Biophysical and human factors determine the distribution of poached elephants in Tsavo East National Park, Kenya

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Abstract

This study investigates the distribution of poached elephants as well as the biophysical and anthropogenic factors that determine the distribution of the poached elephants in Tsavo East National Park (TENP), Kenya. Data on the distribution of poached elephants, from 1990 to 2005, were acquired from elephant mortality database of the Kenya Wildlife Service (KWS). The distribution of poached elephants was not random but exhibited a clustered pattern. Poaching of elephants was higher in the central and northern areas of TENP. Poaching hotspots occurred along the main rivers (i.e. Tiva, Galana and Voi Rivers). During the wet season, a high density of poached elephants was recorded within the grassland, bushland and open bushland. In the dry season, the density of poached elephants was highest in the woodland, bushland, open bushland and grassland environments. The distribution of poached elephants was significantly correlated with land cover, proximity to main rivers, surface water, ranger patrol bases, park gates, roads and park boundaries. Priority security patrols should be performed along the Galana, Tiva and Voi Rivers.

Key words: Elephant distribution, physical and human factors, mortality, poaching

Résumé

Cette étude examine la répartition des éléphants braconnés, ainsi que les facteurs biophysiques et anthropiques qui déterminent la répartition des éléphants braconnés dans le Parc National de Tsavo Est, au Kenya. Les données sur la répartition des éléphants braconnés, de 1990 à 2005, ont été acquises à partir de la base de données du Service Kenyan de la Faune (KWS) sur la mortalité des éléphants. La répartition des éléphants braconnés n'était pas aléatoire, mais présentait une configuration regroupée. Le braconnage des éléphants était plus élevé dans les zones centrales et septentrionales du parc. Les points névralgiques de braconnage se trouvaient le long des rivières principales (c.-à-d. Tiva, Galana, et Voi). Au cours de la saison pluvieuse, on a enregistré une forte densité d'éléphants braconnés dans les herbages, la brousse et la brousse ouverte. Pendant la saison sèche, la densité des éléphants braconnés était la plus élevée dans la forêt claire, la brousse, la brousse ouverte et les herbages. La répartition des éléphants braconnés avait une corrélation significative avec la couverture du sol, la proximité des principaux cours d'eau, les eaux de surface, les bases de patrouilles des écogardes, les entrées du parc, les routes et les limites du parc. Les patrouilles prioritaires de sécurité devraient s'effectuer le long des fleuves Galana, Tiva et Voi.

Introduction

Poaching of elephants for ivory is the main issue affecting the African elephant population (Blanc et al., 2007; Thouless et al., 2008; AFESG, 1997; WWF, 1997). African countries that have elephants invest massive financial resources and personnel to protect the species (Thouless et al., 2008). The minimum recurrent expenditure that wildlife agencies in Africa need to protect elephants in their natural ranges is about USD 50–200 per km^2 annually (Cumming et al., 1990; Jachmann & Billiouw, 1997). While these suggested expenditures are likely to be out of date, it may be useful to note that apart from South Africa (USD 4,350), Tsavo East in Kenya (USD 1,450), Burkina Faso (USD 132), Luangwa Valley in Zambia (USD 82.2), which operated above or within this minimum range of expenditure, other African countries operated well below (e.g. Zaire, USD 2; Tanzania, USD 18; Sudan, USD 12; Cameroon, USD 5; Malawi, USD 49), with most other African countries operating below a tenth of the suggested minimum (Cumming et al., 1990; Jachmann & Billiouw, 1997). However, under different circumstances, for example where a protected area is close to an international border like TENP, budgetary needs to protect elephants effectively may be higher (Jachmann & Billiouw, 1997).

In terms of personnel, Jachmann and Billiouw (1997) recommended a minimum of one park ranger for every 24 km^2 of protected area if effective patrolling and policing is to be realized. KWS, like most wildlife departments in other African countries, is understaffed with about one ranger per 100 km^2 of protected area. Furthermore, Kenya is unable to meet this financial obligation and is thus unlikely to be able to allocate more funds towards wildlife conservation. It is therefore important to explore strategies that involve more efficient use of the limited available resources. By assessing spatial and temporal patterns of elephant mortality, important insights about the characteristics of particular areas of TENP where elephants are more vulnerable to human-induced death can be generated, which in turn can help guide effective deployment of policing resources.

TENP was chosen for the current study because it is the largest park in the country (KWS, 2003), and has both the highest concentration of elephants and highest incidences of elephant poaching (Economist, 2002; Hammer, 1993; Robinson, 2000). TENP is a predominantly semi-arid bushland with only a small area of the Park developed and open for tourism. Unfavourably hot climate, poor accessibility and the large size of the park, make patrolling difficult and more challenging with currently available resources (Kioko, 2002).

