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Zero tolerance: evolving wildlife management in Kenya

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Abstract: This study investigates the impact of contrasting wildlife management regimes on the probability of elephant presence in the Tsavo ecosystem base on the New York “zero tolerance policing”. Point data for the location of elephant, elephant carcasses, cattle, buffalo, giraffe, occupied bomas, charcoal kilns, settlements and farms, and water points were collected through aerial survey from 7-12 February 2011. Secondary data layers included main rivers, 30m resolution digital elevation model, and moderate resolution imaging spectro-radiometer (MODIS) 250m spatial resolution normalized difference vegetation index (NDVI) data for January 2011. Information on the three management regimes (none, passive, and active) adopted by protected areas and ranches in Tsavo ecosystem was identified through interviews. The Maxent algorithm was used for modeling the probability of elephant presence in the ecosystem. Multicollinearity of the fourteen explanatory variables was tested using Eigen values and Condition Index (CI). We used Maxent with elephant location points as the presence only data and the twelve explanatory variables as environmental variables. Bootstrapping of ten replications was included in the model. The accuracy of the model was determined using the area under the curve (AUC) of the Receiver Operating Characteristic (ROC) function. The results indicated that elephants were significantly more likely to be found in the protected areas than the non-protected areas. The northern sector of Tsavo West and the Voi sector of Tsavo East were the most likely areas to record elephants. Sectors with protected areas and ranches that practiced active management were more likely to show elephant than those with passive or no management. The areas with high probability of elephant occurrence coincided with actual high elephant density. Elephant carcasses, buffalo, giraffe, and settlements were the main variables that predicted the probability of elephant presence. Elephants are more likely to be in protected areas and ranches that were managed actively than those passively or not managed. In order to capitalize on the notion of protection and active management, we propose a wildlife management model based on the New York ‘zero tolerance’ policing. Any misdemeanor is not tolerated, especially illegal charcoal burning and livestock grazing in the ranches.

Keywords: Tsavo, Ecosystem, Protected Area, Elephant, Livestock, Charcoal

1. Introduction

The Tsavo ecosystem is home to Kenya’s largest elephant population (Blanc et al., 2007) with over 35,000 animals in 1974 (Cobb, 1976) and 11,733 in 2008 (Omondi et al., 2008). The ecosystem consists of the Tsavo National Parks (NPs) and the Taita Ranches. Sample and total aerial counts have been carried out in the ecosystem since the early 1970’s. The latter 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). Sample counts include those by Cobb (1976); Leuthold (1976); WCMD (1976); IUCN (1978), and Inamdar (1996). The 1994 count took place in June after the rains the others at the end of January or first week of February, both dry months. The results from the 2005 and 2008 counts show that about 10-30% of the elephant were outside and 62-90% inside the protected areas (Ngene et al., 2011). Fewer elephant occurred outside the protected area during wet years (Douglas-Hamilton et al., 1994; Ngene et al., 2011).

Since 1988, there is a steady increase in the number of elephant in Tsavo ecosystem from the declines recorded in the late 1970s and early 1980s (Kahumbu et al., 1999). The 1988 distribution of fresh carcasses confirmed heavy poaching especially on the periphery of the Tsavo East and West National parks (Olindo et al., 1988). The distribution of elephants from 1989 onwards suggested that elephants previously counted along the periphery had moved further inside the parks, even as the population continued to increase in size (Douglas-Hamilton et al., 1994; Ngene et al., 2011).

Two contrasting management responses were adopted by the Kenyan Wildlife Service (KWS). The “Leakey-model” of the early 1990s focused on controlling poaching in the protected areas, whereas the “Western-model” of late 1994-1996 aimed at coexistence of wildlife and people in community ranches surrounding protected areas. From 2000 onwards, non-residents graze their livestock, convert savanna into crop fields, poach and produce charcoal in the community ranches. Here we investigate the impact of land use outside the protected area on the probability of elephant presence in the Tsavo ecosystem. In 2010, KWS devolved management to sectors or mini-parks each with their own personnel, finances, and equipment. In parallel, capacity building at ranches and community wildlife sanctuaries equipped communities and individuals with the skills to police and manage wildlife on their land (KWS, 2012). The approach taught is modeled on the ‘zero tolerance’ policing approach of New York city ’Zero tolerance’ policing does not tolerate minor offences (e.g., littering, careless overtaking and parking), in the expectation that if minor offences are left unpunished, major offences (violent robbery, major motor vehicle accidents among others) escalate to crime. In addition, the decrease in minor offenses may result in better living conditions for the community.

