will continue to kill wildlife to sustain their livelihoods while undertaking logging and charcoal burning. The second option is to fence the western boundary of South Kitui National Reserve with an electric fence as well as set up structures (human and physical) for the management of the reserve. This will ensure that humans are kept off the reserve. At the moment, people enter the northern part of Tsavo East National Park through the open and unmanaged South Kitui National Reserve. The third option is to fence the South Kitui National Reserve, have management structures in the reserve and an additional aircraft at Ithumba. This aircraft is to cover aerial patrols in northern parts of Tsavo East National Park and South Kitui National Reserve. The fourth option is to station an additional aircraft in Ithumba without fencing South Kitui National Reserve. At the moment, the entire Tsavo East National Park including south Kitui National Reserve is patrolled by one aircraft based at Voi. This overstretches the aircraft making air patrols in the far northern parts of Tsavo East National Park and South Kitui National Reserve not to be adequately patrolled.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The elephant population in Tsavo-Mkomazi ecosystem continued to increase although at a declining rate (2%) in the last three years. The buffalo's population in Tsavo West National Park showed a drastic decline. The reasons for this decline are not so far well understood. Further studies are needed to understand this population. Logging and charcoal burning continue to encroach into wildlife habitats in the Northern parts of Tsavo East National Park. If this is left unchecked, most of wildlife habitat in this area will be destroyed. Livestock incursions into the protected areas, especially Tsavo West National Park, are a threat to the Tsavo-Mkomazi ecosystem integrity.

7.2 Recommendations

The following is recommended:

i. The existing water pans in the protected areas within the ecosystem needs to be de-silted to be able to accumulate water throughout the year. These are to be distributed at a distance of not less that 10km from each other. In addition new water pans and dams needs to be established in the northern parts of Tsavo east national park. These areas have little water resources for wildlife.

ii. To control human encroachment in the northern parts of Tsavo East National Park and South Kitui National Reserve, a 150km electric fence needs to be constructed along the boundary of south Kitui national reserve, from Umbi to about 10km along the eastern boundary of Tsavo east.

iii. To control livestock encroachment in the southern parts of Tsavo East and West National Parks and other illegal activities in the ecosystem, the KWS top management (ECOM and board) needs to deliberate on the options provided above and adopt one of the options for implementation.

REFERENCES

Ayeni, J.S.O. (1974) Observation of waterhole utilization by wild game in Tsavo East National Park. MSc thesis, University of Nairobi, Nairobi, Kenya.

Belsky, A.J. 1987. The effects of grazing: confounding of ecosystem, community, and organism scale. *Am. Nat.* 129: 777-783.

Belsky,A.J.,Amundson,R.G.,Duxbury,J.M.,Riha,S.J.,Ali,A.R. and Mwonga,S.M.(1989) The effects of trees on their physical, chemical and biological environments in a semi-arid savannah in kenya. *Journal of Applied Ecology*, 26: 1005-1024.

Blanc,J.J.,Thouless,C.R.,Hart,J.A.,Dublin,H.T.,Douglas-Hamiliton,I.,Craig,G.C.and Barnes, R.F.W. (2007) *African elephant status report 2007: An update from the African Elephant Database.* Occasional paper of the IUCN Species Survival Commission No.33. Gland, Switzerland and Cambridge, UK: IUCN

Cobbs, S. (1976) The Distribution and Abundance of the Large Herbivore Community of Tsavo National Park. D.Phil. Thesis Univ. of Oxford.

Corfield, T.F. (1973) Elephant mortality in Tsavo National Park, Kenya. *East African Wildlife Journal.* 11: 339-368

Douglas-Hamilton, I. and Hillman, A.K. (1981) Elephant carcasses and skeletons as indicators of population trends in Low-level aerial survey techniques. ILCA Monograph

Douglas-Hamilton, I. Gachago, S., Litoroh, M., Mirangi, J. (1994) Tsavo Elephant Count 1994. Kenya Wildlife Service

Douglas-Hamilton, I. (1996) Counting elephants from the air: total counts. In: Kangawana, K.F. (ed.), Studying Elephants. AWF Technical Handbook Series Vol. 7.pp.28-37. Nairobi: African Wildlife Foundation.