In this study, we used GIS to describe spatial patterns of elephant mortality attributed to poaching. We identify areas within the TENP and its environs that are at greater risk to elephant poaching. Lastly, we investigate the biophysical and human factors that determine the distribution of poached elephants in the park. Such information would be useful in guiding the deployment of policing resources in the park and its immediate vicinity.

Materials and methods

Study area

The TENP was gazetted in 1948 and is among the oldest parks in Kenya (Smith & Kasiki, 2000). It covers approximately 12,000 km^2, accounting for about 40% of the total area covered by parks in Kenya (KWS, 2003). Elevation within the park increases westwards from 150 m at the eastern park boundary to 1,200 m on the western boundary (Tolvanen, 2004). Rainfall is bimodal with the long rains occurring between March and May, and the short rains occurring between October and December. January–February and June–September are considered to be the dry season.

Like elevation, rainfall in the park increases from about 250 mm in the eastern part to about 450 mm in the western part (KWS, 2003). The main source of permanent water in the park is the Galana River, which is formed by the union of Athi and Tsavo rivers. Seasonal sources of water include the Tiva and Voi Rivers, the Aruba Dam and a few scattered ponds and swamps (Fig. 1).

Vegetation within TENP is mainly bushland/grassland savannah and semi-arid *Acacia* and *Commiphora* woodlands with *Premna, Bauhinia* and *Sericocomorpsis* scrub scattered with *Delonix elata* and *Melia volkensii* trees and interspersed with open plains (McKnight, 2000). Riverine vegetation dominated by *Acacia elatior, Hyphaene compressa*, and *Suaeda monoica* occurs along the rivers. The vegetation is generally denser in the western part of the park and lighter in the eastern part, corresponding to a decreasing rainfall gradient (KWS, 2003).

Figure 1. Location of Tsavo East National Park in southern Kenya.

Data on elephant mortality

Data on elephant mortality from 10 October 1989 to 2 July 2005 was obtained from the KWS elephant mortality database, which has been developed over the years during routine daily patrols by rangers and aerial counts of elephants and other large mammals—including elephant carcasses in 1989, 1991, 1994, 1999, 2002 and 2005 (Douglas-Hamilton et al., 1994; Omondi et al., 2002; Omondi & Bitok, 2005).

The elephant mortality data were first entered in an Excel spreadsheet with each record having the following fields: X and Y coordinates (using Universal Transverse Mercator), date of mortality, cause of mortality and name of location where mortality occurred. The datasets were categorized as shown in Table 1.

The data were then saved into dBase IV format and added into ArcGIS 9.2. Shapefiles for each category in Table 1 were created using ArcGIS 9.2 (ESRI, 2006) with associated attribute data (Fig. 2). Then each dataset category was analyzed to discern its spatial patterns as described by Mitchell (2005). More than 90 records, which were missing spatial reference, were omitted from the analysis.

A 10 km buffer of TENP was generated and used to clip elephant mortality data to the buffer area in order to reduce edge effects during point pattern analysis (Fig. 2). The spatial extent of all subsequent data sets generated for this study were based on the 10 km buffer.

Table 1. Categories of mortality datasets used to describe elephant mortality patterns

Point shapefile	Number of records
Year round poaching	75
Wet season poaching	40
Dry season poaching	35

NB: The year round poaching period is from 10 October 1989 to 2 July 2005.