The private and community ranches surrounding the protected areas vary considerably in their level of management, protection and patrolling. Ranches with no illegal activities boost of high elephant numbers (Ngene et al., 2011). In contrast, community ranches with few or no wildlife protection strategies have no or few elephant present (Olindo et al., 1988; Omondi et al., 2008; Ngene et al., 2011). We test whether the probability of elephant presence is higher in the sectors within protected areas and at ranches practicing active management using the Maximum Entropy (Maxent) model (Phillips, 2008). The Maxent model is an empirical, deterministic and non-parametric, pixel-based, machine learning method that uses presence-only data. Maxent predicts probabilities of distribution from point records of the study species against a set of environmental variables (Gils et al., 2012 Phillips and Dudik, 2008). Maxent was selected as it automatically produces probability distribution maps as well as the receiver operation curve (ROC) to indicate model suitability.

Using data from a total aerial survey of the Tsavo Park system and surrounding community ranches, we hypothesize that sectors and ranches practicing active management show a relative high probability of elephant presence. Based on our findings, we propose management recommendations.

2. Materials and Methods

2.1. Study Area

The Tsavo ecosystem (48,319 km2) consists of Tsavo East, Tsavo West, Mkomazi, and Chyulu National Parks, South Kitui National Reserve, Taita and Galana ranches and other areas (Figure 1; Omondi et al., 2008). The ecosystem is located at 2° - 4° S, and 37.5 - 39.5° E (Figure 1). Four main rivers (Galana, Voi, Tiva, and Tsavo) traverse the ecosystem (Omondi et al., 2008). The mean annual rainfall in the ecosystem varies from 250 to 500 mm (Leuthold, 1978; Omondi et al., 2008). Bi-modal rainfall is experienced from middle March to May and November to December (Tyrrell & Coe, 1974; Omondi et al., 2008). June through October constitutes the long dry season whereas the short dry season occurs from January to March (Leuthold, 1978). The highest rainfall is recorded between the Taita Hills and Kilimanjaro (Tyrrell & Coe, 1974).

The terrain, elevation, drainage, and soils have been described in detail by other authors Ngene et al., 2011; Mukeka, 2010; Omondi et al., 2008; Leuthold, 1978). The flora and fauna has been described by Ngene et al. (2011), Belsky et al. (1989), Belsky et al. (1987), Wijngaarden (1985), Cobb (1976), Tyrrell & Coe (1974), and Napier-Bax & Sheldrick, (1963).

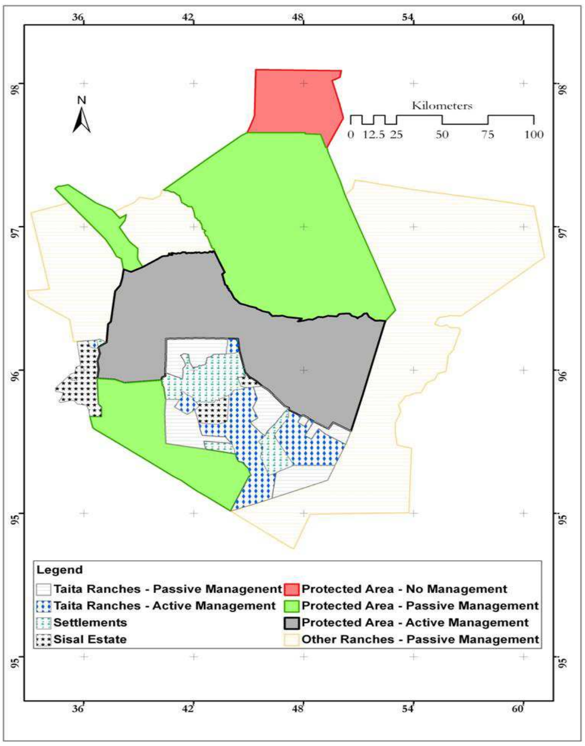

Figure 1. *Management regimes in the Tsavo ecosystem and other land uses (sisal estate and settlements)*