ESRI (1997) Enterprise Spatial Data Management with SDE. ESRI ARC News, Summer, 1997, 8

ESRI. (2007) ArcGIS Desktop: Tools for authoring, editing, and analyzing geographic information. Redlands, CA: ESRI Press.

Fowler, J., Cohen, L. & Larvis, P. (1998) *Practical Statistics for Field Biology*. John Wiley and Sons, West Sussex, U.K.

Inamdar, A. (1996) *The Ecological Consequences Of Elephant Depletion*. Unpublished PhD thesis, University of Cambridge.

IUCN (1978) Results of an Aerial Census of the Tsavo National Park and Ecosystem. Typescript.

IUCN (2010) IUCN Red List of Threatened Species. Version 2010.4 www.iucnredlist.org

Kahumbu, P., Omondi, P., Douglas-Hamilton, I., King, J. (1999) Total Aerial Count of Elephants in Tsavo National Park and Adjacent Areas. Kenya Wildlife Service.

Laws, R.M. (1969) The Tsavo research project. *J.Repro. Fert. Suppl*. 6:495-531

Laws, R.M. (1970) Elephants as agents of habitat and landscape change in East Africa. Oikos 21, 1-15.

Leuthold, W. (1973) Recent Elephant Counts in Tsavo National Park. Tsavo Research Project. Typescript.

Leuthold, W. (1976) Age structure of elephants inTsavo National Park, Kenya. *Journal of Applied Ecology*, 13, 435-444.

Leuthold, B.M. (1978) Ecology of the giraffe in Tsavo East National Park, Kenya. East *African Wildlife Journal*, 16 (1):1-20. (Behavior and Ecology)

Leuthold, B.M., Leuthold, W. (1978) Ecology of the giraffe in Tsavo National Park, Kenya. *East Africa Wildlife Journal.* 16, 1-20

Milner-Gulland, E.J.and Beddington, J.R. (1993a) The exploitation of elephants for ivory trade: an historical perspective. *Proceedings Royall Society London (B)* 252: 29-37

Milner-Gulland, E.J.and Beddington, J.R. (1993b) The relative effects of hunting and habitat destruction on elephant population dynamics overtime. *Pachyderm* 17:75-90

Mitchell, C. (2009) *Status and distribution of Icelandic-breeding geese: results of the 2008 international census.* Wildfowl & Wetlands Trust Report, Slimbridge.

Mukeka J. (2010) Analyzing the distribution of the African elephant (*Loxodonta africana)* in Tsavo, Kenya. M.Sc thesis, Miami University,Oxford, Ohio, USA.

Napier Bax, p. and Sheldrick, D.L.W. (1963) Some preliminary observation on the food of elephants in Tsavo East National Park of Kenya. *East African Wildlife Journal* 1:40-53

Ngene, S.M., Skidmore, A.K., Van Gils, H., Douglas-Hamilton, I. and Omondi, P.O.M. (2009) Elephant distribution around a volcanic shield dominated by a mosaic of forest-savannah (Marsabit, Kenya). *African Journal of. Ecology*. 47, 234–245.

Olindo P, Douglas-Hamilton I, Hamilton P. (1988) Tsavo elephant count 1988. Nairobi: Wildlife Conservation and Management Department and Ministry of Tourism, Kenya.

Bitok, E., Omondi, P.O, and King, J. (2002) *Total aerial count of elephants and buffalo in the Tsavo/Mkomazi ecosystem* Nairobi: Kenya Wildlife Service.

Omondi, P. and Bitok, E. (2005) Total Aerial Count of Elephants, Buffalo & other species in the Tsavo/Mkomazi Ecosystem. KWS/ MIKE Programme Report.

Omondi, P., Bitok E.K., Mukeka, J., Mayienda, R.M. & Litoroh, M. (2008) Total aerial count of elephants and other large mammal species of Tsavo/Mkomazi ecosystem. Kenya Wildlife Service.

Tyrrell, H.G. and Coe, M.J. (1974) The rainfall regime of Tsavo National Park Kenya and its potential phonological significance. *Journal of Biogeography*. 1,187-192.

WCMD (1976) Report of Aerial Counts of Tsavo. Typescript.

Wijgaarden W. (1985) Elephants – trees- grazers: Relationship between climate, soil, vegetation and large herbivores in a semi-arid ecosystem (Tsavo, Kenya). ITC Publication #4.