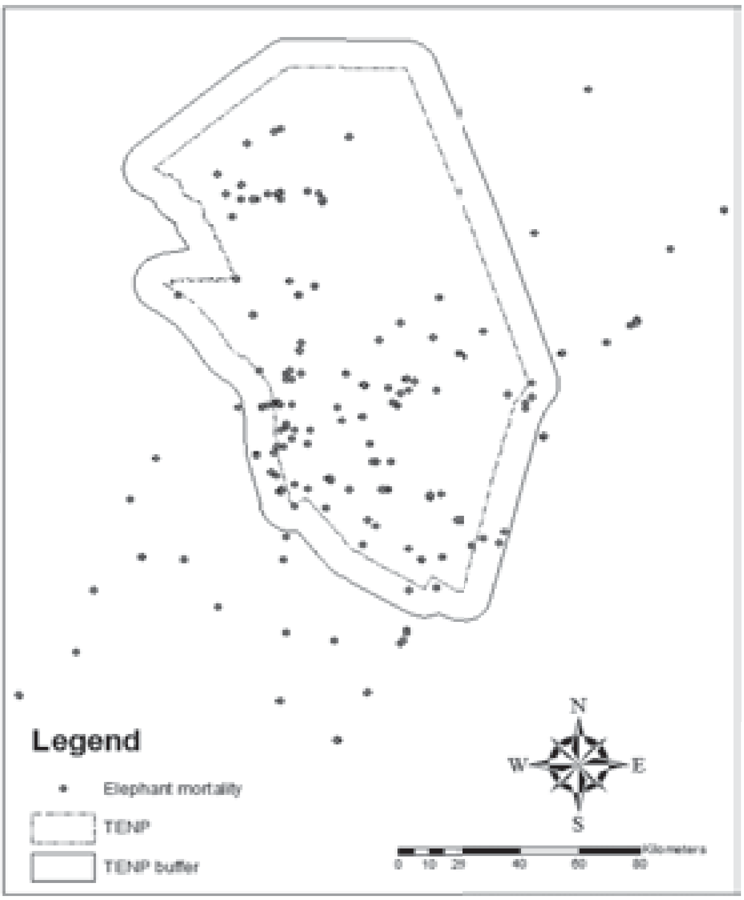

Figure 2. A point map showing the distribution of elephant carcasses in Tsavo East National Park and a 10 km buffer (10 October 1989 to 2 July 2005).

GIS data layers

We examined the relationship between biophysical and anthropogenic factors on the distribution of poached elephants in TENP. The biophysical and anthropogenic factors used to explain the distribution of poached elephants were: (a) distance to patrol bases (b) distance to park gates (c) distance to park boundary (d) distance to park roads (e) distance to main rivers (f) distance to seasonal rivers (g) distance to water-holes (h) elevation (i) slope (j) vegetation cover type. Data on the distribution of live elephants in TENP was not included in the analysis as the data available were an indication of the elephant distribution on the date and time the aerial counts were conducted (Fig. 4). Therefore, this data were considered not to be a true reflection of the distribution of the elephants for the study period (10 October 1989 to 2 July 2005, as shown in Fig. 4).

The locations of the six ranger patrol bases and park gates were obtained by visiting the sites and recording their locations using a hand-held global positioning system (GPS). Park boundary locations were obtained from the KWS GIS unit. Roads, rivers and waterholes were digitized in ArcGIS using the mosaic of Landsat ETM+ images (Fig. 3). In addition, 1:50,000 topographic maps based were used to supplement information generated from the Landsat ETM+ images. A 90-m DEM compiled from the Shuttle Radar Topographic Mission (SRTM) was used to obtain elevation grid and slope of the study area. The vegetation cover map of the study area was developed by classifying the vegetation types from Landsat images taken on 22 January 2000 and 4 March 2001. The images were classified as described by Oindo et al. (2003) and implemented using ERDAS software.

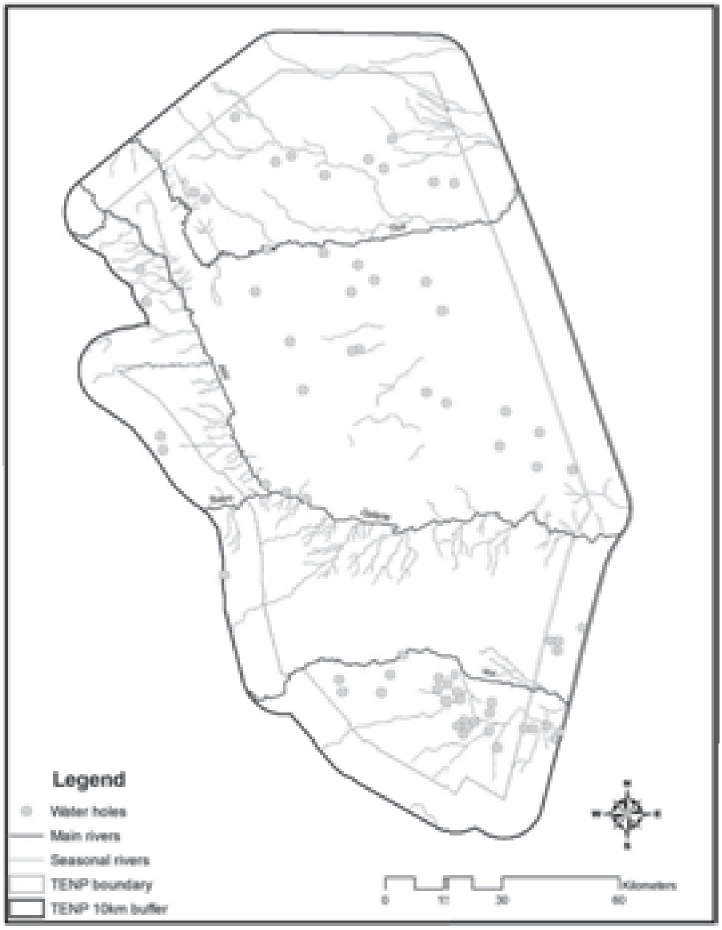

Figure 3. GIS data layers generated and used in the analysis.

