Status and trends of the elephant population in the Tsavo–Mkomazi ecosystem

Shadrack Ngene,[1] Steve Njumbi,[2] Martha Nzisa,[1] Kenneth Kimitei,[1] Joseph Mukeka,[3] Shadrack Muya,[4] Festus Ihwagi [5] and Patrick Omondi [6]*

[1] Kenya Wildlife Service, Biodiversity Research and Monitoring, Tsavo Conservation Area, PO Box 14, Voi, Kenya
[2] International Fund for Animal Welfare, PO Box 25399 – 00603, Nairobi, Kenya
[3] Kenya Wildlife Service, Biodiversity Research and Monitoring, GIS Unit, PO Box 40241 – 00100, Nairobi, Kenya
[4] Jomo Kenyatta University of Agriculture and Technology, PO Box 62000 – 00200, Nairobi, Kenya
[5] Save the Elephants, PO Box 54667 – 00200, Nairobi, Kenya
[6] Kenya Wildlife Service, Biodiversity Research and Monitoring, Species Conservation and Management, PO Box 40241 – 00100, Nairobi, Kenya
*Corresponding author email: sngene@kws.go.ke or ngene@itc.nl

Abstract

This paper updates the data on the population status of elephants in the Tsavo–Mkomazi ecosystem. Data were acquired through aerial census of elephants in the ecosystem, from 7 to 12 February 2011. The census covered an area approximately 48,319 km^2, which was divided into 44 counting blocks. Each block was assigned to a specific aircraft; the crew consisted of a pilot, front-seat observer and two rear-seat observers for the four-seater light aircraft, and a pilot and an observer for a two-seater light aircraft. The census lasted five days and involved nine light aircraft and about 252 hours of actual counting time, representing a mean search rate of about 191 km^2/hr. A total of 12,573 elephants were counted, indicating a modest increase of 2% after the 2008 census and a 96% increase after the 1988 census (n = 6,399). Most elephants (69%, n = 8,614 individuals) were counted inside the protected areas; about 31% (n = 3,859 individuals) were outside protected areas. About 50% of the elephants (n = 6,214) were in Tsavo East National Park, 22% (n = 2,751) in the Taita ranches and 17% (n = 2,142) in Tsavo West National Park. A programme of providing water to elephants in the northern parts of Tsavo is recommended as well as electric fencing and establishment of administration and security structures at South Kitui National Reserve. This will create more space for the increasing population of elephants as well as improve their security.

Additional key words: aerial census, carcass, drought

Résumé

Ce document met à jour les donnés sur la situation des populations d'éléphants dans l'écosystème de Tsavo-Mkomazi. Les données ont été acquises grâce à un recensement aérien des éléphants dans l'écosystème, du 7 au 12 février 2011. Ce recensement a couvert une superficie d'environ 48.319 km^2, qui était divisée en 44 blocs de comptage. On avait assigné à chaque bloc un avion spécifique, l'équipage étant composé, pour l'avion léger à quatre places, d'un pilote, d'un observateur sur le siège avant et de deux observateurs sur le siège arrière, et pour un avion léger biplace, d'un pilote et d'un observateur. Le recensement, auquel ont participé neuf avions légers, a pris cinq jours et environ 252 heures de temps de comptage réel, ce qui représente un taux de recherche moyen d'environ 191 km^2/heure. Un total de 12.573 éléphants ont été dénombrés, ce qui indique une légère augmentation de 2% après le recensement de 2008 et une augmentation de 96% après le recensement de1988 (n = 6.399). La majorité des éléphants (69%, n = 8.614 éléphants) ont été comptés à l'intérieur des aires protégées; environ 31% (n = 3.859 éléphants) étaient en dehors des aires protégées. Environ 50% des éléphants (n = 6,214) étaient dans le Parc national de Tsavo-Est, 22% (n = 2,751) dans les ranchs de Taita et 17% (n = 2,142) dans

le Parc national de Tsavo Ouest. Un programme d'approvisionnement en eau pour les éléphants au nord de Tsavo est recommandé ainsi que les clôtures électriques et une mise en place des structures administratives et sécuritaires dans la Réserve nationale du sud-Kitui. Cela va créer plus d'espace pour l'augmentation de la population d'éléphants ainsi qu'améliorer leur sécurité.

Mots clés supplémentaires : recensement aérien, carcasse, sécheresse

Introduction

The Tsavo ecosystem is home to Kenya's largest elephant population (Blanc et al. 2007). This population was over 35,000 animals by the end of 1974 (Cobb 1976) and about 11,733 in 2008 (Omondi et al. 2008). The 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, as had happened during the unusually dry conditions of 1970 and 1971 that led to elephant mortality of unanticipated magnitude. Between 6,000 and 9,000 elephants died in the eastern sector of Tsavo National Park (Corfield 1973; Cobb 1976).

The ecosystem has been the subject of detailed sample and total aerial counts since the early 1960s. Recent total counts include Olindo et al. (1988), Douglas-Hamilton et al. (1994), Kahumbu et al. (1999), Omondi et al. (2002), Omondi and 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 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% decline in the adjacent non-protected areas since the 1972 total counts (Olindo et al. 1988). Two major factors have contributed to the observed overall continental decline of elephant numbers: reduced carrying capacity of Africa for elephants due to habitat change, and hunting for ivory (Milner-Gulland and Beddington 1993a,b). Since 1988, there has been a steady increase in elephant numbers. 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 had taken place in the heart of the reserves in the early 1980s. The distribution of elephants in 1989 confirmed that elephants previously counted along the periphery had moved further inside the parks. 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%. Despite this, the 1989 count was the first authoritative confirmation that the elephant population was on a recovery course, a trend observed till 2008.

