Assessing Wildlife Distribution and Population Trends in the Greater Mara Ecosystem, Kenya: the synergistic effects of landscapes and threats

Louisa Richmond-Coggan

MSc Conservation Biology
Durrell Institute of Conservation and Ecology
University of Kent

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Abstract

As the biodiversity crisis continues there is a need to measure the loss of habitat and species. So far, investments in protected area (PA) or community-based conservation initiatives have had limited success. In Kenya, protected areas constitute an impressive 12.3% of its designated land, yet the majority of these PAs are too small to maintain viable populations of threatened wildlife with large home ranges. The Greater Mara Ecosystem (GME) in southern Kenya covers 6,000km^2, consisting of the Masai Mara National Reserve (MMNR) and 10 surrounding group ranches. In response to the need to simultaneously improve both wildlife conservation and local livelihood prospects alike, DICE, Friends of Conservation and the Massai developed, implemented and ran a community-driven scout programme that was supported by the Darwin Initiative.

From 2004-2006, some 74 Maasai scouts monitored the abundance and population trends of 26 wildlife species across the GME. This M.Sc. dissertation focused on four species, wild dog (*Lycaon pictus*), lion (*Panthera leo*), elephant (*Loxondata africana*) and zebra (*Equus burchelli*), that vary in their vulnerability to the different threat types across the GME. Fixed transect surveys were conducted to record focal species encounter rates thereby determining the population trends over two years. Non-fixed transects were also conducted to record encounter rates of threat types. Binary logistic regression analyses were performed to investigate the spatio-temporal physical variables and threat variables influencing focal species population trends and presence. The final models identified population trend and abundance patterns for elephant and lion populations, and abundance patterns only for wild dogs. Declines in elephant abundance were located in areas with lower retribution killings of crop pests and medium levels of bushmeat poaching. Declines in lion abundance were located in areas with medium threat levels in retribution of livestock predators and in areas closer to the MMNR border. Finally, wild dogs, which have suffered large scales declines over the past 30 years, were present in the wet and dry season in areas with high elevation and only the wet season in areas closer to rivers. This study aims to understand the variables affecting vulnerable species to enable future conservation programmes to the target key areas and reduce the decline of wildlife across the GME. The study also aims contribute to a wider understanding of patterns and causes of species decline across similar bioregions.

Key words: community scouts, binary logistic regression, Masai Mara National Reserve, presence, wildlife population trends.

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1. Introduction

1.1 Global biodiversity declines and global conservation initiatives

As the biodiversity crisis continues there is a need to measure the loss of habitat and species. There is also a need to understand the underlying processes in order to identify the conditions needed for successful conservation projects. A major cause is the rapid growth of human populations and the associated increased demand for natural resources and/or the space that they occupy. This population growth is more pronounced in tropical countries, which presents a greater problem because these countries tend to have the highest levels of biodiversity richness and endemism (Myers et al. 2000).

PAs have been traditionally recognized by the conservation community as the best approach to conserving biodiversity. However, PAs cover only 12% of the terrestrial land cover (Secretariat of the Convention on Biological Diversity 2004), are often under-funded, small, or both, and biodiversity extends outside of the PA network into growing rural populations (James *et al.* 1999, Newmark *et al.* 1993, Leader-Williams and Albon 1988). The creation of many PAs were often at the expense of the local communities who where evicted from their traditional land through law enforcement without compensation for loss of property and traditional hunting rights (Lane 1996). Thus, PA creation resulted in negative local attitudes towards wildlife conservation. Further problems facing conservation in developing countries is corruption of government, political instability and PAs just being ‘paper parks’ (Frazee *et al.* 2003) as the country lacks financial and management capabilities to provide any law enforcement. PAs require continuous management and a constant financial input to maintain the reserve. There is direct correlation between the funds available and the level of adequate law enforcement needed to create an effective PA (Burner *et al.* 2001). Developing countries have limited funds with their priorities in other sectors such as health and the development of services. It has also been suggested that PAs are not as effective for species conservation as originally thought. Burner *et al.* (2001) identified that PAs were successful at stopping land clearance but not so when dealing with hunting, fire and grazing. Thus, gaining community support is essential to the long-term survival of wildlife both inside and outside of PAs This has lead to the progression from a ‘fines’ and ‘fences’ PA approach (Johannesen and Skonhoft 2005) to a community based conservation (CBC) approach.

The CBC approach typically seeks to integrate conservation initiatives with local community's traditional land use practices and cultural beliefs. Examples of such initiatives include Integrated Conservation and Development Projects (ICDPs), CAMPFIRE in Zimbabwe and ADMADE in Zambia (Johannesen and Skonhoft 2005). More specifically, community based natural resource management (CBNRM) aims to achieve a 'bottom-up' approach in conjunction with rural development. The success of CBC projects has had varied levels of successes. Barrett and Arcase (1995) identified that ICDPs raise local expectations to unattainable levels leading to stimulated demand in the market for meat and wildlife products.

The underlying CBC concept is that the benefit generated from wildlife conservation must be shared with the community either directly or indirectly through schemes such as trophy hunting, nature-based tourism, ranching, cropping and direct employment. Receiving sufficient benefits from wildlife can increase community tolerance towards wildlife pest species that may cause direct or indirect economic costs to these same communities. Monitoring change in population trends is necessary to evaluate the effectiveness of conservation initiatives aimed at local communities. Long-term monitoring of population trends should provide conservation managers with reliable information to be used for adaptive management. Involving local communities in protecting their wildlife can be cost-effective as it relies on local knowledge. The use of community wildlife scouts is one way that conservation activities have been integrated into the community. For example, the International Gorilla Conservation Programme developed a ranger based monitoring programme for the conservation of the mountain gorilla (*Gorilla beringei beringei*) (Gray and Kalpers 2005). One of the activities conducted to increase programme success was extensive ranger training in enhanced data collection methods, but this required a greater time and funds. The rangers were unable to carry out rigorous scientific sampling as in this case their primary focus was law enforcement rather than monitoring. The benefits of rangers are that, once trained, they are able to train other rangers, thereby increasing the local capacity for improved conservation. Other advantages of local ranger/scout programmes include data collection can be spread over wider areas and through the increased responsibility of duties, moral and interest generated by the project. Community involvement can range from discussions and workshops to patrolling and monitoring to law enforcement and direct employment. Local rangers are able to protect wildlife which will benefit nature tourism, this in turn can raise local revenues. These funds will increase tolerance in the local communities of wildlife and motivate rangers to reduce the threats and conserve species.

1.2 Threats to wildlife in Africa

As the human population expands its need for natural resources increases. This puts pressure on the finite resources available. Technological developments lead to transformations in local agricultural processes to increase production rates and yield. As the demand for food availability by urban areas grows more land is required to be turned over to agricultural use. In the tropics, these changes in land use practices are often in direct conflict with wildlife conservation. Homewood *et al.* (2001) have shown that households in developing countries have multiple ways of generating income from livestock production, tourism, subsistence cultivation or mechanized maize production or in some cases a combination, all related to socio-economic factors. This represents the complexity of conserving wildlife outside that occupies these household areas outside PAs. Furthermore, tropical wildlife is poached for their meat, or bushmeat.

In Tanzania, the utilization of bushmeat was found to represent the largest economic value of wildlife, far in excess of legalized hunting, tourism or trophy values (Barnett 2000). Bushmeat poaching, and the benefits it brings to the community, are in direct conflict with wildlife conservation objectives. The targeted species tend to be those with most meat, so larger mammals such as ungulates, primates and rodents (Robinson and Bodmer 1999). Quality of the meat can also be a factor in choosing a species to hunt. In urban areas market forces and supply determine the species available creating an informal industry. In the Democratic Republic of Congo over 90% of both bushmeat and fish production is sold at market (de Merode *et al.* 2004). Large bodied animals such as primates have low reproductive rates and so are most susceptible to over-exploitation compared with more r-selected species such as rodents, which apparently can tolerate relatively intensive hunting (Wilkie and Carpenter 1999). In the Kiuti District, Kenya a survey identified that 79.9% of the community used bushmeat, with 67% describing bushmeat as the most important source of protein, with the price of bushmeat 129% cheaper than domestic meat across Kenya (Barnett 2000).

As the demand for bushmeat grows hunters are expending greater amounts of time and, consequently, hunting seasons are becoming longer if not all year round (Barnett 2000). The use of bushmeat in Kenya “no longer represents a limited subsistence orientated activity conducted by a few rural traditional societies but is increasingly an integral trade and subsistence activity” (Barnett 2000). Bushmeat is now seen by rural communities as a widely available and acceptable alternative to the traditional sources of protein, such as livestock, which represents household capital and cultural assets. Across the GME, droughts and floods are becoming more frequent and, so, communities are increasing looking for inexpensive alternative protein sources (Barnett 2000). Throughout Kenya, there has been a reduced poaching catch per effort, increased trade supply, increased use of sophisticated weapons, off-take from PAs, negligible law enforcement and destruction of traditional hunting seasons (Barnett 2000). All these factors in combination with environmental degradation and land use changes across the GME lead to potentially unsustainable demands and pressures being placed on wildlife populations.

Land-use and land-cover changes affect key aspects of the Earth’s functioning (Lambin *et al.* 2001), including a direct impact on global biodiversity (Sala *et al.* 2000). It is estimated that since 1850, the global expansion of croplands has converted six million km² of forest/woodlands and 4.7 million km² of savannahs/grasslands/steppes with a respective 1.5 and 0.6 million km² of this cropland then being abandoned (Ramankutty and Foley 1999). A consequent of these human modifications of the natural environment is the growth of rangelands, semi-natural habitats. Rangelands have a natural ‘carrying capacity’ for livestock, and exceeding this causes degradation in tropical and subtropical zones (Lambin *et al.* 2001). The carrying capacity is based upon the agro-ecological potential of the land. Rangelands in arid or semi-arid zones, such as the GME, are seen as being in non-equilibrium, and, so, modification to the biological productivity is determined by biophysical drivers, such as El Niño Southern Oscillation (ENSO) (Lambin *et al.* 2001). Thus, it is necessary to maintain livestock grazing in order to maintain the tropical rangelands.

Intensification of agricultural practices occurs because of three main factors: land scarcity; commodification; and, intervention. These factors all aim to increase production and market values (Lambin *et al.* 2001). Over the past three decades, changes in development policies and donor involvement in land use projects, in Africa have altered traditional patterns of land use and have consequently left weakened indigenous pastoral production systems that have lead to economic decline (Oba *et al.* 2000). Intervention into local land use practices, which have altered land-cover, will have a direct effect on the wildlife in the GME. Over a six-year period of grazed and non-grazed areas in northwest Kenya, the principal vegetation type, dwarf shrub (*Indigofera cliffordianan*), was found to have declined by 6% and 60% respectively (Oba *et al.* 2000). As traditional Maasai culture allows for livestock and wildlife to graze together, it is inevitable that in the future certain vegetation types will continue to deteriorate and the amount of grazing land available will become smaller. Pastoralists may subsequently become less tolerant of having to share these natural resources with wildlife, reducing available wildlife habitat further.

African elephant's range is up to 80% outside protected areas (Hoare 1999), and so are continuously coming into contact with humans. As both elephant populations and human density rises, the need to expand agricultural land grows this will lead to an increase in human-elephant conflict (HEC). Damage to crops and property will create negative attitudes towards elephants by the local communities. Hoare (1999) identifies that there is inadequate management of HEC which will lead to further declines of elephant populations and their distribution. Elephants are perceived to cause damage to crops, watering holes and other food sources, directly affecting rural livelihoods and in turn retribution killings increase. Various mitigation methods are being tried and tested throughout Africa with varying success (Hill *et al*. 2002). These general threats to wildlife are directly relevant to the GME. Understanding the historical and socio-economic factors behind the threats will lead to a greater understanding of their interactions across the GME.