Nearest neighbour analyses

Using ArcGIS 9.2, first order nearest neighbour analysis was performed for each eleuphant mortality. The following variables were recorded for each mortality dataset: (a) observed average distance (m) between nearest neighbouring mortality records [Observed neighbour distance] (b) expected average distance in metres between nearest neighbouring mortality records [expected neighbour distance] (c) nearest neighbour statistic [R statistic] (d) Z score and (e) remarks.

Kernel density analyses

Kernel density analyses were performed to identify areas within the study area that were hotspots for elephant poaching. Kernel density analyses for different elephant mortalities due to poaching were performed using ArcGIS 9.2. A band of about 24 km was selected in the analysis because it corresponds to mean home range size for TENP elephants. Female elephants in TENP have an average home range of 2,400 km^2 while that for males averages at 1,200 km^2 (Leuthold and Sale, 1973). Mukeka (2010) reported that the minimum and maximum home ranges of elephants in

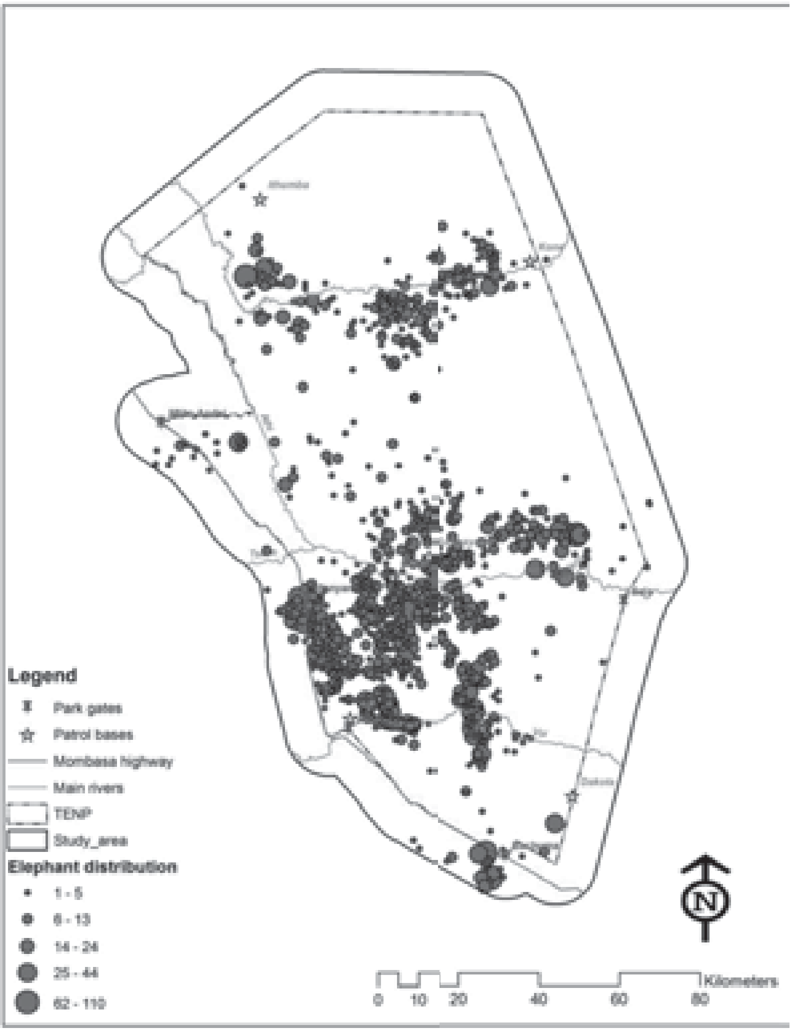

Figure 4. The distribution of elephants in Tsavo National Park in late January 2005. (Source: KWS Database, Elephant Programme)

Tsavo East and West National Parks were about 400 km^2 and 1,900 km^2 respectively. The maximum radius within which an elephant moved in the Tsavos was about 24.7 km, which is a value close to the width of band (24 km) used in this analysis (Mukeka, 2010). During the dry season, however, the size of an elephant home range increases (Leuthold & Sale, 1973; Mukeka, 2010), and as such, a wider band width (31.5 km) was used for the analysis of dry season poaching.