3. GIS Data Layers

Point data for the location of elephant, elephant carcasses, cattle, buffalo, giraffe, occupied bomas, charcoal kilns, settlements, and water points were collected through aerial survey from 7-12 February 2011 following Douglas-Hamilton (1996). The study area was divided into forty four counting blocks (Omondi et al., 2008). Flight lines of one kilometer spacing were chosen to ensure that all features were sighted and counted. The blocks were defined by recognizable features including roads, rivers, hills and protected area boundaries. The average block size was 1098 km2 (SE = ±445 km²; n = 44). The smallest and largest block were about 248 km² (block 21) and 2008 km² (block 12C) respectively (see supplementary material 1). In the larger blocks more than one team were deployed to ensure counting completion within a day.

Nine aircraft (Cessnas and Huskys) with high wings for unobstructed ground view were used for the count. The crew consisted of a pilot, one front seat observer (FSO) and in case of a four seater two rear seat observers (RSOs) as well. The GPS units were set to Universal Transverse Mercator (UTM) kilometer grids. The teams took off at dawn ensuring that counting started before the day warmed up and animals sought shade. Parallel lines with an interval determined by the front observer and the pilot based on terrain and visibility were flown. Fuel was strategically distributed at the various airstrips in the ecosystem for convenience of refueling. In a few blocks, the topography influenced the flight paths as rugged terrain was avoided. Test flights were conducted a day before the actual counting commenced to familiarize and/or refresh the crew and standardize observer methods across the crews of the 9 aircraft. Speeds of approximately 130-180 km/hr and heights of about 200-400 feet above ground level were maintained as recommended by Douglas-Hamilton (1996). 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. (See Supplementary material 2). Waypoints were downloaded to ArcGIS 9.3. The tabulated species data was input to the ArcGIS software and a spatial join created based on observation way points (Mitchell, 2009). The way point data was converted into a shapefile for each block. Duplicates in the zones of overlap of adjacent blocks were identified and corrected before merging all datasets.

Spatial data of main rivers were acquired from the Kenyan Wildlife Service GIS Database.

3.1. Remote Sensing Data Layers

The remote sensing data layers included elevation and Normalized Difference Vegetation Index (NDVI). Elevation was extracted from a 30m resolution digital elevation model (DEM) (NASA, 2000). Moderate Resolution Imaging Spectro-radiometer (MODIS) NDVI data for January 2011 were obtained from the Warehouse Inventory Search Tool (NASA, 2009). These 250 m spatial resolution NDVI datasets, referred to by the product name MOD13Q1 provide a measure of the NDVI of each image pixel over a 16 day composite. The MOD13Q1 product has half a pixel positional accuracy (NASA, 2009). Procedures described by Knight and Voth (2011) were used to acquire the NDVI data and produce NDVI raster images.

3.2. Management Regimes in Protected Areas and Ranches

Three management regimes (none, passive, and active) adopted by protected areas and ranches in the Tsavo ecosystem were identified. First, the parks were visited and appraised. Those with offices were awarded three marks while those without were awarded zero marks. Second, the conditions of the offices were rated as good (graded: 3) and poor (graded: 1). Third, availability of security guards was appraised for protected areas as well as ranches. Twenty or more security guards were awarded a three (3), while ranches with less than twenty or no guards were awarded a one (1) one mark. Finally, the extent of security patrols coverage was used to establish area coverage on a monthly basis. Those with good (>50%) and poor (<50%) coverage were awarded a three (3) and a one (1) respectively. Finally, all the scores were added and the sums classified in three categories active (>9), passive (5-9) or no management (<5). The information was collected through personal observations, discussion with protected area and ranch managers and staff.

3.3. Data Analysis

The Maxent algorithm (Phillips et al. 2006) was used for modeling the probability of elephant presence. The maxent model was selected as it automatically generates a ROC curve with an AUC value that indicates the contribution of all the explanatory variables to the species distribution. The model uses a machine learning method that makes predictions from species presence-only data (Phillips et al., 2006). The model uses a maximum likelihood method to allocate probability of presence (Yost et al. 2008). The explanatory variables are outlined in table 1.