1.3 Wildlife conservation in Kenya

Kenya's PAs cover *c.* 7,194 million hectares of its total 58,037 million ha (EarthTrends 2003). This represents 12.3% of Kenya's total land mass has been protected under all seven categories as outlined by IUCN (1994). National Parks IUCN protected areas categories I and II (IUCN 1994) comprise the majority of the seven categories covering a total of 3,432 million ha (EarthTrends 2003). Kenya has an estimated total of 400 mammal species, of which 32 are threatened (IUCN 2006) PAs and nature tourism have become inextricably linked in Kenya, with tourism now generating large revenues for conservation. This is set to continue as the tourism industry is estimated to be worth 1 billion by 2010 (Karanja 2001). Kenya's tourism started off as hunting trip by the wealthy and aristocratic with Theodore Roosevelt being one of the many notables. The hunting expeditions gave Kenya its reputation as the 'Big Five' country, now known as a must see tourist's list was originally related to the five most dangerous animals to hunt. In 1960, there were 35,000 tourist arrivals in Kenya. This number of arrivals rose dramatically to 750,000 tourists in 1991, with the industry directly employing 110,000 people in 1987 (Karanja 2001). Of the Kenyan PAs, the Masai Mara National Reserve (MMNR) is one of the most famous and, consequently, one of Kenya’s top attractions for both international and national visitors. There are approximately twenty one lodges and campsites both inside and on the MMNR border. This is only set to rise as tourist numbers and the demand for beds increases across the GME. Tourists normally spend between one and three nights within the MMNR (Mara Conservancy *per coms.*) Recent concerns about Kenyan PAs are that some have reached their carry capacity for tourists (Kisotu *per coms.*). This has lead to the Kenyan Wildlife Service (KWS) to raise the gate entrance fees to generate more revenue to reduce the environmental degradation caused by the increased number of tourists. Community-based ecotourism (CBET) allows for the community to receive an economic benefit from nature tourism. As the tourists arrivals have shown, Kenya’s tourism industry is of great economic value both at the national and local level. However, the industry is unpredictable and highly competitive and can be influenced numerous factors including political instability. The most recent example being the increased popularity of South Africa as a safari destination and Kenya’s recent political instability that saw a period of depression in the tourism industry having knock-on consequences into other business sectors. Kiss (2004) identifies the Il Ngwesi ecotourism project established by a Maasai Group Ranch (1996) as having the highest number and density of tree and herbaceous species, and 93% more sightings of wildlife, inside the sanctuary than on similar ranch land outside. As other group ranches environment deteriorated the group ranch maintained its vegetation as it was receiving benefits from tourism and so had the motivation to do so. Nature tourism, land use policies and the conservation of wildlife in the GME are dependent on each other and need to be looked at holistically in order to achieve sustainable goals.

1.3.1 Land use policies and wildlife conservation in the Greater Mara Ecosystem

The Land (Group Representatives) Act Cap. 287 (1968) was the act that formed the group ranches as they can be seen today in the GME. This act provides for the incorporation of representatives of groups who have been recorded as owners of land under the Land Adjudication Act Cap 284 of 1968 which connect collective pastoral management and resource use. The objectives of the Land (Group Representative) Act (1968) was to increase productivity of pastoral land by increasing off-take, pre-empt landlessness among Maasai, improve earning capacity of pastoralists and reduce environmental degradation from over grazing on communal lands. The group ranches were formed and incorporated only after the process of land adjudication and registration had been completed under the Land Adjudication Act (1968). The Land Adjudication Act (1968) is enforced by the group ranches through elected stakeholders who are community members. These members are chosen through local annual elections. A problem with the elections is that ministers often stay on longer than their allotted time as the re-election procedures are delayed.

Due to commercialization the individual members of the community are increasingly expressing a desire to obtaining their own individual land parcels, instead of all the land being controlled by the whole community. This recent development is cause for concern for wildlife conservation as each area may be fenced off, which would reduce the available habitat for wildlife. These parcels of land, if equally divided, will be small in relation to the human population of the group ranch. It has been shown that for livestock rearing, one cow requires two acres of land, but some individual parcels of land may be no bigger than 30 acres, which would be insufficient for most Maasai herdsmen. Furthermore, when the individual land parcels degrade, the farmer will have nowhere else to graze their livestock. The Land Adjudication Act (1968) states that every individual must have equal share of the land, a resolution is therefore required to ensure that equal acreage is decided upon. This act legally binds the Group Ranch members to hold meetings in order to sub-divide the land accordingly. To make the sub-division legal, a letter from the government confirms the process. After a three stage process of surveying, mapping and registration, the individual will legally own the parcel of land. The Ministry of Land and Settlement oversees the enforcement for the acquisition of the land, through the county council under The Land Control Act (1967). The main issue is that there is no real law enforcement to ensure the land is fairly divided. The Kenyan government does not have a department within its administration that focuses solely on land use designations and issues. Recently Maasai communities are pooling their land parcels to become conservancies and leasing them out to tour operators as conservation areas. Unfortunately grazing rights are limited which causes problems during droughts. Across the GME threat levels and land use changes vary, understanding the combined affect and spatial distribution is necessary in order to carry out adaptive management for the focal species.

1.4 Study objectives

The social, economic and ecological landscape across the GME is changing. The different factors that are contributing to this change include new land use management policies, the conversion of natural habitat to small agricultural holdings and associated increases in human-wildlife conflicts, increased tourism with associated increased human disturbance on wildlife. These factors can work synergistically to increase the threat status of the economically important wildlife across the GME, but the response of these species to these factors, individually or in combination, are not clearly understood. Thus, the overall aim of this study was to assess the population status and presence of four wildlife species with varying levels of vulnerability to the different threat types presence across the GME. More specifically this study investigated:

- The spatio-temporal landscape and threat variables that influenced focal species population trends between the 2005 and 2006 wet season; and,
- The spatial landscape and threat variables that influenced focal species presence during the 2005 wet season.

2. Study area and study animals

2.1 Greater Mara Ecosystem

The study area was the Greater Mara Ecosystem (GME), Southwest Kenya. The GME is made up of the MMNR and bordering group ranches. The MMNR lies between latitudes 1º15´ and 1º45´ South and longitudes 34º 45´ and 35º 25´ East. The GME forms part of the larger Serengeti-Mara ecosystem spanning 25,000km^2 between Northern Tanzania and Southern Kenya.

Figure 2.1 - The 1,510 km^2 Maasai Mara National Reserve, Southwest Kenya, East Africa (as shown in red on the insert).

(source Africa map: http://www.masai-mara.net/images/kenya_mara_map.jpg)

(Source Kenya map: http://www.tenwek.org/twk/graphics/kenya-in-africa.gif)

The MMNR was originally established as a Wildlife Sanctuary in 1948 (Koikai 1992), a smaller area than the present reserve but included the Mara Triangle an area of 520km^2 between the Siria Escarpment, the Tanzania border and the Mara River (Karanja 2002). In 1961, the MMNR borders were extended to 1,831km^2 and it was reclassified as a Game Reserve where hunting was regulated. Some 1,627km^2 of this area was given the status of National Reserve in 1974, under Legal Notice 271 (WPU, 1983), but 159km^2 was returned to the local communities (Walpole *et al.* 2003). The GME is approximately 6,000km^2, of which the MMNR covers 1,510km^2 of the total area leaving approximately 4,490km^2 as unprotected land inhabited by Maasai and other agro-pastoral communities (Walpole *et al.* 2003). The Mara Triangle, as of May 2001, came under the management of the Mara Conservancy, a non-profit organization. In the 1970s, the group ranches were established by securing a land tenure status for the Maasai (Lamprey and Reid 2004). The GME consists of ten group ranches: three occur inside Transmara district (Kerinkani, Oloirien, Kimintet) and seven inside Narok district (Koiyiaki, Lemek, Olderkesi Naikarra, Siana, Maji-Moto, Olkinyei).

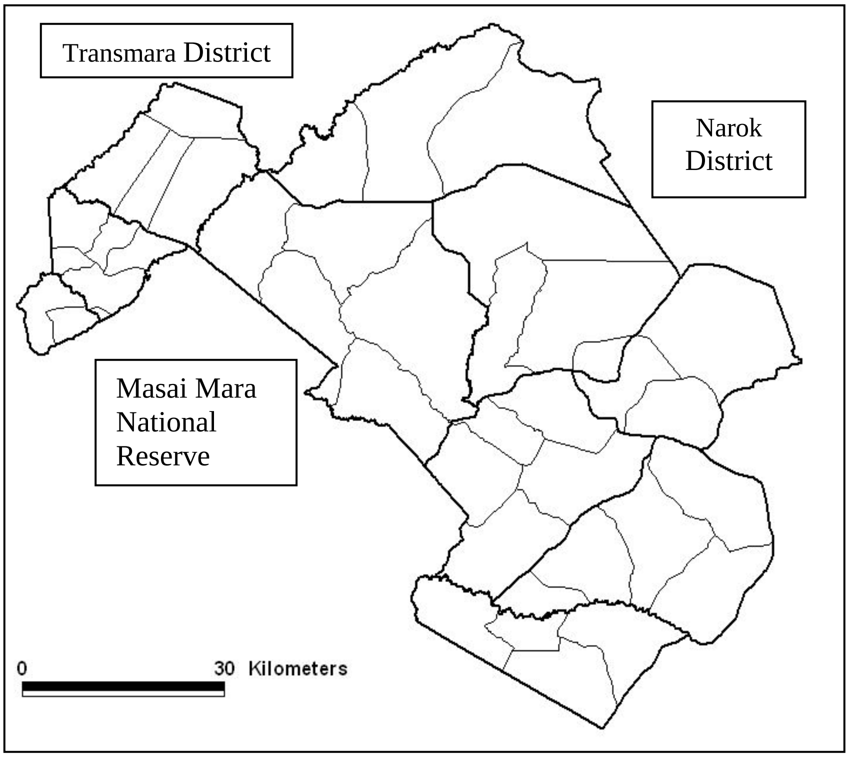


Figure 2.2 – The Greater Mara Ecosystem (GME) consisting of 10 group ranches and 39 cluster areas in Narok and Transmara districts that surround the Maasai Mara National Reserve (MMNR). The Mara River is the dominant river of the GME, with the Talek and Sand River being the permanent tributaries of the Mara River

The eastern GME is classified as 'Arid and Semi-Arid Lands' (ASAL) with between 30-50% of the land having either arid or semi-arid characteristics (Kisotu unpublished). The soil fertility reflects the semi arid environment with low in nutrients and organic matter levels which are compounded by high evapotranspiration rates and low rainfall rates. The combination of these two factors can lead to increased risk of salinization, alkalization and sodification (Kisotu unpublished). The soils of the MMNR are mainly volcanic alkaline soils ranging from brown sandy loam to black heavy clay (Karanja 2002). The GME has an annual rainfall for the region of 400-600mm and seldom exceeds 800mm with an average temperature of 25ºC-30ºC (Kisotu unpublished). The MMNR vegetation is classified as being in the Biogeographical Province 3.05.04 (East African Woodland/Savannah) (Karanja 2002). The GME consists of shrub, dry bush, grasslands and woodlands. Extensive grassland covers the MMNR which are dominated by *Themeda triandra* and interspersed with woody vegetation consisting of *Acacia* and *Balanites* spp. The group ranches surrounding the MMNR are dominated by the woody shrub *Croton dichogamus* with *Euclea dinovorum* being found in the reserve (Karanja 2002). The GME topography made up of the Loita, Ole Nturoto, Meguarra, Paraikong and Enkorika plateaus are the highest areas in the Eastern Mara with a range of 1,800m–2,400m above sea level. Within the GME there are few permanent rivers with seasonal streams only flowing during the wet season. Across the GME, the crop grown are maize (*Zea mays*), millet (*Eleusine coracana*), sorghum (*Sorghum vulgare*), cassava (*Manihot esculenta*), bean (*Phaseolus vulgaris*) and sugarcane (*Saccherum officinarum*), mainly for subsistence although there is a small commercial market developing. Other crops grown include vegetables, such as kale (*Brasica* spp.), potatoes (*Ipomea patatas*) and pumpkins (*Curcubita maxima*), and fruits, such as bananas (*Musa domestica*), avocadoes (*Persea americana*), oranges (*Citrus sinensis*) and tomatoes (*Lycoposicon esculentum*) Within the study area there is only one growing cycle, planting starts in late December with a subsequent harvest in mid August.