The 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, from 8,068 to 9,284 (Kahumbu et al. 1999). Fifty percent (n = 10) of the recent carcasses were recorded in Galana, where poaching pressure was high in the 1970s and 1980s. The figure could have been an underestimate as the thick vegetation may have obscured some carcasses. The census noted a remarkable increase in livestock in the protected areas from about 820 animals in 1999 to about 5,190 animals in 2002 (Omondi et al. 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 large discrepancies observed between sample and total counts in the 1970s. Over the years, elephant densities varied considerably both by 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 and Bitok 2005; Omondi et al. 2008). Surface water availability and security are believed to be the major factors influencing elephant distribution. In 2002, a dramatic shift in elephant distribution was observed between Tsavo East north and Tsavo East south, as the former had received more rainfall prior to the count (Omondi et al. 2002). Understanding these ecosystem-use dynamics by elephants and other large mammals is important in their management.

The goal of the 2011 aerial survey was to sustain the long-term aerial monitoring of elephants in the 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. Therefore, it is important to continue with the tri-annual aerial census of elephants in the Tsavo–Mkomazi ecosystem. The information generated will show the number, density and distribution of elephants in the ecosystem. The information will be used by park managers and policymakers to make management decisions regarding the management of emerging trends and distribution of elephants in the ecosystem.

Materials and methods

Study site

The Tsavo–Mkomazi ecosystem consists of an area of about 48,319 km^2 (Cobb 1976). The ecosystem lies between 2–4°S, and 37.5–39.5ºE. Common rivers traversing the ecosystem include Galana, Voi, Tiva, Tsavo and Athi (Figure 1).

The ecosystem's mean annual rainfall varies locally between 250 and 500 mm (Leuthold 1978). Most of the rain falls in two rainy seasons: in March–May and November–December (Tyrrell and Coe 1974); June through October constitutes a long dry season (Leuthold 1978).

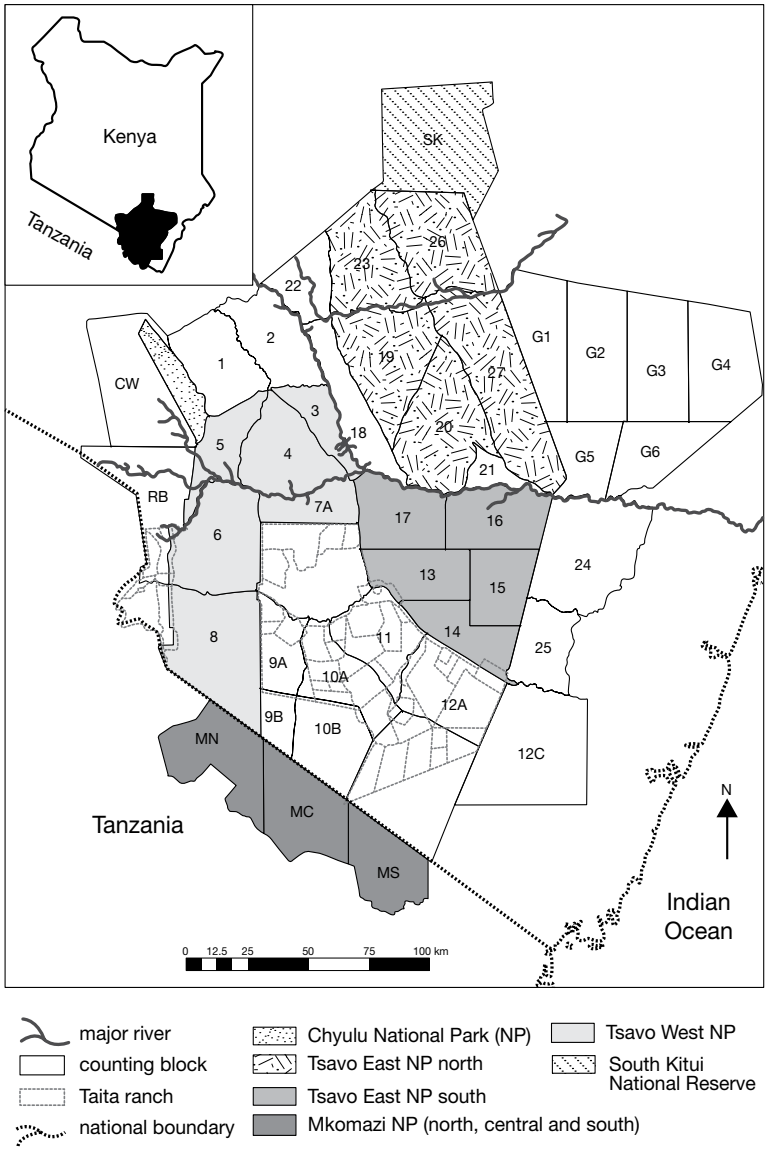

Figure 1. Counting blocks used during the aerial count of elephants and other large mammals in the Tsavo–Mkomazi ecosystem (7–12 February 2011). Blocks 7B, 9A, 10A, 12B and RB cover the Taita ranches, blocks G1–G6 represent Galana ranches, blocks 24 and 25 represent other ranches east of the ecosystem, and blocks 13, 14 and 15 represent the Ndii–Ndara plains. (Source: KWS, 2011.)

The terrain of the Tsavo–Mkomazi ecosystem is generally flat and undulating in the southeastern and northern sections (Leuthold 1978). Mukeka (2010) provides a detailed description of the ecosystem's terrain. Generally, the area lies about 300–500 m above sea level. The soils of the Tsavo–Mkomazi ecosystem show a wide range in depth, colour, drainage condition, structure and chemical and physical properties. The soils are rich in quartz and ferruginous gravel, with finer sand cemented by a red lateritic crust. Sand and gravel of the alluvial soils are cross-bedded together along the river loops of the Galana (Leuthold 1978).

The vegetation consists of remnants of formerly extensive *Commiphora–Acacia* woodlands that

have been destroyed or at least thinned out by elephants (Cobb 1976). The vegetation communities in the ecosystem are described in detail by Napier-Bax and Sheldrick (1963), Laws (1969, 1970), Tyrrell and Coe (1974) and Mukeka (2010).