Multicollinearity of the twelve explanatory factors was tested using Eigen values and Condition Index (CI) as outlined in SPSS 10 (SPSS, 2009). Variables with CI > 15 were eliminated. CI was preferred than variance inflation factor (VIF) as it is more robust in detecting multicollinearity than VIF (Weisberg, 1985; Dormann et al., 2012). A correlation matrix of was inspected to identify two correlated explanatory factors. When two factors had correlation values > 0.7, the factor that was correlated with other factors was dropped from the analysis. Since no two factors had correlations of more than 0.7, the ten explanatory factors with CI<15 were used in model. The presence records were converted into CSV files, whereas the explanatory variables were rasterized and converted to ASCII files using ARCGIS 10 (ESRI, 2010).

Table 1. *The explanatory variables*

Abbreviation	Full name	Source	Type	Proxy
DBO	D-occupied boma	TCA 2011	Vector	Disturbance
DBF	D-buffalo	TCA 2011	Vector	Graze materials
DCT	D-cattle	TCA 2011	Vector	Competitor
DCKL	D-charcoal kiln	TCA 2011	Vector	Disturbance
DEC	D-elephant carcass	TCA 2011	Vector	Disturbance
DGF	D-giraffe	TCA 2011	Vector	Browse materials
DRV	D-river	KWS 2012	Vector	Source of water
DSH	D-shoat	TCA 2011	Vector	Disturbance
DWP	D-water point	TCA 2011	Vector	Source of water
DST	D-settlement	TCA 2011	Vector	Disturbance
ELV	Elevation	30m GDEM	Raster	Topo-climate
NDVI	Vegetation Index	MODIS Jan 2011	Raster	Primary productivity
NP	Not protected	TCA 2011	Vector	Management regime
PT	Protected	TCA 2011	Vector	Management regime

We used a model building process as described by Phillip et al. (2006). A bootstrap of ten replicates was included in the model. The importance of each variable was appraised using jackknife procedures (Phillip et al., 2006). The accuracy of the model was determined using the Area Under Curve (AUC) of the Receiver Operating Characteristic (ROC) function (Phillip et al., 2006). In addition, the threshold dependent evaluation of the accuracy of the model was undertaken as outlined by Liu et al. (2005) and Hernandez et al. (2006).

A kernel density of elephant was created in ARCGIS 10 (Mitchell, 2009). We extracted the values of the probability of elephant presence, management status category, and elephant density at each elephant location. Analysis of variance (ANOVA; Statsoft 2002) was used to test the significance of the variations of probability of elephant presence across management regimes as well as for elephant's probability of presence versus density. Standard protocols for the use of ANOVA were followed (Zar, 1996). We assumed that if the model represents a real situation, high probability of elephant presence will coincide with high elephant densities. Normality was assumed at $P > 0.05$. Non-normal data was log10 transformed (Zar, 1996). Statistical significance of test parameter occurred at $P < 0.05$ (Zar, 1996).

4. Results

4.1. Multicollinearity

Table 2 shows the Eigen values and Condition Index of the identified fourteen explanatory factors. The first ten variables were used as input in the Maxent model as they had CI of less than fifteen. Elevation, NDVI and protection status "Not Protected (NP)" was excluded (CI > 15). Protection area status "Protected (PT)" was excluded as an input explanatory variable as it yielded a tolerance value close to zero indicating a multicollinearity problem.

Table 2. *A table showing approximated Eigen and CI values of potential explanatory factors to predict probability of elephant presence. Shoats included goats and sheep. D = Distance to respective explanatory variable.*

Abbreviation	Full name	Eigen value	Condition Index	Comment
DBO	D-occupied boma	1.98	2.20	Passed
DBF	D-buffalo	0.52	4.30	Passed
DCT	D-cattle	0.47	4.60	Passed
DCKL	D-charcoal kiln	0.36	5.20	Passed
DEC	D-elephant carcass	0.25	6.20	Passed
DGF	D-giraffe	0.20	6.90	Passed
DRV	D-rivers	0.17	7.50	Passed
DSH	D-shoat	0.11	9.40	Passed
DWP	D-water point	0.05	10.00	Passed
DST	D-settlement	0.05	14.60	Passed
DELV	Elevation	0.03	17.60	Not passed
NDVI	Vegetation Index	0.02	20.20	Not passed
NP	Not protected	0.02	25.00	Not passed
PT	Protected	-	-	Not passed