During the late 1980s, there was rapid population growth creating settlements such as the town of Talek. From 1983 to 1999, the number of Maasai bomas in Koyaiki group ranch increased by 6.4% per annum with human population growth rising at 4.4% per annum (Lamprey and Reid 2004). In 2004 Naikarra group ranch had a population of 9,297 with a projected growth rate of 3.3% annually. The ratios of males to females in the population are approximately even. The group ranch has an average of 8.8 individuals per household. The land in both Naikarra and Olderkessi group ranches is owned communally and so all natural resources are shared equally. The KWS is a parastatal of the Kenyan Government; it owns and is responsible for all wildlife within Kenya. The main sources of income in both group ranches are the sale of cattle, goats and sheep. For example, the total number of cows within Naikarra in 2005 was 97.19 cows/km^2 with a calving rate per year of 39.28%. The shoat (goats and sheep combined) reached 55.87 shoats/km^2 with a lambing rate of a third of the total number kept (Kistou unpublished). Agriculture is not the primary source of income due to the local environmental conditions. The dominant vegetation type and landscape of the study area is intrinsically linked to climatic variations.

2.2 Climate of GME

The MMNR and its group ranches have their own micro-climate but it is also important to put these variations into a broader perspective, within the Southern hemisphere. The rainfall pattern is bimodal with two peaks influenced by the Inter-Tropical Convergence Zone (ITCZ). The dry season typically occurs from mid-June to mid-October and a shorter dry season from January to February, inter dispersed with the wet season. The El Niño Southern Oscillation (ENSO) is based on the Southern Oscillation index (Figure 2.3), which during cold ENSO events caused above average rainfall, in contrast to warm ENSO events that caused the opposite (Ogutu in press). ENSO consists of El Niño events and are associated with enhanced rainfall over the wet season and La Niña which creates unusually dry seasons. The dry seasons affect wildlife movements, migration patterns and interspecies relationships as they seek out surface water remaining from the wet season. Over the past 40 years, rainfall within the MMNR has varied between the two seasons, both the wet and dry season show a five year quasi-periodicity with extremes in either linked to ENSO events forcing the rainfall out of phase (Ogutu in press). Norton-Griffiths *et al.* (1975) found that rainfall increases from the Southeast to the Northwest within the GME. During 1999-2000, the wet season failed causing widespread drought throughout the GME. This drought not only affected wildlife but livestock populations as well. In relation to studying population trends, drought will cause the stronger age bands to survive producing an unnatural skew in the population dynamics (Serneels *et al.* 2001). The Southern Oscillation index (Figure 2.3) shows the cyclic affect of El Niño and La Niña on climate of the GME.

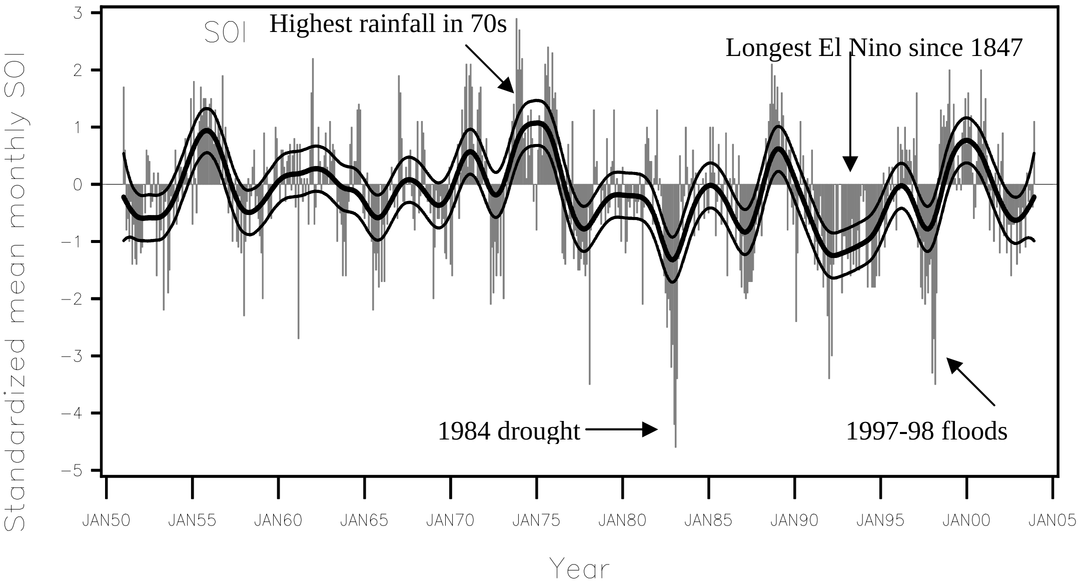


Figure 2.3: Standardized Southern Oscillation index (SOI) from 1951-2005. The superimposed trend line was fitted by a semi-parametric generalized linear mixed model with a radial smoother covariance structure (Ogutu in press).

From the climatic data, there was unusually high rainfall during the 1970s, severe droughts in 1984 and floods between 1997 and 1998 (Figure 2.3). The most severe ENSO was from 1989 to 1995, which had significant repercussions causing a severe drought in 1993. Drought is a common feature of the GME and is reoccurring due to the irregular cycles of rainfall. At a finer scale, the ENSO effect in Narok district from 1999-2004 was in 1999-00 there was an extreme drought; in 1993 and 1997 were server droughts. During 2003 there was a very wet year with 1998 and 2001 being extremely wet (Ogutu in press). Annual rainfall data in Narok district has been recorded by a permanent rain gauge since 1914, showing the ENSO spike from 1997-98 that caused flooding. The monthly rainfall data (Figure 2.4) was collected using a network of 16 rain gauges throughout the GME.

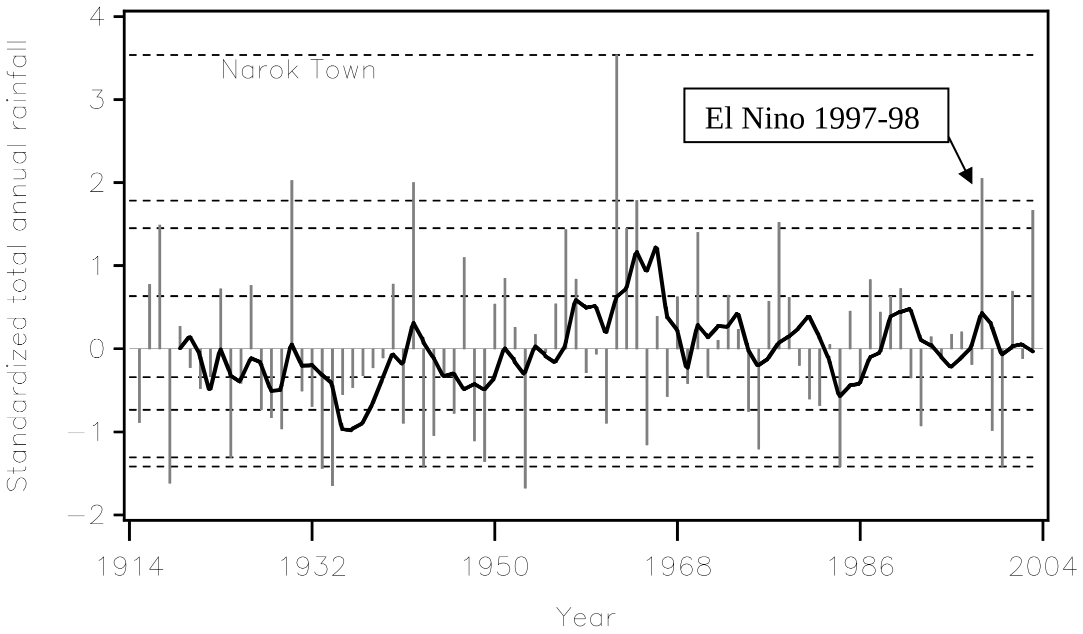


Figure 2.4: Normalized annual rainfall in Narok district all normalized relative to their respective long-term means and SD. Needles indicate the normalized records and solid lines the five year running means. The dashed horizontal lines are the percentile frequency distributions of each rainfall component (Ogutu in press).

Looking at the overall temperature fluctuations within the GME there is no clear temperature pattern but the wet season is becoming hotter (Ogutu in press). The principal influence on the dynamic of sub-Saharan rangelands is the climate, as it directly influences plant cover and biomass (Oba *et al.* 2000). The normalized difference vegetation index, which indicates plant vigour (Serneels *et al.* 2001, Appendix 3 Figure A3.1) shows that there is a time lag between rainfall and vegetation growth, which means that any disruption in the global and regional rainfall will have a direct effect on the GME. In the future, this temperature and rainfall variation may lead to a change in vegetation patterns and consequently wildlife distributions. For example, the effect of rainfall patterns on zebra (Equus burchelli) shows a direct correlation between mean rainfall and the density of zebra. It has also been shown that zebra birth dates are affected by rainfall variation of up to two months for zebra prior to the actual birth date. Mduma *et al.* (1999) found that wildebeest (*Connochaetus taurinus*) numbers are greatly affected by rainfall in the dry season as it directly affects the most important extrinsic determinant, food availability. The response to rainfall also depends on the age class of the individual. Figure 2.5 shows the monthly rainfall variation across the GME for 2004 and 2005. The birthing of these two species and other herbivores will in turn directly effect predators. Zebra in numbers of 100,000 and wildebeest of over one million migrate from July to October to the MMNR (Maddock 1979) to give birth all together, due to safety in numbers, and predator birthing coinciding with the increase in food availability. If the birth date were to be either early or late it could have a knock on effect on the mortality rate of young predators. This in turn will distort population trends, as they will be a time lag between the two events.

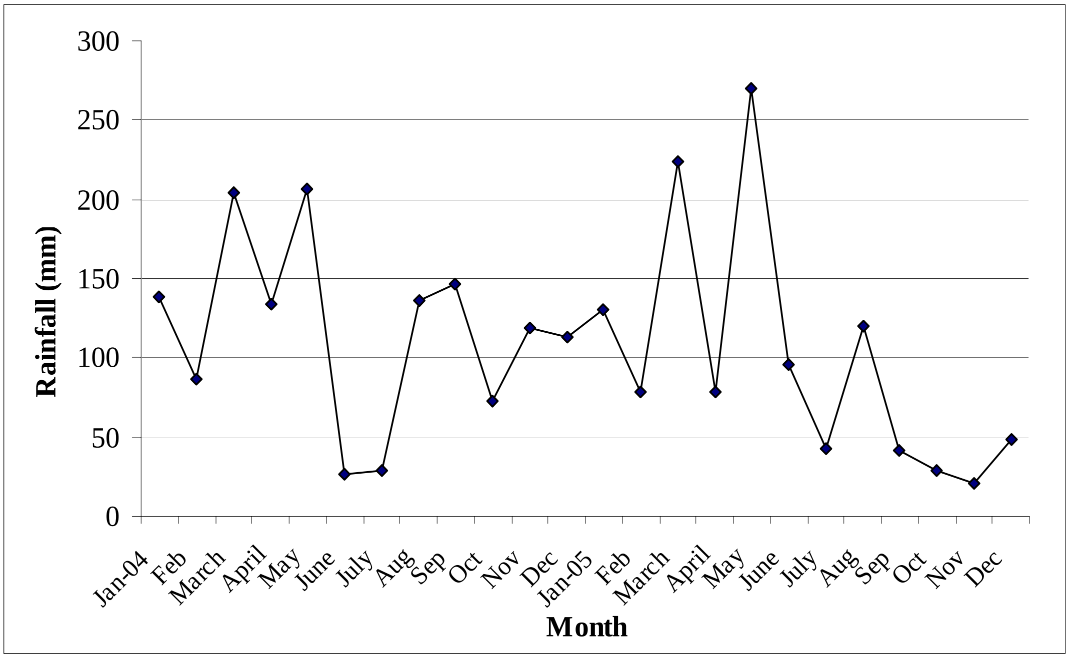


Figure 2.5: Monthly rainfall for 2004-5 across the Greater Mara Ecosystem

The climatic variations across the GME have a direct affect on species distribution which is why during monitoring it is important to know the rainfall patterns.