Exploring relationships between elephant mortality patterns and the biophysical and anthropogenic variables

The ArcGIS 9.2 Spatial Analyst tool was used to create distance surfaces from the buffer zone to ranger patrol bases, park gates, park roads, park boundaries, permanent rivers, seasonal rivers and waterholes (ESRI, 2006). Shape files of the elephant mortality point data were added onto the created distance surfaces. Next, the value of distance of the poached elephants to each respective variable were extracted as described by Mitchell (2005) using ArcGIS 9.2 extraction of value to point tool in spatial analyst (ESRI, 2006). This produced an attribute table with distances values on all elephant poaching mortality locations in of the aforementioned attributes. Additionally, elevation and slope, and land cover types at every elephant mortality location were extracted from the DEM and the TENP vegetation cover map for each poaching category (ESRI, 2006; Mitchell, 2005).

Vegetation cover types were categorical rather than quantitative and therefore, their relationships with the various poaching categories needed to be assessed differently. The land cover types were extracted at each mortality location for all elephant poaching categories examined in this analysis. The number of times (frequency) elephant mortality occurred in each land cover type was tabulated for every elephant poaching category and its respective percentage calculated for comparison with percentage size of corresponding land cover.

All extracted elephant mortality density values in each poaching category were correlated with corresponding distance (or elevation and slope) values extracted for each biophysical and human factor under examination. Before correlation analyses could be performed, the datasets were tested for normality using the Kolmogorov-Smirnov test. The datasets were assumed to be normally distributed when P > 0.05. Almost all the datasets were found not normally distributed and as a result, the Spearman's rank correlation was used.

Results and discussion

Spatial patterns of elephant mortality

Results from quadrat analyses showed that elephant mortality in TENP was not random ($D > D\alpha_{0.05}$) but exhibited clustered patterns (VMR > 1) irrespective of season or period of KWS history examined (Table 2). In addition to showing that elephant mortality in TENP was clustered (R < 1), nearest neighbour analyses confirmed that certain factors other than chance (Z > 1.96) influenced elephant mortality patterns (Table 2)

Relationships between elephant mortality and biophysical and human variables

The frequency of elephants' mortality was high in the bushland followed by grassland, open shrub-land and woodland (Table 3). No case of elephant mortality due to poaching was recorded in cultivated areas (agriculture) or in water (Table 3). However, high mortality densities were recorded within the open bushland, grassland, bushland and herbaceous vegetation for overall elephant poaching. Grassland, bushland and open bushland experienced high poaching densities during the wet season, while during the dry season elephant poaching density was highest in woodland, open bushland, bushland and herbaceous vegetation (Table 3).

Elephant poaching during the wet season was positively correlated with proximity to ranger patrol bases (P< 0.01), seasonal rivers (P<0.05) and park roads (P<0.01), but was negatively correlated with proximity to waterholes (P<0.05) and elevation (P<0.01) (Table 4). The results suggest that elephant distribution is not constrained by resources during the wet season, as there is plenty of food and water available. This may explain why main rivers, which are sources of surface water, did not show significant correlation with elephant poaching patterns observed during the wet season. It is during the wet season that TENP elephants aggregate in large numbers and the herds move further apart in response to their expanding home ranges (Mcknight, 2000). However, elephants need to drink and mud-bathe daily (Estes, 1999) but avoid doing so in rivers (Ngene et al., 2009), hence the significant negative correlation between wet season poaching and proximity to waterholes. On the other hand, poachers target areas with plenty of elephants, but that are remote and infrequently

Table 2. Nearest neighbour analysis of elephant mortality due to poaching in Tsavo East National Park

Category	Observed distance (m)	Expected distance (m)	R statistic	Z score	Remarks
Year round poaching	2,736.1	12,005.9	0.228	12.793	Clustered
Wet season poaching	4,201.9	16,439.8	0.256	9.007	Clustered
Dry season poaching	3,294.7	17,574.9	0.187	9.197	Clustered

NB: Year round poaching period is from 10 October 1989 to 2 July 2005.

Standard deviation ellipse results showed year round poaching (10 October 1989 to 2 July 2005) centered slightly in the northern part of the park (Fig. 4). The results indicate a higher concentration year round poaching mainly in the central and northern parts of the TENP. Kernel density results depicted year round poaching hotspots along the main river (Fig. 4).