Indicates that value was almost zero

4.2. Probability of Elephant Presence

Figure 2 shows the probability of elephant presence in the protected and non-protected areas (ranches and settlement areas) of the Tsavo ecosystem. Elephants were more likely to be in the protected areas than the not protected areas (Figure 2; Figure 3A $F(7,1396) = 50$; $P < 0.05$). The northern and Voi sectors of Tsavo West and East National Parks respectively were the most likely areas to record elephants (Figure 2;). Sectors of protected areas and ranches that practiced active management were more likely to have elephants than those with passive management (Figure 3B; $F(3,1260) = 103$; $P < 0.05$). The prediction agreed with reality as areas with a high elephant density had high probability of elephant occurrence (Figure 4; $F(4,1399) = 42$, $P < 0.05$).

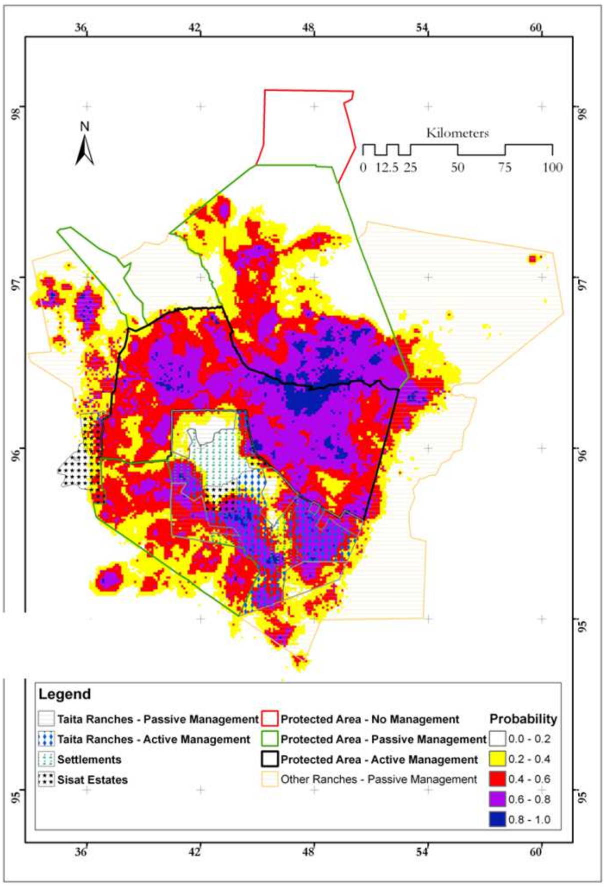

Figure 2. *The probability of elephant occurrence in the Tsavo ecosystem under contrasting management regimes*

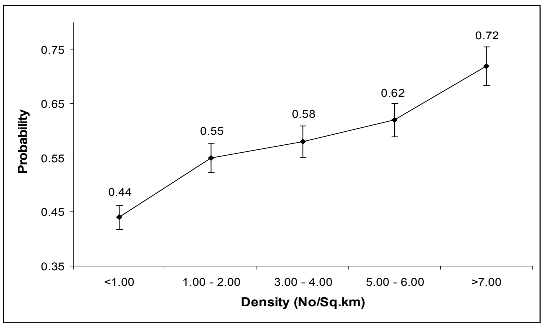

Figure 4. *A probability of elephant presence and density of elephants in the Tsavo Conservation Area ecosystem.*