The major herbivores are elephant (*Loxodonta africana*), African buffalo (*Syncerus caffer*), eland (*Taurotragus oryx pattersonianus*), fringe-eared oryx (*Oryx beisa callotis*), Coke's hartebeest (*Alcelaphus buselaphus cokii*), Burchell's zebra (*Equus burchelli*), impala (*Aepyceros melampus*), giraffe (*Giraffe camelopardalis)* and Grant's gazelle (*Gazella granti)* (Cobb 1976).

Census blocks design

The aerial count followed the method described by Douglas-Hamilton (1996). The aircraft consisted of two-seater crew Supercabs or four seater crew Cessnas. Forty-four counting blocks, as designed for previous censuses, were adopted for ease of comparing findings. Flight lines of 1-km spacing were designed to ensure 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 1,098 km² (SE = ±445 km²; n = 44). The smallest block (block 21) measured 248 km² and the largest (block 12C) 2,008 km². In the larger blocks, two planes were deployed to count simultaneously to ensure counting was completed within a day.

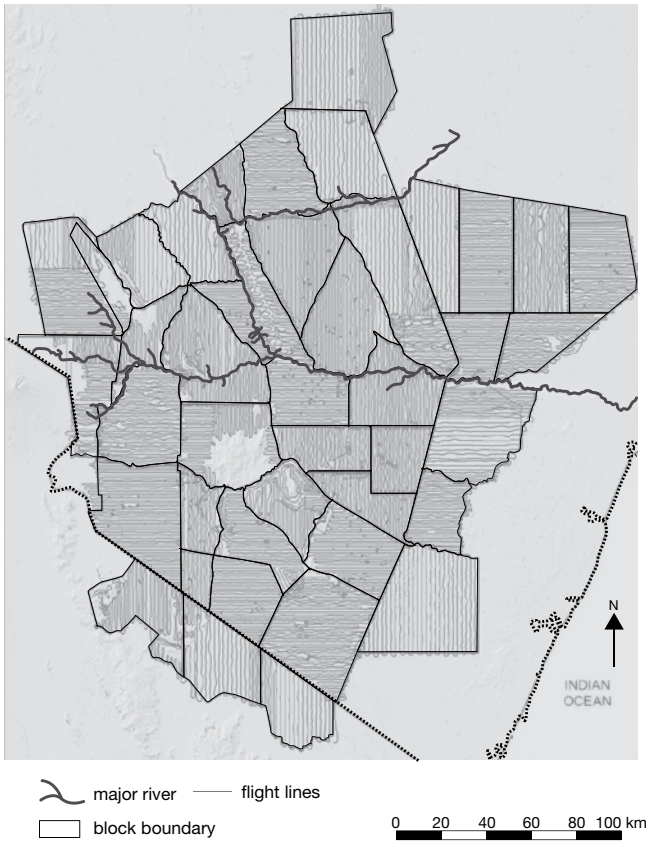

Figure 2. Flight lines used during the aerial count (7–12 February 2011) in the Tsavo–Mkomazi ecosystem.

Aircraft and crew

Nine fixed-wing aircraft (Cessna and Husky) with high wings to give an unobstructed ground view were used during the six-day event. The crew comprised a pilot and one front-seat observer for a two-seater aircraft, and a pilot, one front-seat observer and two rear-seat observers for a four-seater aircraft. Each team was given the flight maps of assigned blocks the evening before to allow the team to plan for the next day. A geographical positioning system (GPS) was used for navigation and to record waypoints and flight paths. The GPS units were set to Universal Transverse Mercator kilometre grids on both north and south axes. The teams took off at dawn, ensuring that counting started before the day got hot. Parallel lines were flown, whose interval was determined by the front observer and the pilot based on terrain and visibility. Fuel was strategically distributed in the various airstrips in the ecosystem for convenience of refuelling from blocks distant from the counting centre. In a few blocks, the topography influenced the flight paths as rugged terrain was avoided.

Data recording and cleaning

The aerial census took place from 7 to 12 February 2011. Most of the crew members were highly experienced. Test flights were conducted a day before the actual counting commenced to familiarize and refresh the crew. Speeds of approximately 130–180

km/hr and heights of about 200–400 ft (60–120 m) 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 1–2 km 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', and the third and fourth as 'old'. Standard codes were used to denote elephants and the different categories of carcasses. Front-seat observers cleaned the data sheets when necessary before handing them over to the data entry team. Waypoints and tracks were downloaded onto ArcGIS 9.3. The tabulated species data were added onto the ArcGIS software and a spatial join was created based on the waypoint (Mitchell 2009). 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 for analysis and preparation of distribution maps.

Data analysis

For regression analysis, data were pooled for areas that were consistently surveyed from 1988 to 2011. These areas included Tsavo East (north), Tsavo East (south), Tsavo West, Mkomazi NP, and 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 observed rate of population increase ($\bar{r}$) was calculated from the natural logarithms of the total number of elephants counted in 1988 and 2011 using the formula (Caughley 1977):

$$\bar{r} = log_e N_t - log_e N_0$$

where log_e = natural logarithm; N_t = total number of elephants counted in 2011; N_0 = total number of elephants counted in 1988.

The orientation of elephant distribution and the centre of their concentration were analysed 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 analysed for elephants. We tested for the general distribution patterns of the elephants using the Getis-Ord general G statistic as described by Mitchell (2009). The distribution of different herd sizes was mapped using the hot/cold-spot analysis; Getis-Ord Gitrations of large (hot spots) and small (cold sports) groups of elephants were sighed during the aerial survey (Esri 2007; Mitchell 2009). *Z* scores were used for interpretation of significance levels of statistical tests (Zar 1996). High positive *Z* score indicates a higher clustering for locations with large numbers of elephants while negative *Z* score indicates clustering of areas with small groups of elephants. The results were interpreted as described in detail by Mitchell (2009).