2.3 Focal species

Four species were chosen for this study because they are all potentially vulnerable to the different threat types operating through out the GME, and they are economically important species for nature tourism across the GME. Three out of the four species were chosen as they are also classified as being threatened on the IUCN Red List of Threatened Species..

2.3.1 African wild dog (*Lycaon pictus)*

The African wild dog is listed as endangered because the species has been virtually eradicated in East Africa, with its remaining strongholds being in Southern Africa (McNutt *et al.* 2004). The total wild dog population is estimated between

3000 and 5500. There has been a dramatic decline over the past 30 years with wild dogs disappearing from 25 of the 39 countries they were once recorded (Woodroffe 1997). The species' major threats are human activities, including direct persecution, which is the single most important cause of wild dog declines throughout Africa, as well as disease (canine distemper and rabies) and habitat fragmentation (Woodroffe 1997, McNutt *et al.* 2004). Woodroffe (1997) stated that human presence poses a serious threat to wild dogs, 61% of adult mortality was caused directly by human activities, even within the largest and well managed PAs, such as Kruger National Park. Wild dogs have developed a reputation for livestock killing, which is rarely justified (Woodroffe 1997). To maintain viable populations, wild dogs require a core area of no smaller than 10,000km² (Woodroffe and Ginsberg, 1998). Wild dogs naturally live at low densities even within PAs. In 1995, 24% of wild dogs were killed by traffic accidents compared to 12% being poisoned (Woodroffe 1997). Currently within Kenya, there are estimated to be less than 15 wild dog packs.

In 1991, wild dogs became locally extinct from the MMNR. Between 1986 and 1989, two packs migrated from the MMNR to the Aitong district and had a home range of 659km² per pack. The first pack bred successfully for three years then 21 out of 23 died of rabies, while the other pack migrated to the Serengeti between 1989 and 1991. The primary diet of wild dogs are ungulates, with preference shown for Thompson's Gazelle (*Gazella thomsonii*) Wild dogs are both in competition with, and predated by, larger carnivores, such as lions and spotted hyenas, as they are also crepuscular. The majority of wild dog pup deaths result from natural causes. Domestic dogs are carriers for diseases which wild dogs are highly susceptible to. This is why in theory the MMNR is unable to support wild dog populations due to its high population numbers of lion, hyena and domestic dogs outside its borders.

2.3.2 African lion (*Panthera leo)*

The GME is a 'honey pot' for national and international tourism with visitors intent on seeing what has become known as the 'Big Five'. The African lion is considered to be vulnerable (Bauer *et al.* 2004) as it has declined in two decades by 30-50% throughout Africa. The highest rate of lion population decline is in West Africa (39%) both inside and outside PAs (Bauer *et al.* 2004) with a 60-80% decline in Masailand, Southern Kenya (Frank *et al.* 2006). The former range of the lion used to cover Southwest Africa, the coastal forest of Northern Africa and from Northern Greece to Southwest Asia to Eastern India. The lion can be found in 34 countries and has continental range of three million km², half of these within formally gazetted PAs and the other half in areas with no official PA status. It is now feared that the Eastern population has become isolated from the Southern population, which will lead to problems of genetic inbreeding, unless steps are taken to relocate individuals, as in 2004 mature individuals only numbered 850 (Bauer 2006). In 2004, East Africa's lion population was estimated at 11,000 mature individuals, with 2280 of these in Kenya, and with 558 of these within the MMNR (Bauer 2006). Population data are lacking for areas outside Kenyan PAs (Frank *et al.* 2006).

The main threats facing lions are habitat loss and degradation, snaring and persecution by rural communities. Many examples exist of lion being legally hunted between 1946 and 1952, with one Laikipia game warden having shot 434 lions (Herne 1999). Retribution killing of livestock predators, such as lions, is a major problem. Retaliatory and pre-emptive killing of lions by rural people, particularly livestock owners is the single greatest threat to lion populations (Frank *et al.* 2006). Ogada *et al.* (2003) recorded that seventy-five percent of depredation on cattle, sheep and goats in the Laikipia District takes place at night, and lions were responsible for over 75% of the total. During the wet season, water holes become numerous causing the prey to disperse making it harder to hunt, lions will turn to killing livestock, this is not limited to a certain age-sex classes (Frank *et al.* 2006). The lion also has cultural significance for the Maasai Moran's, as becoming a man in Maasai culture traditionally involves the hunting and killing of a lion, a practice that still continues but is less common. Kolowski and Holekamp (2006) observed that regional variation in relative livestock depredation by large predators could be linked to relative densities of carnivores, husbandry practices and the relative abundance of stock species. If the herbivores numbers were to continue decreasing across the GME then the levels of livestock predation would rise as lions would look for alternative prey sources. As the flood and drought periods increase across the GME pastoralists will go to greater lengths to protect their livestock and livelihood further reducing their tolerance of lions.

2.3.3 African elephant (*Loxondata africana)*

To attract tourists to the MMNR and compete with fifty other National Parks in Kenya it must contain charismatic and flagship species (Simberloff 1998). The African elephant is considered to be vulnerable (African Elephant Specialist Group 2004). The African elephant has a range covering 950,000km², with African elephants in Kenya range covering 109, 071km² of which 27% is within PAs (Blanc *et al.* 2003). The history of the African elephant has been tumultuous with ivory poaching reaching its peak in the 1970-80's. This lead to the CITES Appendix I listing in 1989 which came into force in January 1990, with a split listing in 2000 due to lobbies by southern African countries. The elephant has a dynamic effect on the landscape and biodiversity because it can modify the vegetation dynamics of an area. Due to its behavioural traits of stripping bark and pulling down trees for fodder it creates a mosaic habitat of savannah and woodlands. As greater areas of land across the GME are turned over to agriculture and the human population expands the likelihood of HEC increases. As sub-division of group ranches to individual plots starts to rise across the GME traditional migratory routes and water holes may become cut off, which could have direct consequences for elephant populations across the GME

2.3.4 Burchell's zebra (*Equus burchelli*)

Burchell's zebra is a common species throughout East Africa numbering up to 0.6 million during the migration (Thirgood *et al.* 2004). Zebras are grazers predominantly on the open savannah grasslands preferring short to long swards, as predator evasion is easier. It has been shown that between 1970s and 1990s there was a non-migratory specie decline in Kenya's wildlife population by 58% (Ottichilo *et al.* 2000). As zebras are numerous across the GME change in zebra population trends may reflect a larger change in herbivores numbers

3. Methods

3.1 Field methods

3.1.1 Darwin Scout Programme wildlife monitoring

Wildlife monitoring patrols were conducted between January 2004 and March 2006. Some 51 scouts surveyed 152 fixed transects, for a combined total of 2158 times, covering 39 cluster areas within ten group ranches. A total distance of 695.76 km was walked through all transects with a mean length of 4.58 km, and a range of 1.72-8.15 km. The start point of transects were randomly placed using a stratified random sampling approach within a cluster area. To increase data collection, transects followed pre-existing animal or topographic trails, such as hill ridges, that the focal species and humans would typically use. This method is considered to have created a bias because the transect direction was not randomly determined, but this bias would have existed in all transects and was not considered to be important because the temporal change in wildlife abundance within each individual transect was being measured. In addition, transect placements were made to follow as straight a line as feasibly possible, so as not to record the same individual animal more than once. The location of each transect was recorded using a Garmin 12 global position system (GPS) units (Garmin Corp., Ulathe, Kansas, USA). The data collection was based on using encounter rates to determine changes in the relative abundances of focal species over time and within specific cluster areas.

This method allows for encounter rates to be quantified as each scout pair recorded their start and finish time, and the length of each transects had already been recorded. Due to the project being community-based, an encounter rate technique based on monitoring changes in relative abundance was more suitable than a technically demanding method based on distance sampling to monitor changes in absolute abundance (Burnham and Anderson 1998). Thus, it is important to customize the data collection method at the ability level of the personnel involved. The simpler encounter rate-based method allowed for the scouts to be trained more effectively in data collection techniques, the use of handheld GPS units and transect mapping. This enabled scout pairs to work unsupervised in the field. Each scout pair patrolled transects within their own village cluster, which they were more familiar with. To make patrolling more effective, each scout pair plotted their wildlife monitoring transects and anti-threat patrol route onto 1:50,000 topographic maps that were then digitized within a Geographical Information System.

Transects were conducted in either early morning (from 6-10am) or late afternoon (from 3-6pm), when the majority of the focal species were most active, which was anticipated to increase the number of animals sighted. At the start of each transect, the time, date and season (wet or dry) was recorded. Scout pairs then followed the fixed route on foot and in silence, so as to not disturb the wildlife. Upon encountering a monitoring species, the number of adults and young were recorded (Appendix 1 wildlife monitoring sheet).

Plate 3.1 - Niakarra community scout walking a wildlife monitoring transect through dense vegetation.

3.1.2 Darwin Scout Programme threat monitoring

Wildlife anti-threat patrols were conducted between January 2004 and March 2006. Some 74 scouts covering nine cluster areas within six group ranches patrolled 92 non-fixed transects. A combined total of 352.04 hours patrol effort was conducted with a mean walking time of 3.83 hours, and a range of. 0.87-11.00 hours. The start point of transects were randomly placed within a cluster area. The location of each threat activity was recorded using a GPS unit. Threat data was recorded using pre-designed anti-threat patrol sheets (Appendix 2 threat survey sheets). From the scout records, the main threat types operating across the GME, which were predicted to worse effect the study animals were i) poaching for bushmeat, ii) retribution killing of livestock predators, iii) retribution killing of crop pests, iv) charcoal burning, and v) other forms of habitat clearance.

i) Poaching for bushmeat - Across the GME, illegal hunting for bushmeat typically involves low-tech methods, with wire snares being the most widely used technique. Snares require shorter periods of time to set and have a higher catch rate than other methods. Other poaching methods can include traps, bows and arrows with or without poison tips, poison bate, hunting with dogs, firearms and spears (Carpaneto and Fusari 2000). Wire snares are indiscriminate and will trap small to large bodied animals. The snare can either result in death or a permanent injury. The range of people involved in bushmeat varies from immigrants from areas beyond the MMNR borders, local pastoralists and *ndorobos* (an ethnic minority group). Loibooki *et al.* (2002) found that 32% of the agriculturalists interviewed hunted for bushmeat in the Serengeti National Park. The study showed that 80% considered hunting as their primary source of income, of which 99% were subsistence farmers. Loibooki *et al.* (2002) also identified a relationship between the number of people admitting to being a hunter to the number of cattle they owned, with fewer cattle resulting in an increasing need to obtain alternative incomes, primarily through hunting. As drought kills off livestock, alternatives sources of protein are required for subsistence use. Immigrants enter the MMNR especially during the migration of zebra and wildebeest during the night with or without dogs and silently herd animals into pre-set snare traps.

ii) Retribution killing of livestock predators - The frequency of large predator conflict incidents with local communities is increasing across the GME because the MMNR is considered to be too small for species that require large ranges to maintain a viable population (Kolowski and Holekamp 2006). Homewood *et al.* (2001) states that from the MMNR buffer zone, aerial census data collected during the wet season showed that there was no significant change in cattle population numbers from 1977 to 1997. This must mean that either predator numbers are increasing or pastoralists have expanded their grazing areas next to, and possibly inside, the MMNR. Another possibility is the changes in vegetation patterns that have altered herbivore distributions and locations and have consequently brought predators into greater contact with humans. Livestock predation is linked to multiple factors that include rainfall, abundance of natural prey, livestock husbandry and boma design (Kolowski and Holekamp 2006). Bomas are traditionally made up of three circles with the central corral housing livestock, then the homesteads surrounded by a thorn bush stockade. Kolowski and Holekamp (2006) found that between the group ranches of Koyaiki and Siana on the borders of the MMNR, 130 depredation events occurred between 2003 and 2004.