Woodroffe, R. and Ginsberg, J. R. (1999) Conserving the African wild dog *Lycaon pictus*. Diagnosing and treating causes of decline. Oryx, 33: 132–142

Zar, J.H. (1996) Biostatistical Analysis. Prentice Hall, New Jersey, USA.

APPENDICES

Appendix 1: The Tsavo/Mkomazi total aerial census data Sheet for February 2011

SHEET NO.

Pilot							Block No.	
Front Seat Observer								
Rear Seat Observer(left)							Date	
Rear Seat Observer(right)								
Take off Time		Start count Time			Stop count Time		Land Time	
Way Point No.	Approx Dist. (M)	L/R	Species	Estimate	Frames	End Frame	Photo-count	Comments (Keep approx time)
					Mem card ID			

Appendix 2: Counting hours, scanning rates per block

Block No.	Location	Area (km^2)	Flight length(km)	Flight time(hrs)	Count effort (Hrs)	No. of planes / day	Scanning rates (Km^2 / hr)	Elephants
1	Other Areas	980.28	1960	11	3:58	1	273.8	3
2	Other Areas	955.86	1910	11	3:13	1	305.4	11
3	Tsavo West	451.25	902	5	4:25	1	106.2	208
4	Tsavo West	1088.39	2176	12	4:54	2	239.7	781
5	Tsavo West	653.94	1306	7	2:47	1	264.8	43
6	Tsavo West	1373.6	2746	15	9:04	2	151.9	281
8	Tsavo West	1644.81	3288	18	8:58	2	191.7	509
11	Taita	903.1	1806	10	6:08	1	148.5	182
13	Tsavo East South	804.6	1608	9	3:28	1	245.3	1325
14	Tsavo East South	729.21	1458	8	5:41	1	134.8	246
15	Tsavo East South	743.98	1486	8	5:59	1	133.1	736
16	Tsavo East South	988.36	1976	11	5:49	1	180.0	873
17	Tsavo East South	964.83	1928	11	6:40	1	150.8	940
18	Tsavo East North	865.34	1730	10	7:39	1	117.1	214
19	Tsavo East North	1425.77	2850	16	3:39	2	420.6	194
20	Tsavo East North	1523.54	3046	17	4:38	2	347.8	687
21	Tsavo East North	247.63	494	3	1:27	1	195.0	196
22	Tsavo East North	595.83	1190	7	4:14	1	143.9	68
23	Tsavo East North	1190.73	2380	13	1:00	2	1190.7	73
24	Other Areas	1680.09	3360	19	5:42	2	310.0	460
25	Other Areas	749.72	1498	8	5:57	1	134.6	

Block No.	Location	Area (km2)	Flight length(km)	Flight time(hrs)	Count effort (Hrs)	No. of planes/day	Scanning rates (Km2/hr)	Elephants
26	Tsavo East North	1409.72	2818	16	4:25	2	331.7	
27	Tsavo East North	1984.65	3968	22	11:36	3	174.7	662
10A	Taita	899.99	1798	10	7:50	1	120.0	437
10B	Tsavo West	917.76	1885	10	7:30	1	130.5	196
12A	Taita	1157.21	2314	13	7:20	2	160.7	579
12B	Taita	1835.49	3670	20	11:32	3	162.1	631
12C	Other Areas	2007.72	4014	22	6:23	3	322.3	
7A	Tsavo West	543.66	1086	6	3:14	1	173.1	123
7B	Taita	1482.1	2964	16	5:34	2	277.5	158
9A	Taita	595.35	1190	7	4:27	1	139.4	764
9B	Tsavo West	309.25	618	3	2:07	1	149.4	1
CW	Chyullu West	1880.61	3760	21	10:24	3	183.7	135
G1	Galana	1080.2	2160	12	3:44	2	314.0	
G2	Galana	1309.51	2618	15	11:09	2	118.1	10
G3	Galana	1240.28	2480	14	3:06	2	405.3	1
G4	Galana	1237.41	2474	14	5:34	2	231.7	199
G5	Galana	720.71	1440	8	5:47	1	131.8	188
G6	Galana	846.14	1692	9	5:54	1	152.7	
MC	Mkomazi	1150.92	2302	13	7:27	2	158.3	32
MN	Mkomazi	1135.22	2270	13	5:32	2	213.4	224
MS	Mkomazi	907.23	1814	10	3:15	1	288.0	
RB	Other Areas	1176.58	2352	13	5:30	2	222.0	35
SK	Other Areas	1930.27	1356		6:53	1	295.6	
	Total	48318.84	96645	537	251:33	71		