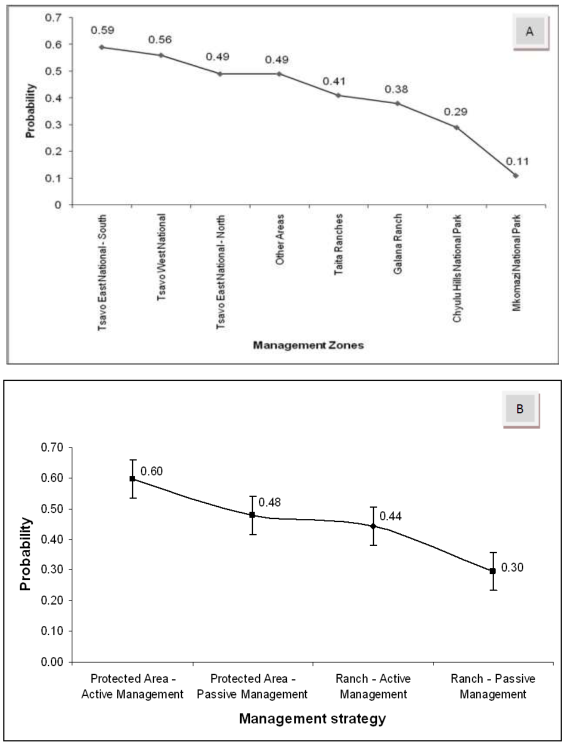

Figure 3. *Graphs showing the mean probability of elephant presence in Tsavo ecosystem. A: The probability in different management zones. B: The probability in protected areas and ranches under different management regimes. The vertical bars denote 95% confidence intervals (CI).*

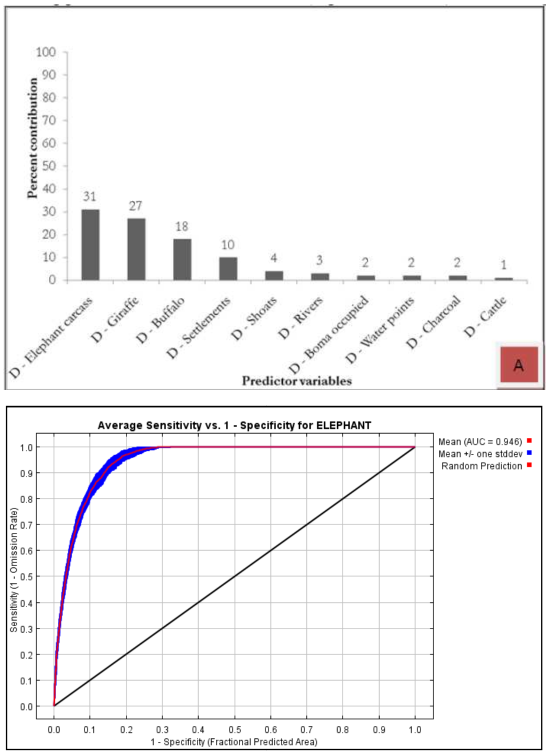

Figure 5. *A - The percent contribution of ten predictor variables on the probability of elephant distribution in different management zones. D - Denotes distance to the respective predictor variable. B - Receiver Operation Curve (ROC) of the Area Under the Curve (AUC) of the selected best model.*

4.3. Factors Contributing to the Elephant Presence Probability Model and Model Fitness

Figure 5A details the contribution of the explanatory variables to the probability of elephant presence. Distance from elephant carcass, buffalo, giraffe, and settlements in that order of importance were the main variables contributing to the probability of elephant presence in the Tsavo ecosystem (Figures 5A). These variables showed the highest decline in training gains when omitted in the model (Figures 3A and 3B) as well as high AUC values: 0.95 (Figure 5B).

5. Discussion

The core areas of the Tsavo ecosystem, which contain high elephant numbers, are heavily patrolled by KWS rangers, who arrest apprehended miscreants. The core areas have high frequency armed patrols with specific operations to protect endangered species such as the rhino by 24 hour protection. The peripheral areas of the Tsavo NPs are less frequently patrolled by high number of armed rangers and consequently charcoal burning and poaching is on the rise, and as a consequence elephants have withdrawn to the core patrolled areas which are undoubtedly safer. The surrounding private and community ranches vary considerably in their level of management, protection and patrolling. Similar to the Tsavo Protected Area, ranches with zero tolerance of illegal activities contain high elephant numbers. Community ranches without or with little wildlife protection strategies show low elephant presence or even absence.