To analyse the relationship between elephant 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 (Mukeka 2010). A simple density surface for water pans (dry and wet) and distance surface for rivers was 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 2007). Then the extracted values were exported into an 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 an index of the previous year's mortality (Douglas-Hamilton 1996), noting that 2009 to early 2010 was marked by a severe drought.

Results

Aerial census effort

A total of about 252 hours of actual counting time was spent during the census. This represents a mean search rate of about 191 km^2/hr or 5.2 hours for every 1,000 km^2 in a counting area of about 48,319 km^2. The search rate was more intense than the aerial counts in 1988, 1994 and other preceding counts (see Olindo et al. 1988; Douglas-Hamilton et al. 1994; Omondi et al. 2002; Omondi and Bitok 2005; Omondi et al.

2008) although the difference in the number of hours spent per 1,000 km² during this census and those of past aerial census (1988 to 2008) was not statistically significant.

Status and trends of elephants

The estimate for the February 2011 aerial census was 12,573 elephants in the Tsavo–Mkomazi ecosystem, representing a modest increase of about 2% in the last three years (Table 1). Of these elephants 69% (n = 8,614) were counted inside the parks and 31% (n = 3,859) outside the parks. About 50% (n = 6,214) of the elephants were in Tsavo East NP, 22% (n = 2,751) in the Taita ranches and 17% (n = 2,142) in Tsavo West NP (Table 1). The number of elephants increased from about 6,399 in 1988 to about 12,573 in 2011, which represents a 96% increase in 23 years. From 1999 (n = 9,447), the population increased by 33%. 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). The estimated observed rate of population growth over the 23-year period was 0.68, representing an approximate annual growth rate of 0.03.

Distribution and density of elephants

Figure 4 shows the distribution of elephants in the ecosystem. Most of the herds were found in Tsavo East NP, within about 45 km north and south of the Galana River. High densities of about 1 elephant/km² were recorded in Tsavo East NP, south of the Galana River (Figure 5).

The elephants exhibited a highly clustered distribution (Z score = 5.36, P = 0.01, critical value = 2.58). Taita ranches have the largest herds of elephant concentration while the smallest herds are found in Tsavo East north of the Galana River. The mean centre of the distribution was within the Ndara plains in Tsavo East NP, south of the Galana River (Figure 6). Elephants occurred as individuals (n = 213

Table 1. Elephants counted in the Tsavo–Mkomazi ecosystem from 1962 to 2011 (no.)

Area	2011	2008	2005	2002	1999	1994	1991	1989	1988	1978*	1973	1972	1970*	1969*	1965*	1962
Tsavo East (N)	2,094	4,118	2,499	4,089	1337	399	450	134	770	220	9,011	6,435	0	6,619	8,056	4,073
Tsavo East (S)	4,120	3,731	3,896	2,087	3221	2,733	3,436	3,020	2,283	2,469	3,955	6,633	6,008	5,709	4,744	1,358
Tsavo West	2,142	2,161	2,626	2,168	2,119	3,132	1,233	2,106	1,274	1,938	9,208	4,328	6,592	8,134	2,238	1,394
Chyulu NP	135	131	–	–	–	–	–	–	–	–	–	–	–	–		–
South Kitui NR	0	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–
Mkomazi NP	256	8	41	63	77	302	131	11	93	667		2,067	–	–	–	–
Galana	398	308	11	14	27	46	50	74	90	1,076	500	4,379	–	2,964	–	3,540
Taita	2,751	1,108	1,292	828	1,245	287	1,413	642	853	79	–	1,235	–	500	–	–
Rombo	0	0	31	2	12	446	–	193	–	–	–	–	–	–	–	–
Other blocks	509	130	1	35	30	26	50	46	–	–	–	300	100	–	–	–
Outside	168	38	1,376		1,391	1,107	1,644	966	1,036	–	–	–	–	–	–	–
Total (parks)	8,614	10,149	9,062	8,344	6,754	6,566	5,250	5,271	4,420	5,294	22,174	19,463	12,600	20,462	15,038	6,825
Total (non-parks)	3,959	1,584	2,680	940	2,693	1,466	3,157	1,728	1,979	1,155	500	5,914	100	3,464	–	3,540
Total	12,573	11,733	11,742	9,284	9,447	8,032	8,407	6,999	6,399	6,449	22,674	25,377	12,700	23,926	15,038	10,365

Source: Leuthold 1973; Olindo et al. 1988; Douglas–Hamilton et al. 1994; Kahumbu et al. 1999; Omondi et al. 2008

* Data in that year were acquired using the sample counts method; in years without *, data were acquired using the total count method. From 1999 to 2011, data were collected in late January or early February (dry season); from1962 to 1994 data were collected in June, immediately after the April–May wet season.

N = north, S = south, NP = national park, NR = national reserve.

– Periods when no aerial census took place in the location.

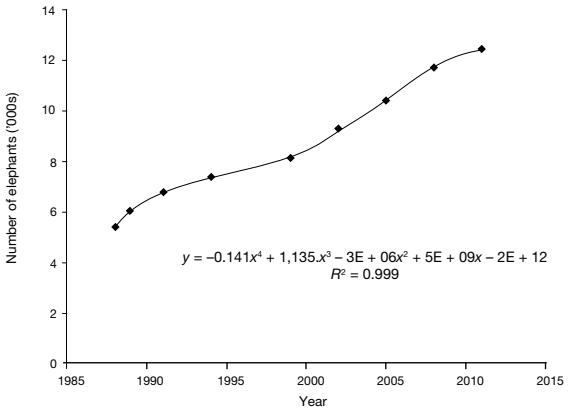

Figure 3. Total aerial count estimates of the Tsavo–Mkomazi ecosystem elephant population, 1988–2011.

herds) or in groups (n = 1,195 herds). The herd sizes ranged from 2 to 189 animals with ±95% confidence interval of herd sizes being 10–11 elephants. The observed and expected size of elephant herds was significantly different (X^2 = 1,725, df = 9, P < 0.05). Larger herds of elephants were found in the Taita ranches, southern parts of Tsavo West NP (Njukini and Jipe areas) and north Mkomazi NP (Figure 7). The smallest herds of elephants were counted north to northeast and south of the Galana River in Tsavo East NP (Figure 7). High densities of elephants occurred close to wet water pans and rivers; 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). There was a weak negative relationship between elephant density and distance to water pans (r = 0.37; n = 1408; P < 0.05).