Appendix 3: Species codes used in recording data

CODE	SPECIES
BN	Baboon
BF	Buffalo
BB	Bushbuck
CH	Cheetah
CM	Colobus monkey
CC	Crown cranes
DD	Dik dik
DK	Duicker
ED	Eland
EL	Elephant
F	Elephant carcass fresh
O	Elephant carcass old
R	Elephant carcass recent
VO	Elephant carcass very old
FE	Fish eagle
FX	Fox
GN	Gerenuk
GR	Giraffe
GG	Grants gazelle
HP	Hippo
HR	Hirola
HY	Hyaena
IM	Impala
JK	Jackal
KL	Klipspringer
KG	Kongoni / Hartebeest
KB	Kori bustard
LK	Lesser kudu
LN	Lion
OX	Oryx
OS	Ostrich
RB	Reedbuck
SC	Secretary bird
TG	Thomson gazelle
TP	Topi
VM	Vervet monkey
WH	Warthog
WB	Waterbuck
WD	Wild dog
WL	Wildebeest
ZB	Zebra Common
ZG	Zebra Grevy

Appendix 4: List of participants in 2011 Tsavo-Mkomazi Ecosystem total elephant count

No.	Name	Organization	Role
1	Julius Kipngetich	KWS, HQs	Official sposkeman
2	James Isiche	IFAW	Official sposkeman
3	Samuel Kasiki	KWS, HQS	Official sposkeman
4	Julius Kimani	KWS, TCA	Official sposkeman
5	Patrick Omondi	KWS, HQs	Team leader/technical spokesman
6	Steve Njumbi	IFAW	Team leader/technical spokesman
7	Robert Obrien	KWS, NCA	Pilot
8	Richard Moller	SWT	Pilot
9	Danny Woodley	KWS, TCA	Pilot
10	Andrew Francobe	STE	Pilot
11	Kenneth Ochieng	KWS, CRCA	Pilot
14	George Mwangi	KWS, Lamu	Pilot
15	Moses Lelesit	KWS, TCA	Pilot
17	Erustus Kanga	KWS, HQS	Front seat observers
18	Shadrack Ngene	KWS, TCA	Front seat observers
19	Kenneth Kimitei	KWS, TCA	Front seat observers
20	A. Mbevi	KWS	Finance & procurement
21	Yusuf Watol	KWS	Front seat observers
20	Barbara McKnight	TER	Front seat observers
21	Lekishon Kenana	KWS, SCA	Front seat observers
22	Geoffery Bundotich	KWS, ECA	Front seat observers
23	Solomon Kyalo	KWS	Rear seat observers
25	Peter Mwangi	KWS, NCA	Front seat observers
26	David Kones	KWS, WCA	Front seat observers
27	Charles Musyoki	KWS, HQs	Front seat observers
28	Samuel Andanje	KWS, HQs	Front seat observers
29	David Kimtai	KWS, SCA	Front seat observers
30	Elephas Bitok	KWS, TCA	Rear seat observers
31	Malik Marjan	GOSS	Rear seat observers
32	Alexander Gombe	IFAW	Rear seat observers
34	Ian Sounders	Sheldrick	Rear seat observers
35	Christine Boit	KWS, TCA	Rear seat observers
35	Donat Mnyagatwa	TANAPA	Other guests
36	Jake Wall	STE	Front seat observers
41	Joseph Mukeka	KWS,HQS	GIS personnel and data entry
42	Paul Udoto	KWS,HQS	Communications & multi media
43	Elizabeth Wamba	IFAW	Communications & multi media
44	Duncan Willetts	IFAW	Communications & multi media
45	Peter Karanja	IFAW	Communications & multi media
46	Rupi Mangat	IFAW	Communications & multi media