The study showed that hyenas were the cause of 53% of the incidents, with lions and leopard together only 32%. Lions were also found to be responsible for 57% of cattle deaths but only one goat with a greater tendency for attacking grazing herds rather than inside the corral. Kolowski and Holekamp (2006) recorded a total annual loss of cattle to predators of 0.2% of the total cattle holding (11,864), which was the equivalent to 460,000 Kenya Shillings. The Maasai will in turn try and seek out the attacker using snares, poison or a direct hunt using spears. It is not unusual for the entire male population of a village to surround a lion and attack and kill it from all sides with spears. As Serneels *et al.* (2001) has shown there is a correlation between herbivores and the climate, Kolowski and Holekamp (2006) has also confirmed there is a relationship between human-lion conflict and seasonal variation in relation to prey abundance.

iii) Retribution killing of crop pests – Numerous wildlife species crop raid, but elephants cause the most severe damage and crop raid most frequently. HEC is an important conservation issues that needs to be addressed across both African and Asian elephant range, especially where expanding human populations are coming into contact with elephants. As elephant numbers expand and they migrate out of the PAs into the surrounding group ranches, contact with human is inevitable as local communities share 80% of the elephant’s range (Hoare 1999). HEC patterns has been well studied and documented in Africa (Naughton-Treves 1998, Sitati 2003, Sitati *et al.* 2003, 2005), with a variety of mitigation methods being used to deter elephants from crop raiding. The most successful methods are ones which are low technology and sustainable such as chili rope and air horns. Crop raiding is seasonal with the elephant having a strong preference towards nearly mature and mature maize (*Zea ma*ys) (Walpole and Kisotu unpublished). Between 1992 and 1999, a total of 428 elephants were shot by Problem Animal Control Units compared to poachers killing 412 (Leader-Williams *et al.* 2001). HEC can take many forms, from crop raiding, infrastructural damage to human death and disruption of daily activities (Sitati *et al.* 2003). Elephants have become the most notorious human-wildlife conflict species due to the level of danger they pose to human life.

Crop raiding has strong seasonal patterns with most attacks taking place between dusk and dawn (Sitati *et al.* 2003). It has been shown that male elephants are the most common offenders due to their unpredictable behaviour and due to this understanding the spatial pattern of crop raiding has been difficult. Sitati (2003b) studied carried out in the Transmara (from 1999-2000) and recorded a total of 329 crop raiding incidents with 80% of the groups containing ten elephant or less, and with only 2% of the incidents being carried out by lone males. The period between 1986 and 2000 recorded 35 human deaths with 50% occurring after 1996. This study showed a continuation of results of other studies (Sukumar and Badgil 1988) that male elephants are willing to take greater risks by crop raiding closer to town increasing the likelihood of contact with humans (Sitati *et al.* 2003). The main crop preferred by elephants is maize (*Zea ma*ys). Mitigation methods used to deter elephants are low tech non-fatal and inexpensive ranging from barriers to shouting and banging to lighting fires and chili (*Capsicum* spp.) essence (Sitati *et al.* 2005). Sitati *et al.* (2005) identified that non–raided farms were the ones with a significantly higher guarding effort in addition to lighting fires and noises. HEC is a complex issue but it costs the local farmer either if the cash crop or subsistence crop is destroyed, in the GME there is only one planting season a year. As HEC increases and mitigation methods are perceived not to be working local attitudes towards the elephant will become negative leading higher levels of retribution killing.

iv) Charcoal burning - Charcoal burning is a specific type of land clearance that directly links woodland degradation and microeconomics (Kisotu *per coms.*). The process requires a very low level of technology to produce a marketable output, and is normally a secondary income to supplement the sale of livestock. Trees are cut down and placed under a mound of soil and set alight. This mound is then left to burn down, until it is reduced to charcoal blocks. With human population expansion, there is a greater demand a cheap and reliable fuel sources. The traditional stoves are built to use with charcoal but inefficiently and currently there is no other affordable alternative. The activity of creating charcoal is predominantly carried out by the women with the products either being sold at local markets or opportunistically at roadsides. It is not a time efficient process but it can produce a financial return, as the community owns the trees. As charcoal burning targets specific habitat only certain species will be affected, woody areas are important in terms of covered migration routes and direct habitat use.

v) Habitat clearance - From 1975-1995 land use changes in Kenya have been rapid and widespread, with mechanized farming increasing from 4,875ha to 47,600ha during this time (Homewood *et al.* 2001). The growth of the mechanized farming has lead to direct land use conflict, as wet season rangelands were fenced excluding wildlife. The fencing of this area has a direct affect on species densities, such as wildebeest which significantly decreased by 75% between 1985 and 1997 (Homewood *et al.* 2001). Even though the area farmed is only 2.8% of the total Narok District it is the location on the Loita Plains that is in direct conflict with wildlife. Conversion to large-scale wheat farming can be explained by agro-climatic potential with mechanized agriculture becoming less likely the more arid the climate becomes with Narok town also a key factor in terms of communication and focal point (Homewood *et al.* 2001). Other changes have included the expansion of settlements around the MMNR gates such as Talek and Sekanani in relation to increases in tourist numbers providing a secondary income. The expansion of the settlements has lead to a change in land use from natural vegetation to maize crops adjacent to the reserve. As the local population increases the pressure on natural resources as boma construction requires large amounts of wood as well as firewood for cooking. Ten years ago only 19% of Kenyan households cultivated and ten years on it is now 46% (Homewood *et al.* 2001).

3.1.3 M.Sc. data collection

The main source of data collected within this M.Sc. research was conducted from a random selection of cluster areas from the group ranches of Naikarra and Olderkesi. These group ranches were chosen because of their logistical suitability for fieldwork that could be based out of the Friends of Conservation/Darwin research station in Naikarra. Fieldwork was conducted over a two month period from May to June 2006 that occurred during a wet season. The aim of the survey was to estimate the relative abundance of focal species along 25 transects during the first phase of fieldwork (15/05/06 – 01/06/06) and then repeat these surveys along the same 25 transects during the second phase of fieldwork (05/06/06 – 23/06/06). The total length of the 25 transects walked was 116.89km, with a mean effort of 4.68km and a range of 2.85 – 7.32km.

Each transect was repeated within a minimum time period of three weeks between the first and the second phase. The average species abundance was then calculated for each transect. Repeat surveys were conducted to increase the precision of abundance estimates, as determined by calculating the standard deviation for each transect. Due to time and personnel constraints it was not possible to repeat the transects more than twice. The transects are in a straight line to reduce the possibility of recording an animal twice dependent on the vegetation density. To ensure compatibility, the data collection method applied during this M.Sc. research adhered to the scout sampling protocol. The M.Sc. data were combined with the GME scout data to enhance the final dataset.

Plate 3.2 - Community scout and Kenya Wildlife Service ranger next to logged trees.

3.2 GIS methods

For each transect, we assessed five physical parameters and five threat parameters as potential predictors of wildlife population trend change. The physical parameters were the geographic location of roads, rivers, towns and the MMNR, as well as elevation. The threat parameters were poaching for bushmeat, retribution killing of livestock predator species, retribution killing of crop raiding species, habitat clearance for charcoal extraction and other land clearing types.

For each transect, the geographic locations of rivers were obtained from 1:50,000 maps produced by the 4th Edition 1978 created by the directorate of overseas surveys series Y731 (D.O.S 423) sheet numbers 158/2, 159/1 and 159/3. The position of roads and towns were obtained from ILRI (International Livestock Research Institute) and the Ministry of Agriculture/German Technical Co-operation-Transmara Development Programme, who digitized these data from February 2003 Landsat 7 satellite images (Path/Row: 169/061). The MMNR boundary was obtained from ILRI, who digitized its location from 1:50,000 paper maps. All these spatial data were imported into ArcView v3.2 GIS software package (ESRI Inc., Redlands, California, USA), converted into a raster format and georeferenced using the UTM 36s coordinate system using the Arc1960 datum. The mean proximity to roads, towns, rivers and MMNR coverages were individually created using the ‘find distance’ function in the ArcView Spatial Analyst extension file. The digital elevation model (DEM) data were obtained from ILRI and used to produce the elevation coverage. The elevation coverage was used instead of a vegetation habitat map for the GME, developed by Jan Dempewolf (University of Maryland, USA), because of collinearity.

There was insufficient wildlife threat information across the GME because patrols were not conducted in every cluster area. So, the five threat coverages were compiled as categorical data based on the opinions of an expert panel that decided whether each threat type was either ‘low’, ‘medium’ or ‘high’ for each cluster area. The categories used, reflected the known threat activities that were recorded during scouts anti-threat patrols. The expert panel was composed of the FOC Scout Coordinators of Stephen Kisotu, David N’Goet, Samwel Naikada and John Tira, as well as DICE/WWF researcher Dr Noah Sitati. The panel had over 60 years experience of working in the GME and were therefore judged to be adequately qualified to contribute to the threat coverage construction. The five threat activities are poaching for bushmeat, retribution killing of livestock predator species, retribution killing of crop pest species, habitat clearance for charcoal extraction and other land clearing types for reason previously discussed.

3.3. Statistical methods

The transect data and wildlife population trend data were imported into SPSS v.13 software (SPSS Inc., Chicago, Illinois, USA). All analyses were conducted on transects >1km to reduce potential problems with spatial autocorrelation. This resulted in 88 transects being selected from a total of 152 fixed transects that were surveyed for wildlife. The continuous data were logarithmically transformed to reduce the likelihood of extreme results having a disproportionate influence on the overall dataset. The accuracy of the threat coverages was checked by using different data sources. To test the poaching for bushmeat map, snare traps were used as a relevant indicator. For each cluster area with patrol data (n = 23), the relative abundance of snare traps was calculated as the encounter rates (ER) where,

Snare trap ER = number of snare traps detected/patrol hour

The average snare trap abundance from each patrolled cluster area was compared with the expert panel poaching ranking (‘low’, ‘medium’ or ‘high’) using a Kruskal-Wallis test to determine whether cluster areas with a higher threat score had a higher snare trap ER than the other cluster areas. The expert panel map showed a significant and positive relationship with the scout snare trap ER data ($n = 23$, $\chi^2 = 6.17$, $df = 2$, $P = 0.046$).

A combination of land clearance data derived from satellite images provided by ILRI and GTZ was used to test the precision of the land clearance map produced by the expert panel who score each group ranch as having either ‘low’, ‘medium’ or ‘high’ levels of land clearance. A Kruskal-Wallis test was performed to determine whether group ranches with a higher threat score had a higher rate of deforestation (% change/yr) as recorded from satellite image interpretation. The expert panel map showed a significant and positive relationship with the deforestation rate data ($\chi^2 = 5.921$, $df = 2$, $P = 0.052$).

It was not possible to verify the expert panel human-wildlife conflict map, because although human-wildlife conflict data has been collected across the GME, different data collection techniques focusing on either all species or specific species do not allow for a meaningful comparison.

Temporal patterns of population change

To determine the relative abundance of the individual wildlife species, their respective encounter rates (ER) were calculated for each transect as:

Wildlife species ER = total number of animal species sighted/transect length (km)

Next, to determine species specific population trends along each transects, the percentage change in relative abundance between the wet season of 2005 and 2006 and then dry season of 2005 and 2006 was calculated. Population trends for transects within the same cluster area were then pooled and the mean percentage change calculated for the wet seasons and dry seasons.

Spatial patterns of wildlife distribution

A regression analysis was performed to determine which physical and threat factors, in combination or individually, explained wildlife population trends: i) along transects between the 2005 and 2006 wet season; and, ii) along transects between the 2005 and 2006 dry season. To determine whether a linear or logistic regression analysis was more appropriate, population trend data at the transect level were tested for normality by plotting the frequency of their respective raw data. Both sets of these data were not found to be normally distributed, making a binary logistic regression analysis more appropriate for the dataset. Population trends were recoded into a binary code, with '1' denoting a population decline and '0' denoting no population decline.