Number, density and distribution of elephant carcasses

A total of 567 elephant carcasses were recorded during this census. Table 2 provides a summary of the number of carcasses counted during the aerial census, including the carcass ratio. In 2008 there were only 8 recent carcasses; in 2011, 48 recent carcasses were seen, 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 0.031–0.037 km^2) was recorded in Tsavo East NP south of the Galana River (Figure 8), and modest (about 0.02 km^2) and lowest (0.001–0.008 km^2) carcass densities were recorded in Tsavo East NP north of the Galana River and Tsavo West NP; and, the rest of the remaining areas (Figure 8). Figure 9 provides a summary of the general distribution of the elephant carcasses according to age class in the Tsavo–Mkomazi ecosystem.

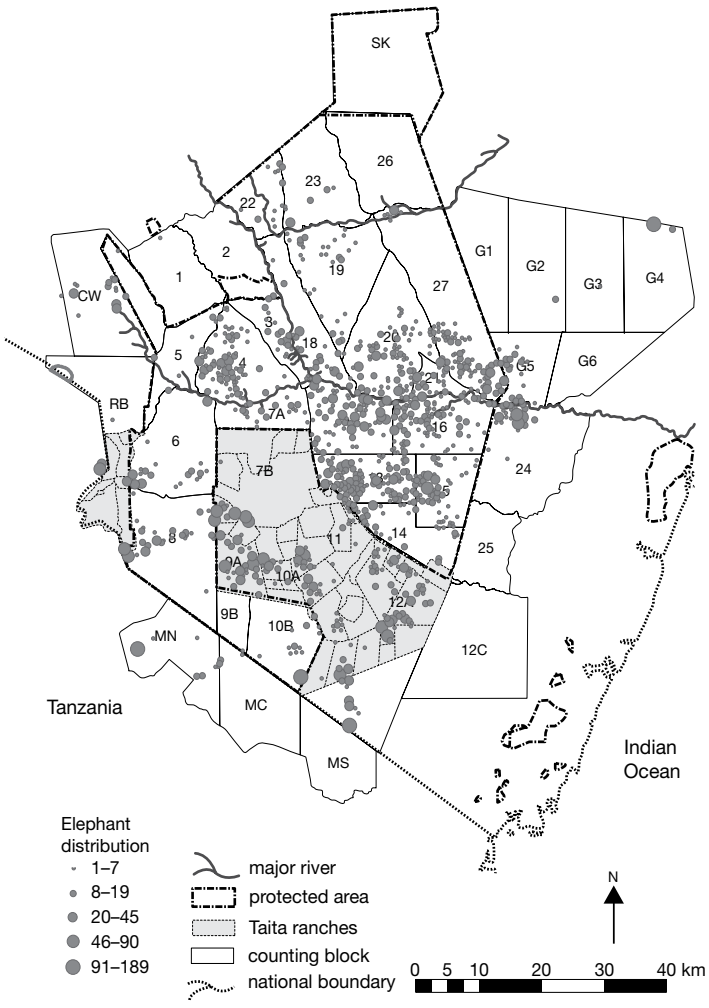

Figure 4. Distribution of elephant herds in the Tsavo–Mkomazi ecosystem. No elephants were counted in South Kitui National Reserve (SK).

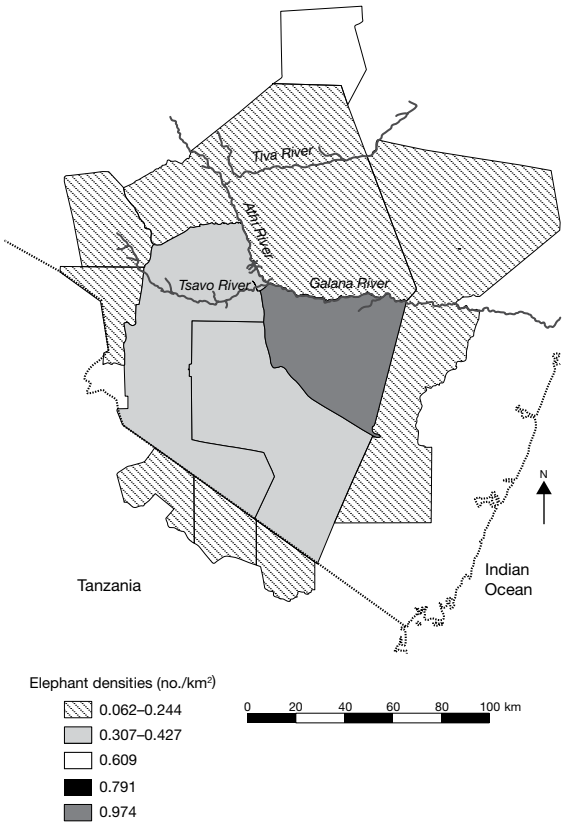

Figure 5. Elephant densities in the Tsavo–Mkomazi ecosystem (7–12 February 2011).