No.	Name	Organization	Role
47	Charles Ooro	KWS,HQS	Communications & multi media
48	Isaac Peroh	IFAW	Finance & procurement
70	Daniel Kassam	KWS,TCA	Finance & procurement
49	Beatrice Owayo	IFAW	Registration & accommodation
50	Kentice Tikolo	KWS, HQs	Communications & multi media
12	Peter Zannetti	Private	Pilot
13	Mrs. V.M.Zannetti	Private	Rear seat observer
13	Patricia Awori	PAWCN	Guest
51	Jeremino Lepirei	STE	Rear seat observer
52	Bernard Lesowapir	STE	Rear seat observer
23	Stephen Ndambuki	KWS, SCA	Front seat observer
24	Sospeter Kiambi	KWS, CRCA	Front seat observer
53	Samuel Amanya	UWA	Rear seat observer
54	John Muhangi	UWA	Rear seat observer
53	Fredrick Lala	KWS. WCA	Rear seat observer
54	Onesmus Kahindi	STE	Front seat observer
55	Samuel Muli	KWS,TCA	Rear seat observer
56	Julius Kabete	KWS,TCA	Rear seat observer
57	Nicholas Bojo	GOSS	Rear seat observer
58	Dr. Lazarus Ando	GOSS	Rear seat observer
59	Julius Muriuki	ACC	Rear seat observer
60	Jimmy Nyamu	ACC	Rear seat observer
61	Joseph Edebe	KWS, HQS	Rear seat observer
62	Festus Ihwagi	STE	GIS personnel and data entry
81	Helen Kezengwa	KWS	Registration & accomodation
64	Jeniffer Olang	KWS	GIS personnel and data entry
81	Christine Ndinda	KWS	GIS personnel and data entry
101	Warda Kamila	VOLUNTEER	GIS personnel and data entry
82	Judith Njuguna	STE	GIS personnel and data entry
66	Rose Malenya	KWS,TCA	Rear seat observer
67	John Kaaya	WD, TZ	Rear seat observer
68	Honori Maliti	TAWIRI	Guest
69	Kiplimo Wekesa	KWS,TCA	Transport
70	Timothy Raburu	DRSRS	Front seat observer
71	Moses Mungai Warira	KWS,TCA	Transport
72	Peter Kipkemoi	KWS,TCA	First aid
73	Daniel Muteti	KWS,SCA	GIS personnel and data entry
74	John Munywoki	KWS,TCA	GIS personnel and data entry
75	Peter Hongo	KWS,HQS	GIS personnel and data entry
76	Moses Maloba	KWS,HQS	GIS personnel and data entry
77	Francis Muthoni	ITC	GIS personnel and data entry
78	Stephen Karanja	KWS, HQs	GIS personnel and data entry

No.	Name	Organization	Role
79	KWS SCA Driver	KWS,HQS	Transport
80	Fridah wanjala	KWS,TCA	GIS personnel and data entry
109	Rebecca Washuka	VWL	GIS personnel and data entry
110	Justina Njeri Muingai	KWS,TCA	Human capital issues
110	Justina Njeri Muingai	KWS,TCA	Human capital issues
83	Daniel Chepkwony	KWS,TCA	Finance & procurement
84	Oswald Sagawe	KWS,TCA	Security & other administrative duties
85	Roseline Kamala	JUDICIARY	Guest
86	Njeri Khaumba	JUDICIARY	Guest
64	Martha Nzisa	KWS,TCA	Rear seat observer
102	Christine Mwinzi	KWS	Rear seat observer
87	Steven Nyaga	KWS, TCA	Rear seat observer
88	Samuel Chege	TER	Rear seat observer
89	Benedit Ndambuki	TER	Rear seat observer
90	TCA Research Driver	KWS,TCA	Transport
91	Bus Driver	KWS,TCA	Transport
92	Community Driver	KWS,TCA	Transport
93	Sammy Muya	KWS,TCA	GIS personnel and data entry
94	Haustings Syengo	KWS,TCA	GIS personnel and data entry
95	Boniface Oyugi	KWS,TCA	Rear seat observer
96	Eng Samson Sanare	KWS,HQS	Aircraft engineers & attendant
97	Christoper Muithinia	KWS,HQS	Aircraft engineers & attendant
98	Antony Mwangangi	KWS,HQS	Aircraft engineers & attendant
106	KWS HQs Driver	KWS,HQS	Transport
107	Driver-Security	KWS,TCA	Transport
108	Katsumi Miura	JICA Volunteer	Telecommunication
37	Shelley Waterland	BORN FREE	Guest
38	Andrew Skidmore	ITC	Guest
39	Linus Nyakundi	JUDICIARY	Guest
121	John Manguye	CCK	Community representatives
122	Josiah Ole Kores	CCOLK	Community representatives
122	Laban Tole	CCT	Community representatives
124	Ansali Sanguli Mwakio	MCV	Community representatives
99	Jane Ndugu	Egerton University	GIS personnel and data entry
100	Lucy Gitau	DRSRS	GIS personnel and data entry
125	Mcharo Bongosa	TTRA	Community representative
126	Robinson Mwaluma	TTWF	Community representative

Appendix 5: The number of elephant carcasses counted in Tsavo-Mkomazi ecosystem in 2011 and other years (1991-2008)*.