For the two sets of analyses, the addition and removal of independent variables from the regression model was controlled by the Wald statistic with respective *P*-values of 0.05 and 0.1. The performance of the model was evaluated by calculating the area under the curve (AUC) of the receiver operating characteristics plot (Manel *et al.* 1999, Pearce and Ferrier 2000, Osbourne *et al.* 2001). These values range from 0.5 to 1.0, and those above 0.7 indicate an accurate model fit, while those above 0.9 indicating a highly accurate model (Swets 1988). In the spatial analysis it was necessary to test for non-independence caused by spatial auto-correlation because landscape features close to each other tend to have similar characteristics (Koenig 1999). The presence of spatial autocorrelation in the model was tested by calculating Moran's *I* statistic (Cliff and Ord 1981) using the Crime-Stat v1.1 software package (N Levine and Associates, Annadale, Virginia, USA). This test was then repeated for wildlife population trends along transects between the 2005 and 2006 dry season.

Species presence

A regression analysis was performed to determine which physical and threat factors, in combination or individually, explained wildlife presence: i) along transects during the 2005 wet season; ii) along transects during the 2005 dry season. To determine whether a linear or logistic regression analysis was more appropriate, presence data at the transect level were tested for normality by plotting the frequency of their respective raw data. Both sets of these data were not found to be normally distributed, making a binary logistic regression analysis more appropriate for the dataset. Presence was recoded into a binary code, with '1' denoting presence and '0' denoting no presence..

For the two sets of analyses, the addition and removal of independent variables from the regression model was controlled by the Wald statistic with respective *P*-values of 0.05 and 0.1. The performance of the model was evaluated by calculating the area under the curve (AUC) of the receiver operating characteristics plot (Manel *et al.* 1999, Pearce and Ferrier 2000, Osbourne *et al.* 2001). These values range from 0.5 to 1.0, and those above 0.7 indicate an accurate model fit, while those above 0.9 indicating a highly accurate model (Swets 1988). In the spatial analysis it was necessary to test for non-independence caused by spatial auto-correlation because landscape features close to each other tend to have similar characteristics (Koenig 1999). The presence of spatial autocorrelation in the model was tested by calculating Moran's *I* statistic (Cliff and Ord 1981) using the Crime-Stat v1.1 software package (N Levine and Associates, Annadale, Virginia, USA). This test was then repeated for wildlife presence along transects during the 2005 dry season.

4. Results

4.1 Spatial factors determining wildlife population trends

Elephants have two significant factors affecting both population trends and presence which were bushmeat poaching and retribution killings of wildlife crop pests. Lions have three significant factors affecting both population trends and presence. Lion presence were related to log$_{10}$ distance to roads, log$_{10}$ distance to the MMNR and retribution killings of livestock predators, with population trends related to log$_{10}$ distance to the MMNR and retribution killings of livestock predators. For wild dogs there were no significant variables that had an affect on population trends across the GME. Wild dog presence was related to log$_{10}$ distance to rivers and log$_{10}$ elevation in the wet season and in the dry season only log$_{10}$ elevation. For zebra there were no significant variables that had an affect on population trends or presence across the GME.

4.1.1 Elephant

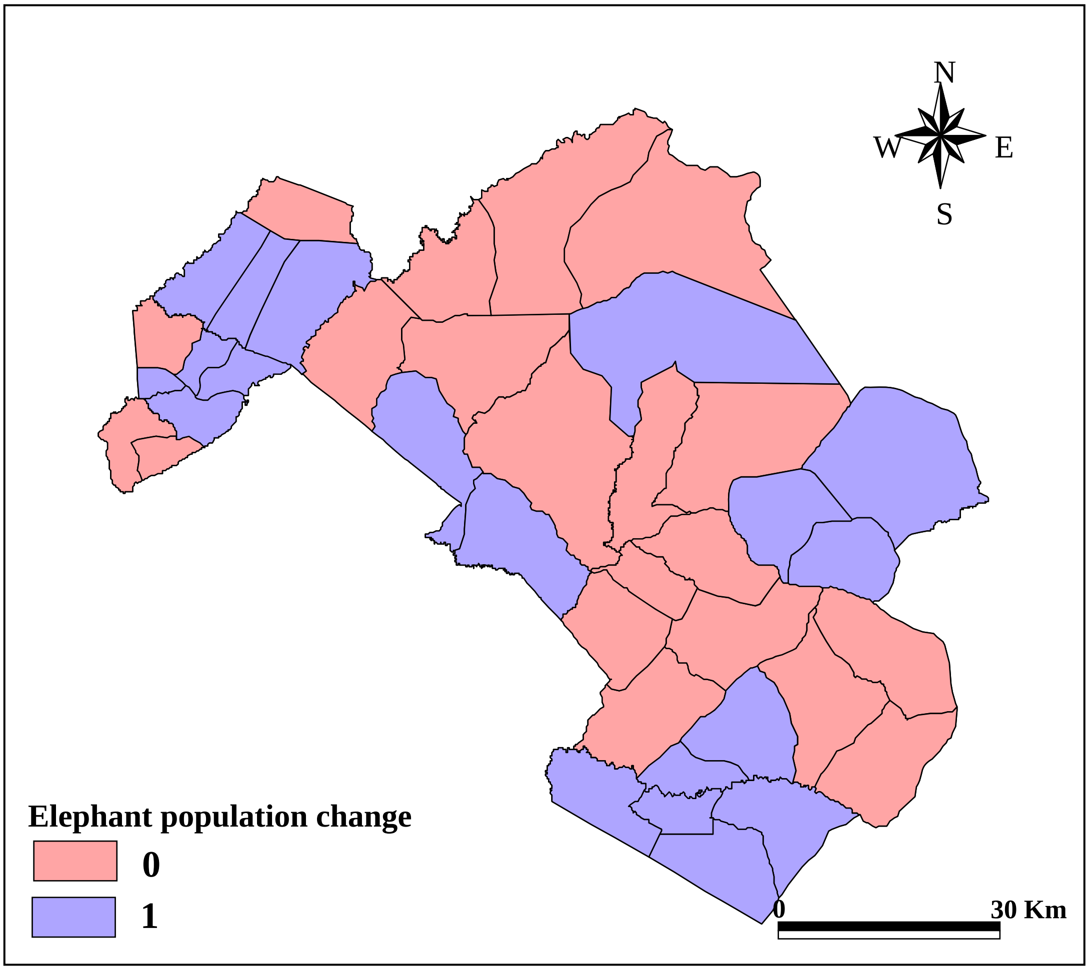


Figure 4.1: Elephant population change in wet seasons between 2005 and 2006 within clusters across the Greater Mara Ecosystem. 0 indicates a decline with 1 indicating no or positive increase.

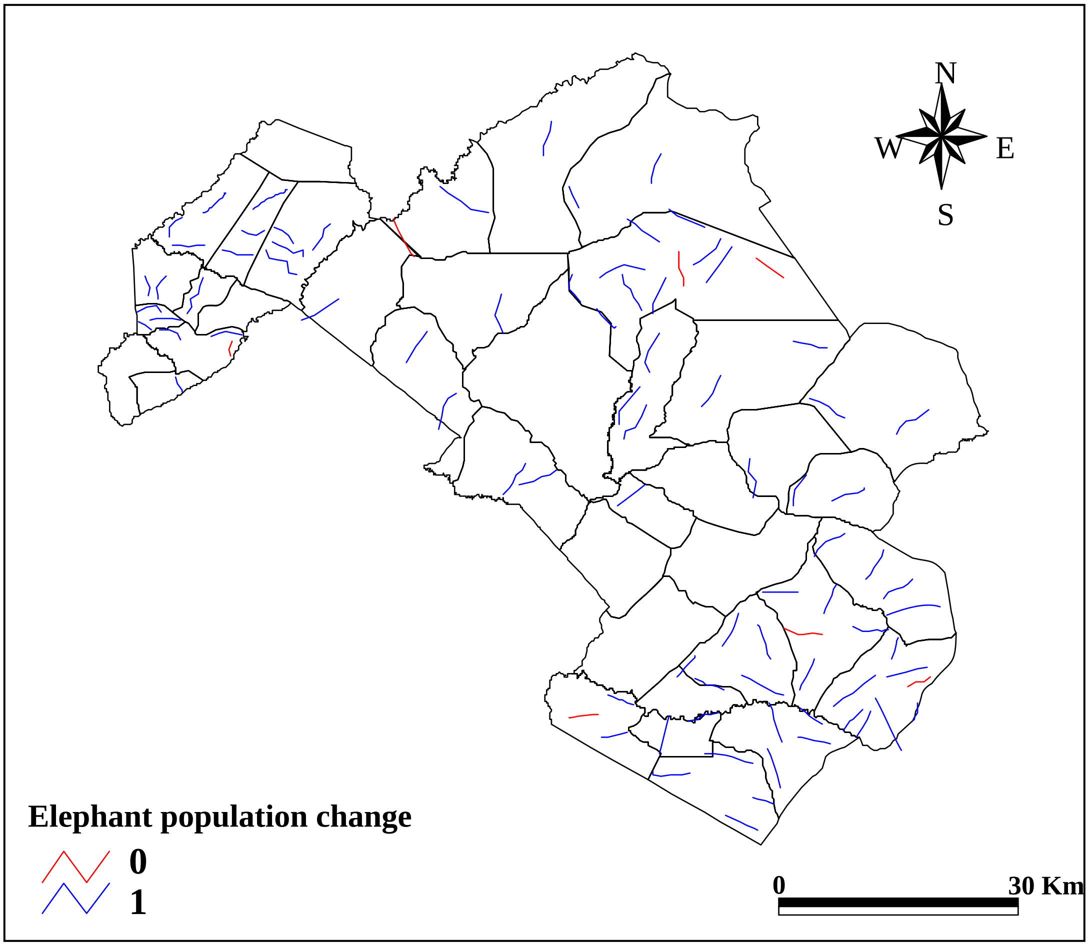


Figure 4.2: Elephant population change in wet seasons between 2005 and 2006 within transects across the Greater Mara Ecosystem. 0 indicates a decline with 1 indicating no or positive increase.

During the 2005 and 2006 wet seasons, declines in elephant population trends were recorded over 50% of the transects (n = 44). The threat variables that best explained the probability of elephant population trends decreasing were related to bushmeat poaching and retribution killings of wildlife crop pests (Table 4.1, Figures 4.3 and 4.4), with no effect from the other variables tested. Declines in elephant abundance were located in areas with lower levels of retribution killing of crops pests and in areas with medium levels of poaching for bushmeat. The model showed that there was no effect from medium levels of retribution killing of crop pests on elephant population trends. The logistic regression model explained 72.7% of the original observations and was not affected by spatial autocorrelation (Moran's $I = 0.02$, $P > 0.1$). The final model had an AUC value of 0.780 indicating an accurate fit.