Concentration of poaching hotspots along the main rivers is probably the result of such areas having a high concentration of elephants because of proximity of the elephants to water and mud-baths daily (Estes, 1999). The results are in agreement with Ottichilo's (1987) findings that elephant poaching was concentrated along the central part of the Galana River and in the north and north-western parts of the park.

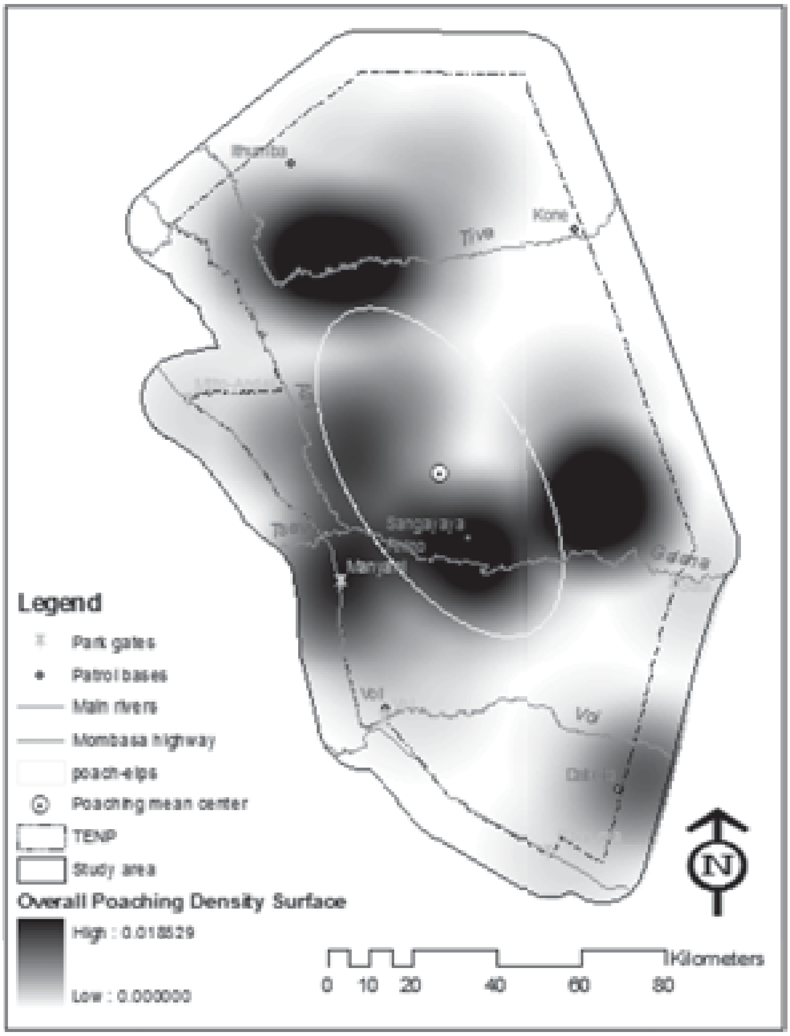

Figure 4. Kernel density and standard deviation ellipse results for year round poaching pattern (10 October 1989 to 2 July 2005).

patrolled by park rangers (Pilgram & Western, 1986; Leader-Williams et al., 1990). Areas close to ranger patrol bases and roads are thus avoided because they are areas frequently patrolled by rangers and any poaching activities can easily be detected. Elevation exhibits significant negative correlations with wet season poaching suggesting that poachers target elephants at low elevations during the wet season; a phenomenon reflecting preference of low elevations by TENP elephants (Smith & Kasiki, 2000).

Dry season poaching was positively correlated with distance to park gates ($P<0.01$) and the Park boundary ($P<0.05$), but negatively correlated with main rivers ($P<0.01$) and seasonal rivers ($P<0.05$). Proximity to patrol bases, slope and elevation, however, showed no significant correlation with dry season poaching. The results indicate that elephants are distributed close to sources of permanent surface water during the dry season. TENP elephant home ranges shrink considerably during the dry season as food and water resources become scarce (Leuthold & Sale, 1973). The elephants then retreat to areas along Tiva, Galana and Voi Rivers (Kasiki, 1998) because these areas have the resources necessary for the elephants' survival during the dry season. Unfortunately, the same areas provide good elephant killing areas for poachers hence the significant negative correlations between dry season poaching and proximity to both main and seasonal rivers.