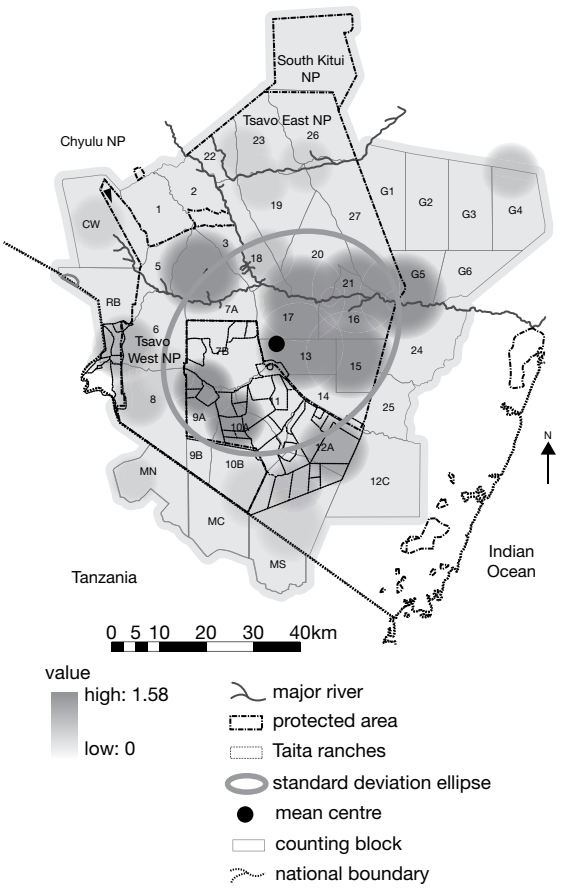

Figure 6. Kernel density of elephants in the Tsavo–Mkomazi ecosystem; mean centre and standard deviational ellipses based on data collected 7–12 February 2011. (J Mukeka, KWS GIS section)

Table 2. Elephants and elephant carcasses counted in theTsavo–Mkomazi ecosystem (no.), 1988–2011

Year	Elephants (no.)	Recent dead (no.)	Total dead (no.)	Carcass ratio (dead/dead plus live) (%)	Std 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

Old carcasses are calculated by subtracting recent dead from total dead. The old carcasses include 'very old' and 'old' carcasses; recent dead include 'fresh' and 'recent' carcasses.

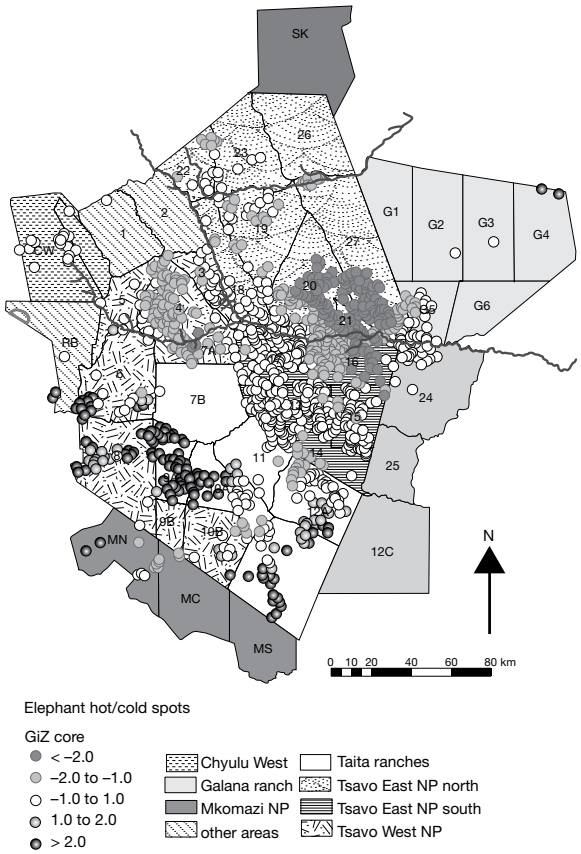

Figure 7. A hot spot analysis of the locations with different sizes of elephant herds in the Tsavo–Mkomazi ecosystem. Large herds of elephants (*Z* score = > 1.0) were recorded in the Taita ranches, northern parts of Mkomazi NP and southern and western parts of Tsavo West NP. High positive values of *Z* scores indicate locations where large groups of elephants occurred (hot spots) whereas low negative values of *Z* scores indicate where smaller groups of elephants (cold spots) were sighted during the aerial survey.

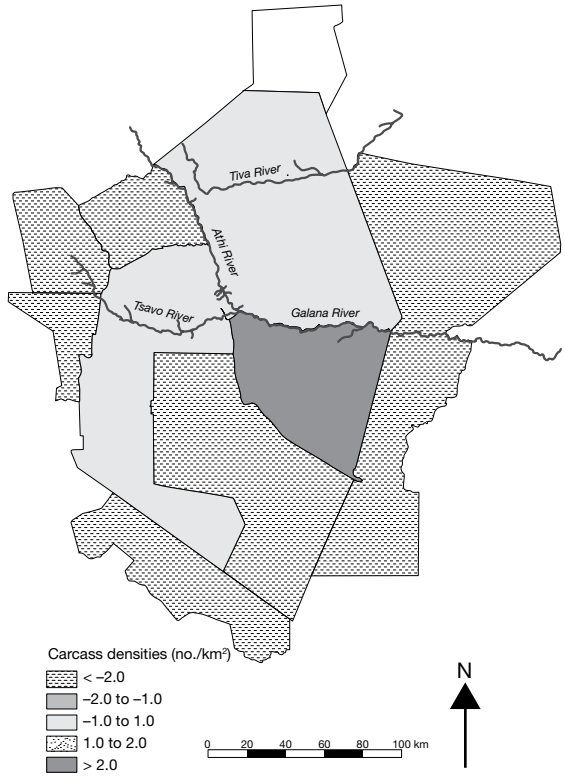

Figure 8. Elephant carcass densities (no./km²) in the Tsavo–Mkomazi ecosystem (early February 2011).