Table 4.1: Best binary logistic regression model describing the relationship between threat variables and elephant population trends across the Greater Mara Ecosystem

Variable	B ± S.E.	Wald	df	*P*
Poaching for bushmeat (high)		13.185	2	0.001
Poaching for bushmeat (low)	2.431±0.766	10.066	1	0.002
Poaching for bushmeat (medium)	4.084±1.341	9.274	1	0.002
Retribution killings of crop raiding species (high)		8.453	2	0.015
Retribution killings of crop raiding species (low)	1.667±0.576	8.381	1	0.004
Retribution killings of crop raiding species (medium)	0.644±0.893	0.521	1	0.470
Constant	-3.042±0.844	12.983	1	0.000

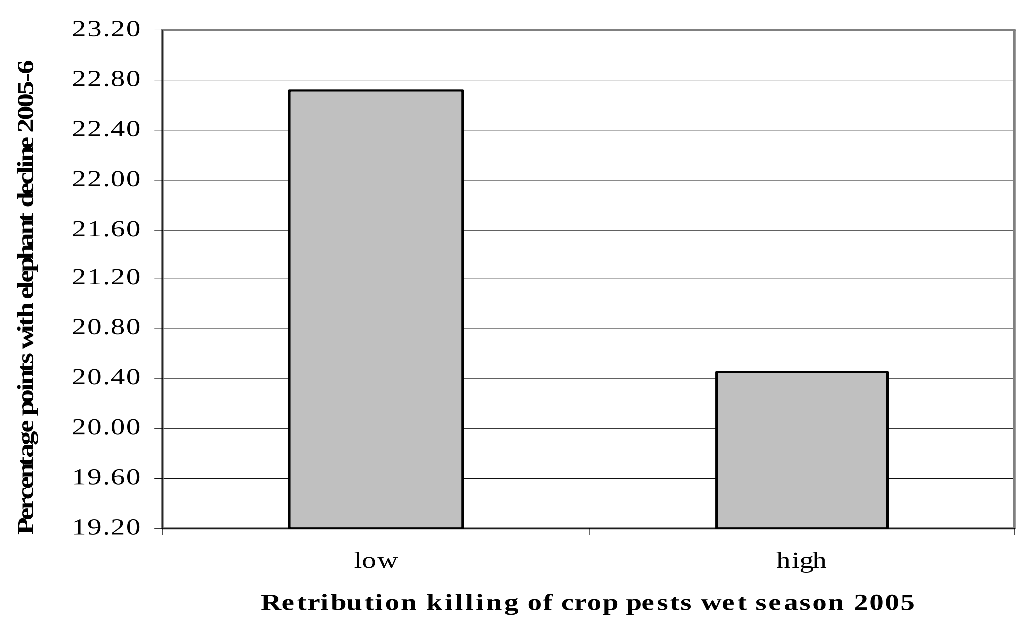


Figure 4.3: Population change of elephants during the 2005 and 2006 wet seasons relative to percentage of points with low or high levels of retribution killing of crop pests.

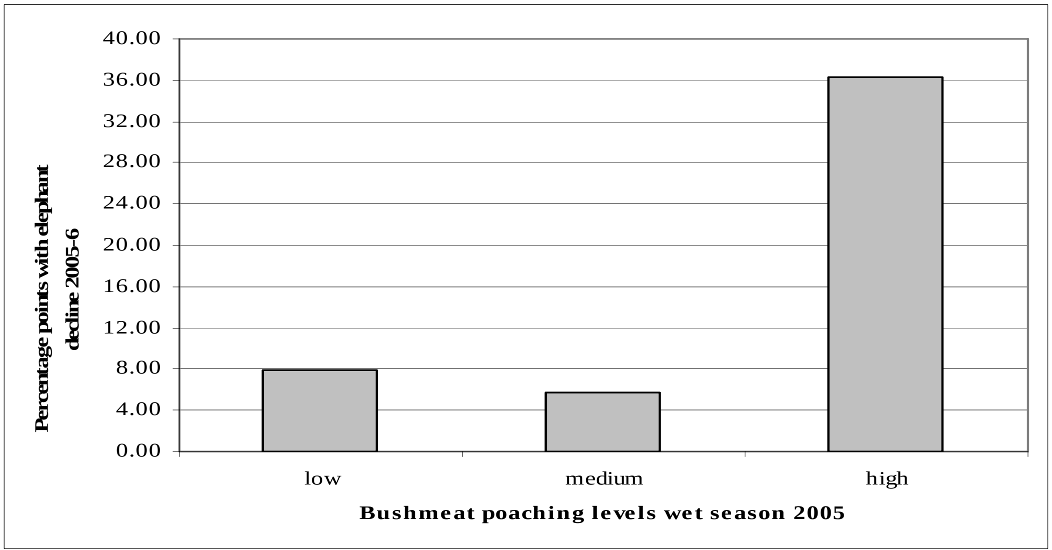


Figure 4.4: Population change of elephants during the 2005 and 2006 wet seasons relative to percentage of points with low, medium or high levels of poaching for bushmeat.

Dry Season

During the 2005 and 2006 dry seasons, declines in elephant population trends were recorded over 83% of the transects (n = 73). The binary logistic model showed that there were no significant variables that had an effect on elephant population trends during the 2005 dry season across the GME.

4.1.2 Lion

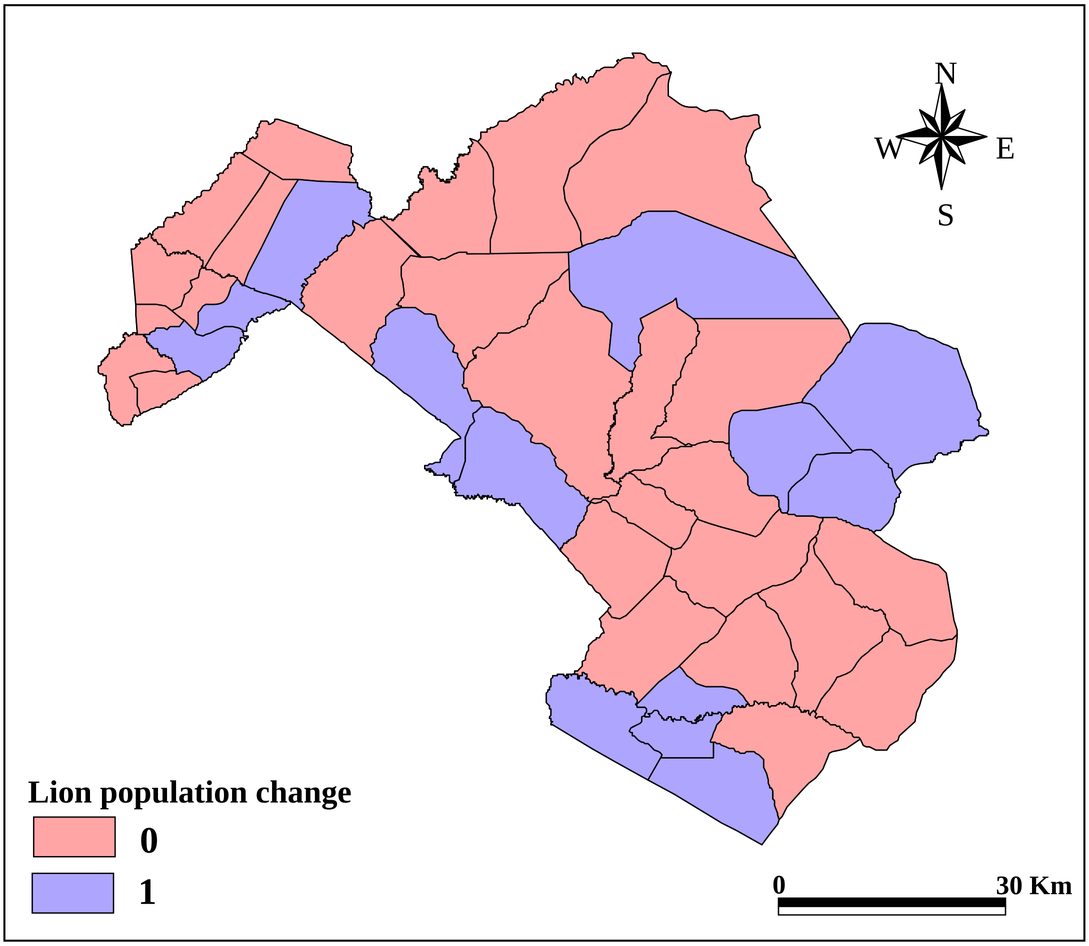


Figure 4.5: Lion population change in wet seasons 2005 and 2006 within clusters across the Greater Mara Ecosystem. 0 indicates a decline with 1 indicating no or positive increase.

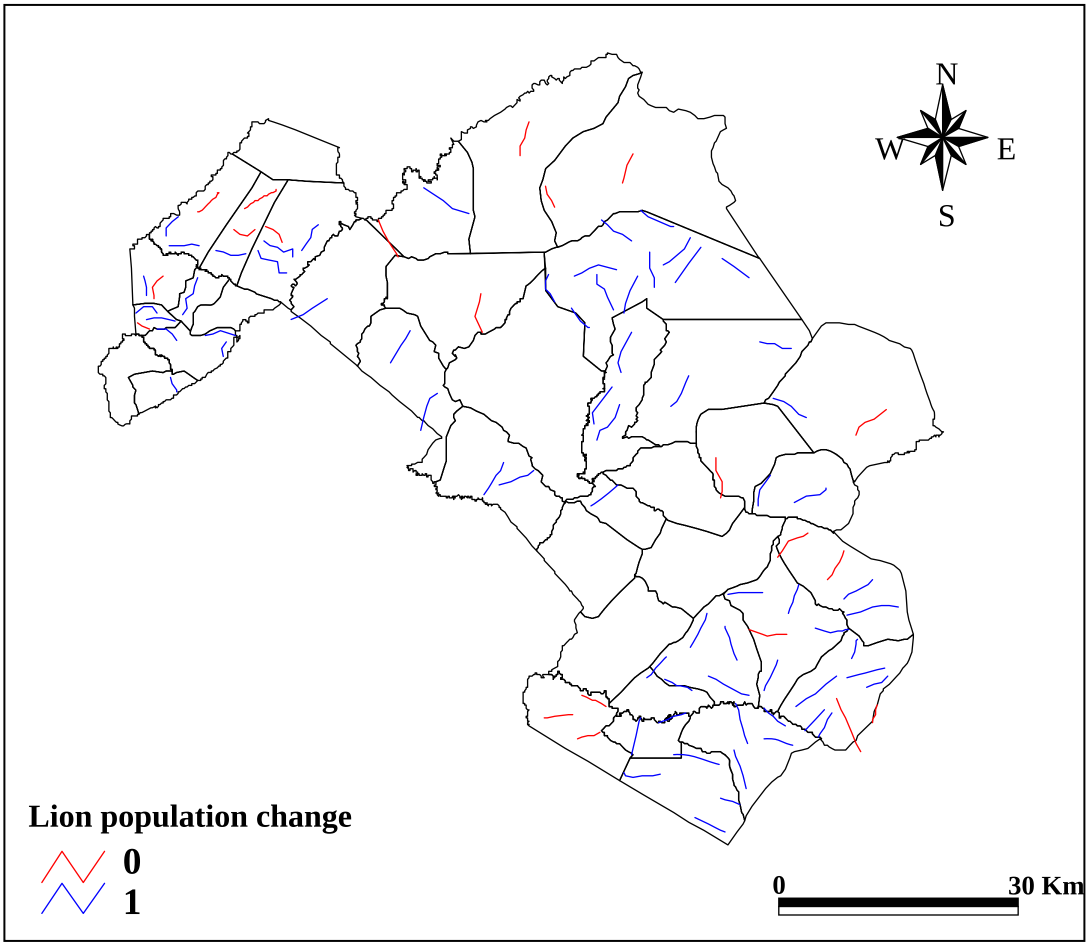


Figure 4.6: Lion population change in wet seasons 2005 and 2006 within transects across the Greater Mara Ecosystem. 0 indicates a decline with 1 indicating no or positive increase.

During the 2005 and 2006 wet seasons, declines in lion population trends were recorded over 45% of the transects (n = 40). The threat variables that best explained the probability of lion population trends decreasing were related to $\log_{10}$ distance to the MMNR and retribution killings of livestock predators (Table 4.2, Figures 4.7 and 4.8), with no effect from the other variables tested. Declines in lion abundance were located in areas that had medium threat levels of retribution of livestock predators and in areas closer to the MMNR border. The model showed that there was no effect from lower levels of retribution killings of livestock predators on lion population trends. The logistic regression model explained 61.4% of the original observations and was not affected by spatial autocorrelation (Moran's $I = 0.02$, $P > 0.1$). The final model had an AUC value of 0.700 indicating an accurate fit.