Our results showed low probability of elephant presence in the Taita-Taveta ranches, which consists of the Voi and Taveta constituencies. Three reasons are advanced to explain this observation. First, there is a high population density of about 8.1 persons/km2 (Voi constituency) and 19.3 persons/km2 (Taveta constituency) within the settlement areas in the Taita-Taveta ranches (Gok, 20100). In addition, the area has a household density of about 4.77 (Taveta) and 2.1 (Voi) house-holds/km2 (Gok, 2010). Our results concur with findings in the Tarangire–Manyara ecosystem in Tanzania (Pittiglio et al., 2012), the W Regional Park in Bukina Faso, Benin, and Niger (Hibert, 2010), Dzanga-Ndoki National Park and Dzanga-Sangha Dense Forest Reserve in Southwest Central African Republic (Blom et al., 2005), Waza National Park in northern Cameroon (Tchamba, et al., 1995), Etosha National Par in Namibia (Harris et al., 2008), Sebungwe region, northwestern Zimbabwe (Hoare and Toit, 1999), Tembe Elephant Park in South Africa (Harris et al., 2008), Maputo Elephant Reserve in Mozambique (Harris et al., 2008), Laikipia in Kenya (Douglas-Hamilton et al., 2005), and Samburu in Kenya (Thouless, 1995). However, Ngene et al. (2009) observed that elephants around Mount Marsabit, Kenya congregated near human settlements as this was the only area with water especially during the dry season. It is possible that the high population and household density in and around Taita-Taveta ranches make elephants to avoid the ranches as well as their surroundings. Parts of the Taita-Taveta ranches are unavailable to elephants because of the Taita, Mbololo, Sangala, Kasigau hills (Bytebier, 2001), as elephants avoid hills to save energy (Wall et al., 2006) and avoid settlements which are predominately on the hills.

Elephant were absent in passively or unmanaged ranches, which we speculate is because these areas are insecure for elephants. Elephants have a good memory (Estes, 1991) and are known to avoid areas where herd members have been killed (Douglas-Hamilton et al., 2005). As Tsavo experienced heavy poaching in the past (Douglas-Hamilton, 1988) we speculate that elephants have learned new behaviours to avoid insecure areas.

A moderate to high probability of elephant presence was found in nine of the Taita-Taveta ranches (i.e., Mugeno, Taita, Rukinga, Bachuma, Choke, Bura, Mbale, Kasigau, and Maungu ranches) as well as two sisal estates (Mwatate and Ziwani) and a proposed ranch. These ranches are actively managed by high frequency patrols that have a low tolerance towards illegal activities. This has kept charcoal burning, illegal livestock grazing, and illegal settlement at a minimum level, encouraging a sizeable population of elephants.

Maingi et al. (2012) reported that the presence of poached elephants Tsavo East National Park could be predicted by the density of elephants and propose that the positive relationship between poaching density and density of elephants is because the poachers target areas with large herds of elephant so as to maximize return for their effort (Kyale et al., 2011; Jackmann and Billiouw, 1997; Ruggiero, 1990; Leader-Williams et al., 1990; Pilgram and Western, 1986). Focusing on the Tsavo region, the high elephant population is superimposed by management layer of varying wildlife protection strategies.

Given the statistically significant relation demonstrated here between active wildlife management and higher elephant density, we propose a policy similar to the 'zero tolerance' policing developed in New York. The 'zero tolerance' policy is based on the concept of not tolerating minor offences (e.g., littering, spitting, careless parking etc), in the expectation that if minor offences are left unpunished, a major escalation in crime will follow (e.g., violent robbery, major motor vehicle accidents among others). In the context of the Tsavo ecosystem, in areas where minor offences (such as charcoal burning, illegal settlement, illegal grazing etc) are not tolerated, the level of poaching is low. Thus we propose a third management model (post Leakey and Western) called the zero-tolerance model. Whether Kenyan policy will evolve around such a 'zero-tolerance' model will largely depend on decisions by the newly appointed head of the Kenyan Wildlife Service, Mr William Kiprono.

6. Conclusion

The probability of elephant presence was higher in protected areas of the Tsavo ecosystem being managed actively, compared with non-protected area. Non-protected areas are shown to have higher populations of non residents involved in illegal charcoal burning and livestock grazing, and these areas are also associated with elephant poaching. We propose a wildlife management model based on the New York 'zero tolerance' policing. Any misdemeanor is not tolerated, especially illegal charcoal burning and livestock grazing in the ranches.

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