Discussion

The results revealed that the population of elephants in the Tsavo–Mkomazi ecosystem increased from 11,733 in 2008 to 12,573 in 2011, representing a 2% increase in three years. Compared with the rate of increase between 2005 and 2008 (4%), this represents a 2% decrease in population change between 2008 and 2011. The decreasing rate of increase could be attributed mainly to natural mortality (Figure 10). The data indicate that natural causes of elephant deaths were high between 2008 and 2010 (84%, n = 674) compared with deaths from 2005 to 2007 (16%; n = 131). 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 in previous years (Figure 10). Of the 674 elephant carcasses reported in the study area between 2008 and 2010, 86% (n = 576) had the two tusks recovered, 1% (n = 9) had one tusk recovered and 13% (n = 89) had no tusks recovered (KWS-TCA 2011). Also, most of the carcasses were classified as 'old' (91%, n = 517), a category for elephants that had been dead for more than one year (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 in the starvation of many elephants. Most of the old carcasses were recorded in Tsavo East and northern parts of Tsavo West NPs; these were the areas that lacked water during the 2009 drought. Elephants are water-dependent animals (Ngene et al. 2009), therefore many could have died during the period due to lack of water.

Search effort during aerial counts determine the

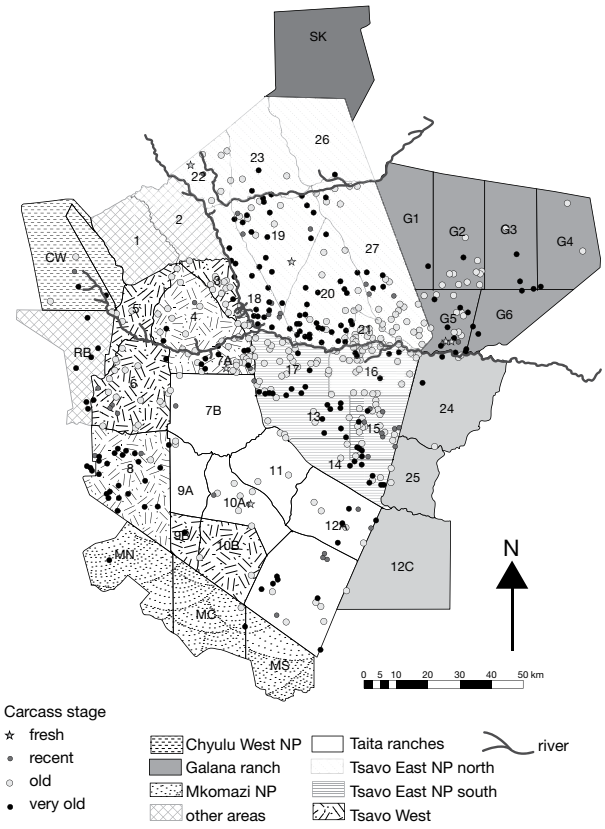

Figure 9. Spatial distribution of elephant carcasses according to different age classes in early February 2011. Most of the carcasses were 'old' and 'very old'.

number of large mammals counted during the exercise (Douglas-Hamilton et al. 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 result in higher and lower numbers of the large mammals being counted (Douglas-Hamilton et al. 1994). The 2011 aerial census recorded a search effort of 191 km^2/hour, which was higher than for previous aerial census—321 km^2/hour in 1988, 276 km^2/hour in 1989, 247 km^2/hour in1991, 210 km^2/hour in 1994, 242 km^2/hour in 2002, 224 km^2/hour in 2005, and 213 km^2/hour in 2008 (Douglas-Hamilton et al. 1994; Omondi et al. 2008). It is therefore possible that the high number of elephants counted in 2011 is not because of actual population increase but due to increased search effort (Figure 11).

High density of elephants was recorded in the southern part of Tsavo East NP. The area was also the mean centre where many groups of elephants were counted. This area has 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 and 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

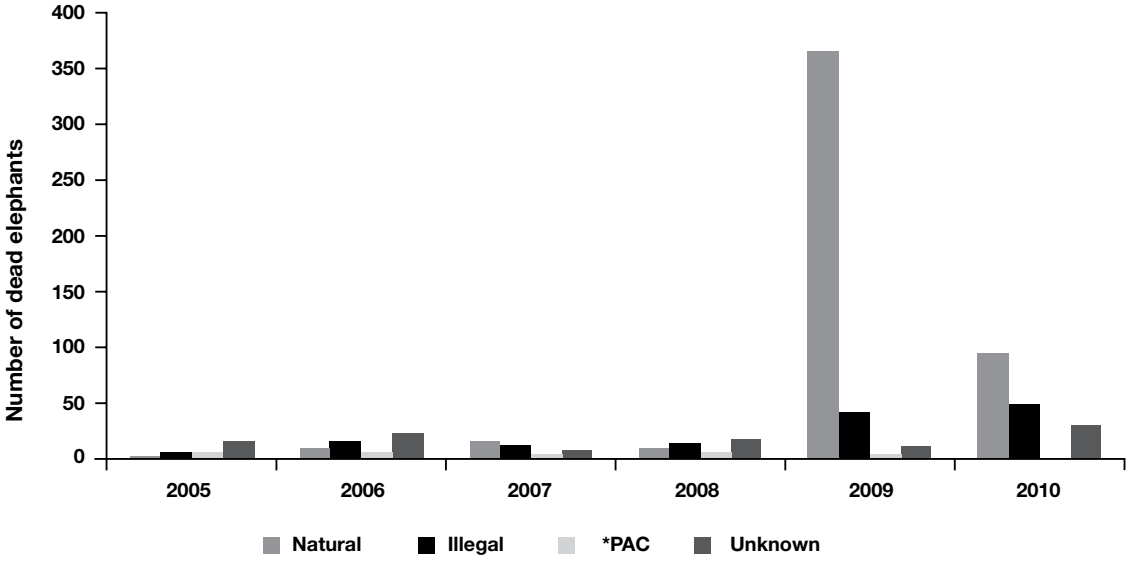

Figure 10. Number of dead elephants against causes of elephant mortality in the Tsavo Conservation Area, 2008–2010. Other causes of death include train accidents, sickness and lion predation.
*PAC = problem animal control.