Annual elephant poaching irrespective of climatic season was positively correlated with distance to ranger patrol bases ($P<0.05$), park roads ($P<0.01$) and the Park boundary ($P<0.05$), but negatively correlated with proximity to main rivers ($P<0.05$) and elevation ($P<0.05$). Poaching is therefore, likely to occur close to sources of permanent surface water irrespective of changes in weather conditions. Similar observations were made by Ottichilo (1987) in TENP and Demeke and Bekele (2000) in Mago National Park in Ethiopia. Moreover, poachers maximize their hunting success by targeting areas where elephants are concentrated (close to main rivers and at low elevations), while minimizing the risk of being detected by keeping to areas farthest from patrol bases, park roads and park boundary.

Of all the biophysical and human factors examined in relation to poaching-induced elephant mortality, proximity to main rivers exhibited the highest correlation (-0.69) with dry season poaching. This factor, however, explained only about 40.7% of the observed variability in dry season poaching

Table 3. Relationship between elephant mortality and land cover types in Tsavo East National Park

Land cover		**Elephant mortality**					
		Year round poaching		**Wet season poaching**		**Dry season poaching**	
Name	Area (Km^2)	Freq	Density	Freq	Density	**Freq**	**Density**
Forest	840	3	0.0036	1	0.0012	0	0.0000
Woodland	3,063	9	0.0029	2	0.0007	9	0.0039
Grassland	3,511	18	0.0051	14	0.0040	3	0.0008
Bushland	7,926	27	0.0035	17	0.0021	14	0.0018
Open bushland	2,664	14	0.0053	5	0.0019	8	0.0030
Herbaceous vegetation	489	3	0.0061	0	0.0000	1	0.0020
Agriculture	106	0	0.0000	0	0.0000	0	0.0000
Water	32	0	0.0000	0	0.0000	0	0.0000
Barren land	683	1	0.0015	1	0.0015	0	0.0000
Total	193,138	75	0.0004	40	0.0002	35	0.0002

Table 4. Spearman's Rank correlates for elephant mortality in Tsavo East National Park

Factors	**Annual poaching**	**Wet season poaching**	**Dry season poaching**
Distance to patrol bases	0.247*	0.422**	-0.148
Distance to park gates	0.065	0.022	0.444**
Distance to main rivers	-0.238*	0.139	-0.686**
Distance to seasonal rivers	0.073	0.338*	-0.409*
Distance to waterholes	-0.216	-0.317*	-0.022
Distance to park roads	0.408**	0.466**	0.147
Distance to park boundary	0.229*	0.200	0.378*
Elevation (m)	-0.258*	-0.424**	-0.169
Slope (degrees)	0.015	0.039	-0.046

Levels of significance: * = $p < 0.05$; ** = $p < 0.01$

(Fig.5). This finding indicates that there were other important factors influencing poaching-induced elephant mortality that were not measured in the current study. Some of these factors may include rainfall distribution, locations of lodges and campsites, park ranger observation posts and political and socio-economic factors that may influence elephant poaching.

Studies on social organization of elephants have shown that elephants of the TENP exhibit aggregation all-year-round (McKnight, 2000). The aggregations constitute large groups that are not family units but those formed in response to stress, harassment and lack of matriarchs to lead family units as a result of previous heavy poaching (Lewis, 1986; Ruggiero, 1990). The aggregating behaviour of previously heavily poached elephant populations may therefore, explain why elephant mortality exhibited clustered patterns in TENP irrespective of season or the KWS historical period analyzed. It would therefore be