	2011		2008		2005		2002		1988		1989		1994		1999	
	Old	Rec	Old	Rec	Old	Rec	Old	Rec	Old	Rec	Old	Rec	Old	Rec	Old	Rec
Tsavo East NP North	151	14	7	2	22	3	68	2	848	47	547	86	700	0	122	3
Tsavo East NP South	149	9	16	2	19	2	51	2	389	5	238	11	142	0	63	1
Tsavo West NP	119	11	24	1	58	1	39	1	360	6	188	2	178	0	83	2
Chyulu NP	4	0	2	0												
South Kitui NR			0	0												
Galana	43	4	1	0	13		30	7	368	57	267	15	157	0	65	
Taita	31	12	1	6	11		51	1	92	22	264	1	100	0	61	
Mkomazi NP	3		1	0	4		15	0	133	12	92	0	54	0	77	
Others	13		11	1	5		34	1	69	13	41	0	30	0		
*Rombo	0	0	0	0	1											
Outside	4	0	0	0	33		130		2259	162	664	16	341	1	153	

*Blank represents periods when no aerial census took place in respective locations. R = recent, O = old, N = north, S = south, NP = national park, nr = national reserve. Note that old carcasses include very old and old carcasses whereas recent cases include fresh and recent carcasses.

Appendix 6: Sum of species counted in the different zones of Tsavo Conservation Area under various managements (February 2011)

	Tsavo East NP(N)	Tsavo East NP(S)	Tsavo West NP	Chuyu NP	Galana Ranch	Taita Ranches	Mkomazi NP	South Kitui NR	Outside TCA	Other Areas	Grand Total
Elephants	2094	4120	2142	135	398	2751	256		168	509	12573
Fresh carcass	2		1		2	2					7
Recent carcass	12	9	10	0	2	10					43
Old carcass	78	107	80	2	24	23	1			4	319
VO carcass	73	42	39	2	19	8	2		4	9	198
Buffalo	2613	3142	641		44	797	121		4	44	7406
Cattle	3810	3932	27054	12373	4460	39586	5085	885	2409	16204	115798
Shoats	3145	763	2995	9120	1502	8504	790	4255	4130	34087	69291
Donkey	2		10	23		28		3	11	33	110
Camel	90			13		1975		927	213		3218
Plains zebra	494	955	2248	890	124	960	195		25	835	6726
Grevy's zebra	29	3				15					47
Eland	63	155	403	200	20	247	266			154	1508
Bush buck	1	5					2			1	9
Gazelles	60	59	102	348	26	55	5	0	4	79	738
Gerenuk	31	11	35	12	24	5	4	2			124
Giraffe	170	222	691	292	93	282	120	6	1	178	2055
Hartebeest	75	338	237	19		144	62		22	29	926
Hippo	32	24	23							40	119
Hirola		11									11
Hyaena	1	3		3			1				8
Impala	45	159	253	178	5	74	11			42	767
Lesser kudu	64	11	68	10	9	102	14	2		1	281
Oryx	397	209	606		179	159	23	13		2	1588
Reed-buck			1								1
Rhino		1									1
Topi	2										2
Water-buck	16	118	91	221	5	15				2	468

	Tsavo East NP(N)	Tsavo East NP(S)	Tsavo West NP	Chuyu NP	Galana Ranch	Taita Ranches	Mkomazi NP	South Kitui NR	Outside TCA	Other Areas	Grand Total
Warthog	15	60	84		15	72	3		4	19	272
Wildebeest			239	33						61	333
Baboon	20	14	34		12	105	42			30	257
Cheetah										400	400
Crocodile	14	7	1								22
Jackal			1	2	1						4
Lion		1	1	3	2						7
Ostrich	42	181	242	64	12	62	40	3		10	656