(Ngene et al. 2009). Analogous findings were made for elephants in Marsabit NP and Reserve (Ngene et al. 2009), Samburu National Reserve in Kenya (Thouless 1995), Masai Mara Game Reserve in Kenya (Khaemba and Stein 2000), Maputo Elephant Reserve in Mozambique (Boer et al. 2000), Serengeti NP 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).

Despite an increase in the number of carcasses since the 2008 census (Figure 12), 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 drought in 2009 and early 2010. Under conditions of low rainfall, as experienced in preceding years, the rate of carcass disintegration is minimal (Douglas-Hamilton and Hillman 1981). As a result, more carcasses would be sighted during an aerial census. Similar to the 1970–1971 dry season census (Corfield 1973), most of the carcasses were recorded in Tsavo East along the 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 when vegetation is limited.

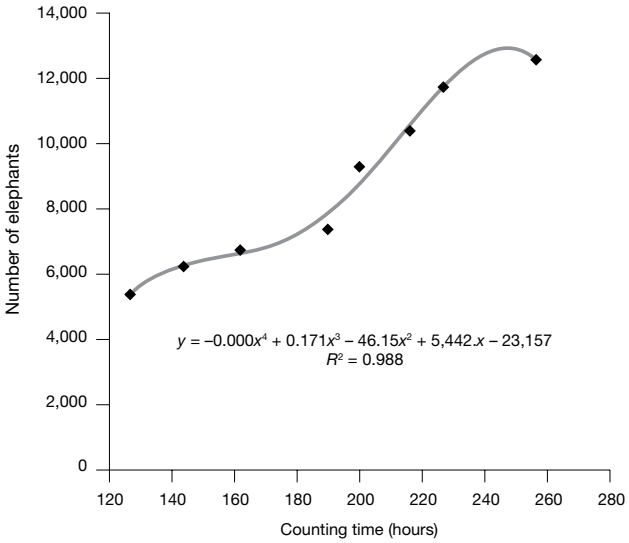

Figure 11. Number of elephants counted in the Tsavo–Mkomazi ecosystem against the total counting hours. (Data are for 1988, 1989, 1991, 1994, 2002, 2005, 2008 and 2011.)

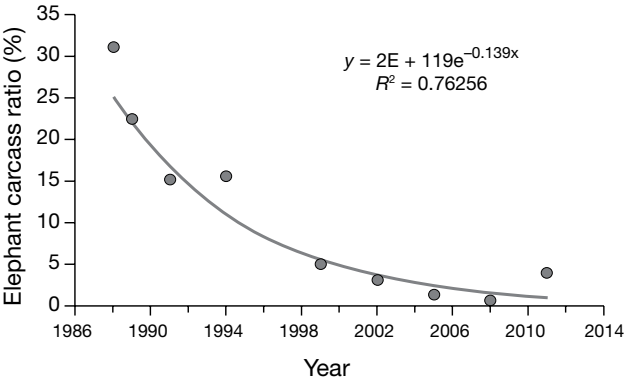

Figure 12. Trends of elephant carcass ratio in the Tsavo–Mkomazi ecosystem, 1985–2011.

Large herds of elephants were recorded outside protected areas (Taita and Galana ranches). Possibly lack of security in these areas, leading to incidence of elephant poaching, is forcing the elephants to congregate in large numbers outside protected areas whereas inside our secure protected areas, the groups are small. Similar results have been reported in Meru NP (Njumbi 1995), Queen Elizabeth NP (Abe 1994) and Mikumi NP (Moss and Poole 1983).

Conclusions and recommendations

Conclusions

From the results and discussion, we conclude:

- Elephant numbers in the Tsavo–Mkomazi ecosytem have continued to increase since 1988, though with a declining rate of 2% over that of the last three years (2008 to 2011). This declining rate is attributed mainly to the drought of 2009 that saw a proportionately high rate of natural mortality.
- The highest elephant densities, of approximately 1 elephant/km^2, were observed in Tsavo East south of the Galana River.
- Elephant distribution in Tsavo–Mkomazi remains clustered inside the protected areas of Tsavo East NP along the Galana River and its tributaries as well as in artificial water points south of the river.
- In contrast, congregations of large herds were recorded outside the protected areas: in the Taita ranches between Tsavo East and West NPs. However, isolated large herds were also observed on the outskirts of Galana ranch,

the southwestern periphery of Tsavo West NP, and northwestern Mkomazi.

Recommendations

We recommend:

- While it is evident that drought, as a natural regulator, can check the population increase of the Tsavo–Mkomazi elephant population, there is need to ensure that human-induced mortality is minimal through effective anti-poaching and human–elephant conflict resolution. This will allow the population to regulate naturally based on habitat condition and climatic characteristics.
- The high density and clustering of elephants along the Galana and Ndii–Ndara plains, relative to the rest of the ecosystem, can be explained by the availability of water. If left unattended, and with increasing elephant numbers, this situation could lead to habitat degradation in these high-density areas. It is recommended, after extensive environmental impact assessment, to desilt old water pans and open new water points north of Tiva River, in the eastern parts of Tsavo East, and in the central to southern parts of Tsavo West NP. In this regard, the South Kitui National Reserve at the extreme northern section of the ecosystem serves as an obvious focus for future water provision.
- The clustering and high density along the Galana River also has implications: patrols andmobile unites should be deployed for anti-poaching efforts.
- Congregation of large herds as observed in the Taita ranches, in northern Galana and in southwestern Tsavo West NP may indicate poaching pressure; thus security should be directed to these areas. In addition, ongoing efforts to establish conservancies in these unprotected areas should be prioritized as a means of ensuring these critical elephant corridors and dispersal areas.

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