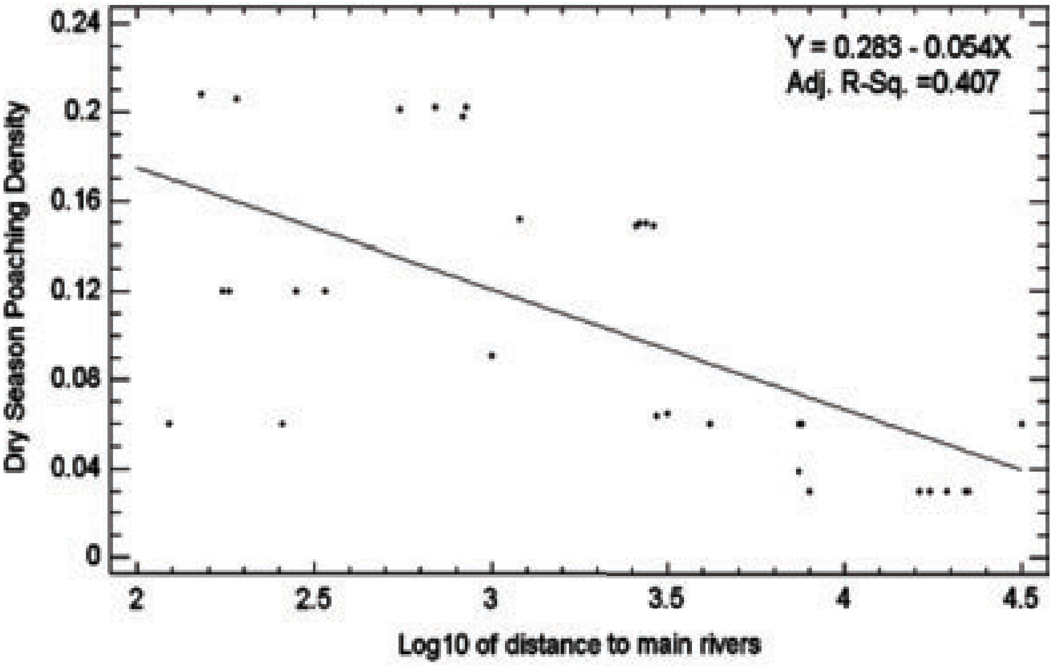

Figure 5. Relationship between dry season poaching and distance to main rivers.

interesting to see if there are any changes in clustering with time. Additionally, poachers often kill more than one large individual elephant in a herd in an effort of maximize haul, thus resulting in clusters of poached elephant carcasses.

The observed high densities of overall elephant poaching in grassland, herbaceous vegetation and open bushland reflect elephant distribution in TENP. Leuthold (1976) indicated that TENP elephants prefer open rather than densely vegetated areas. In addition, during the wet season, grassland and open bushland green up, thus providing elephants with ample food. During the dry season, however, grasslands become depleted, which forces the elephants to shift to woodlands. The high elephant poaching mortality in the dry season in herbaceous vegetation may be attributed to the occurrence of this type of land cover on frequently flooded areas that is characterized by black cotton soils. The soil retains moisture for a long period after the end of the rainy season; vegetation growing on it remains green and palatable longer, which attracts elephants.

The influence of surface water on elephant distribution has also been observed in Maputo elephant reserve in Mozambique (De Boer et al., 2000) and in northern Botswana (Verlindern & Gavor, 1998). Poachers, however, target elephants in remote areas where they are unlikely to be detected during park ranger patrols. As a result, poachers keep away from areas in close proximity to park security presence including park gates and boundaries. Ehrlich (1973) and Milner-Gulland and Leader-Williams (1992) argue that the fear of being detected by law enforcement authorities is a more effective deterrent to commission of a crime than the actual punishment a criminal would receive if caught. The fear of being detected by park rangers therefore, explains why no poaching occurred near Voi gate/patrol base despite Kasiki's (1998) observation that elephants tended to move westwards and aggregate around this area during dry season.

Conclusions

This study set out to assess which areas of TENP were at a higher risk of elephant poaching based on available elephant mortality data (1990–2005). The biophysical and human factors were found to be significantly correlated with poaching-caused elephant mortality patterns when combined with GIS models to generate corresponding risk to poaching maps.

Results obtained from nearest neighbour and kernel density analyses indicated that elephant poaching was not a random event in TENP, and instead exhibited clustered patterns irrespective of season for which poaching-induced elephant mortality was examined in the pre- and post-CITES ban on ivory trade. In addition, nearest neighbour analysis indicated that the clustering of poaching-induced elephant mortality did not occur by chance. Various point pattern analysis techniques, including kernel density and nearest neighbour analysis, revealed a similar distribution of poaching hotspots. The nearest neighbour analysis and kernel density analysis techniques provide the best combination for analysing elephant mortality patterns because of the former's ability to statistically test the significance of the elephant mortality patterns and the latter's ability to visualize hotspots.

Different biophysical and human factors were correlated with observed patterns of poaching-induced elephant mortality. Land cover type, availability of surface water and elevation were the most important biophysical factors limiting poached elephant distribution, while proximity to park roads, gates, park boundary and patrol bases were significant deterrents to poaching. Slope was not significantly correlated with poaching-induced elephant mortality.

Acknowledgements

We feel indebted to the Department of Geography for financially supporting the first author during his studies at Miami University, and to KWS for granting him study leave during this period. The first author is sincerely thankful to his M.S. thesis committee members including Dr John Maingi, Dr Kimberly Medley and Dr Mary Henry, for their constructive input into the M.S. upon which this paper is based. We are also indebted to the KWS staff for assisting in one way or another during the first author's fieldwork in Kenya. Finally, the first author extends his thanks to the Miami University's Departments of Geography and Zoology for their financial support during the fieldwork phase in Kenya.

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