Table 4.2: Best binary logistic regression model describing the relationship between physical and threat variables and lion population trends across the Greater Mara Ecosystem

Variable	B ± S.E.	Wald	df	*P*
Log_{10} distance to the MMNR	-1.881±0.862	4.764	1	0.029
Retribution killings of livestock predators (high)		7.517	2	0.023
Retribution killings of livestock predators (low)	0.823±0.637	1.667	1	0.197
Retribution killings of livestock predators (medium)	1.675±0.625	7.181	1	0.007
Constant	6.916±3.571	3.571	1	0.053

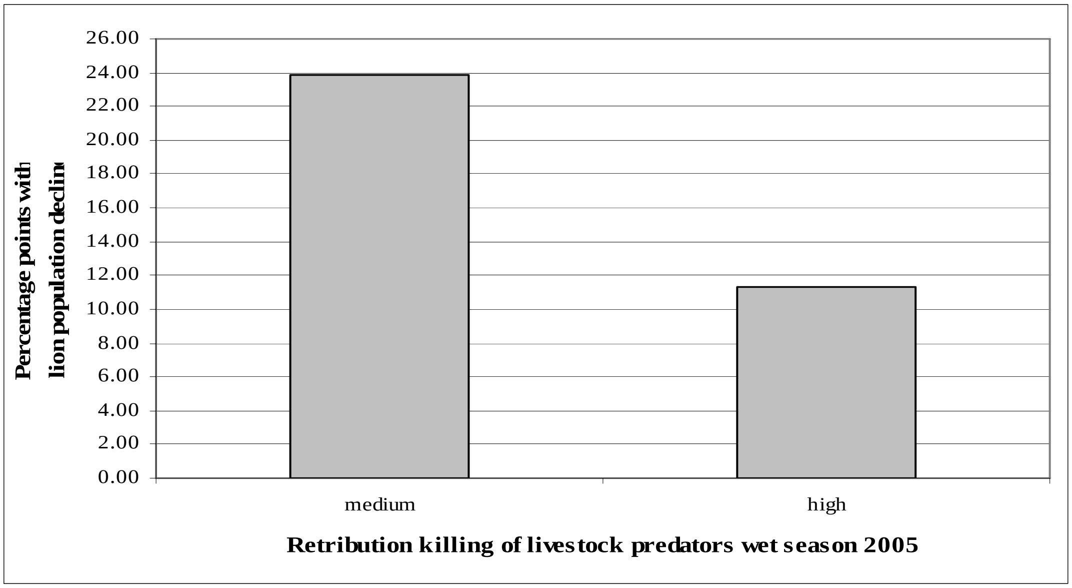


Figure 4.7: Population change of lions during the 2005 and 2006 wet seasons relative to percentage of points with medium or high levels of retribution killing of retribution killings of livestock predators.

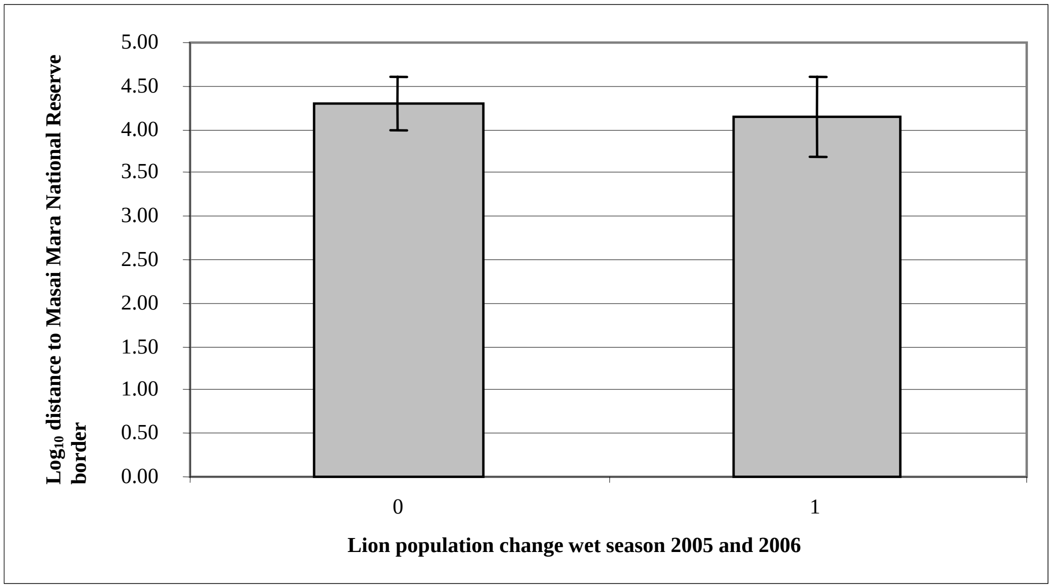


Figure 4.8: Population change of lions during the 2005 and 2006 wet seasons in relation to Log_{10} distance to Masai Mara National Reserve (with S.E. bars).

Dry Season

During the 2005 and 2006 dry seasons, declines in lion population trends were recorded over 57% of the transects (n = 50). The binary logistic model showed that there were no significant variables that had an effect on lion population trends during these seasons across the GME.

4.1.3 Wild dog

During both the 2005 and 2006 wet seasons and dry seasons, individual declines in wild dog population trends were recorded over 10% of the transects (n = 7). For both wet and dry seasons the binary logistic model showed that there were no significant variables that had an effect on wild dog population trends across the GME.

4.1.4 Zebra

During the 2005 and 2006 wet seasons and dry seasons, declines in zebra population trends were recorded over 53% and 67% of the transects, respectively (n = 47 and 59). For both the wet and dry seasons the binary logistic model showed that there were no significant variables that had an effect on zebra population trends across the GME.

4.2 Spatial factors determining wildlife presence

4.2.1 Elephant

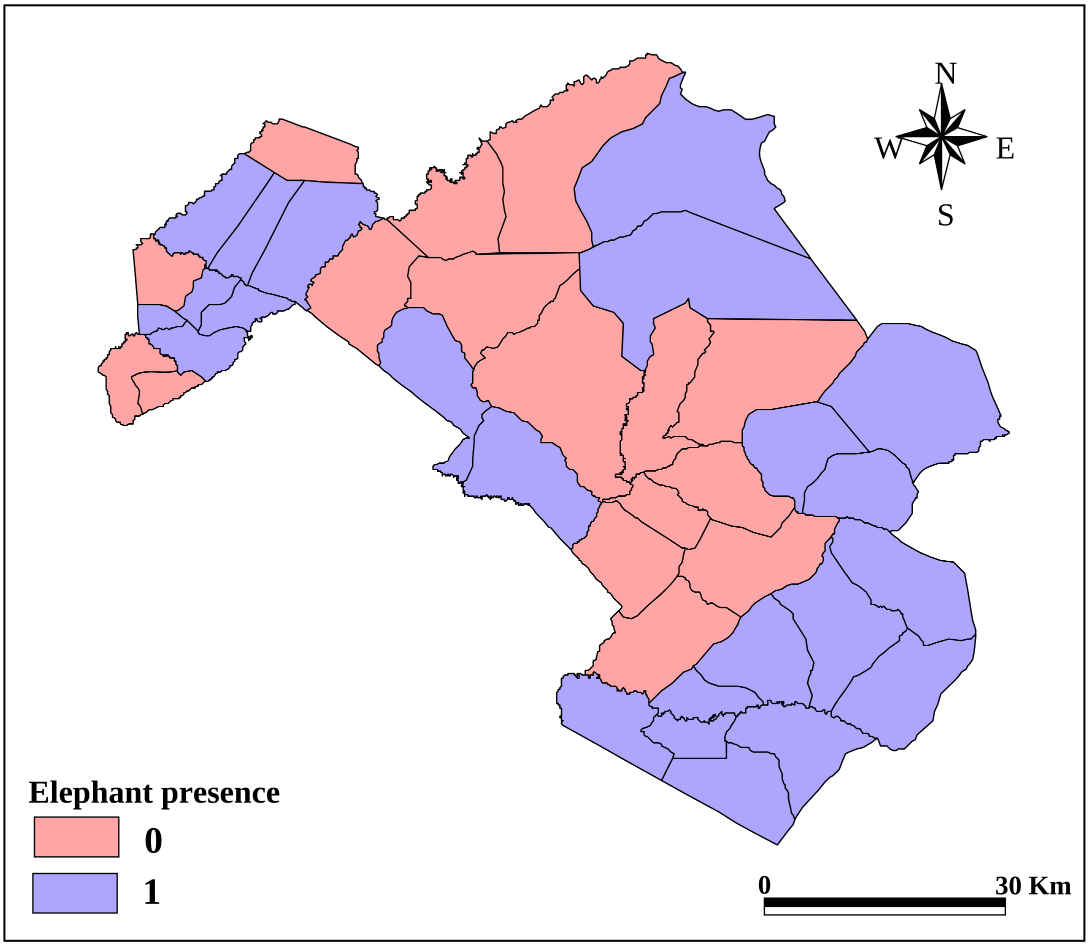


Figure 4.9: Elephant presence in the wet season 2005 within clusters across the Greater Mara Ecosystem. 1 indicates presence and 0 indicates absence.

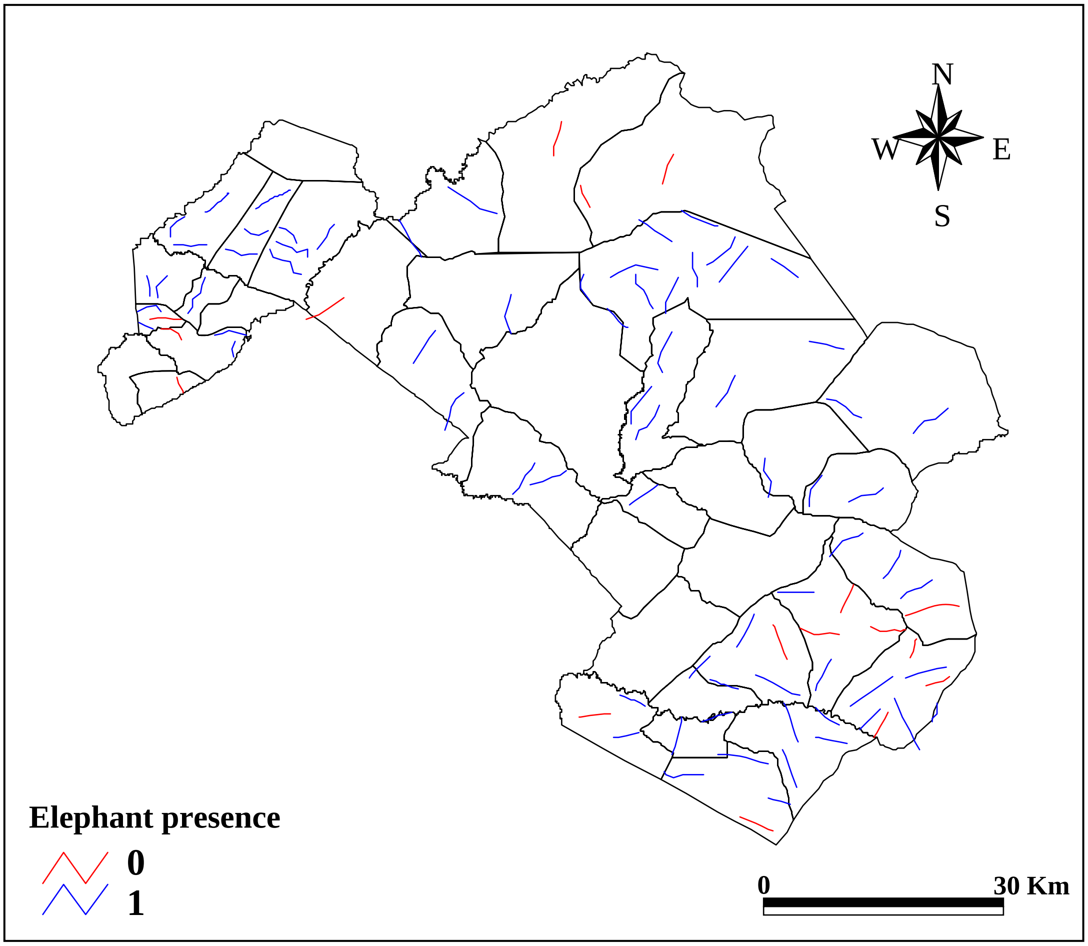
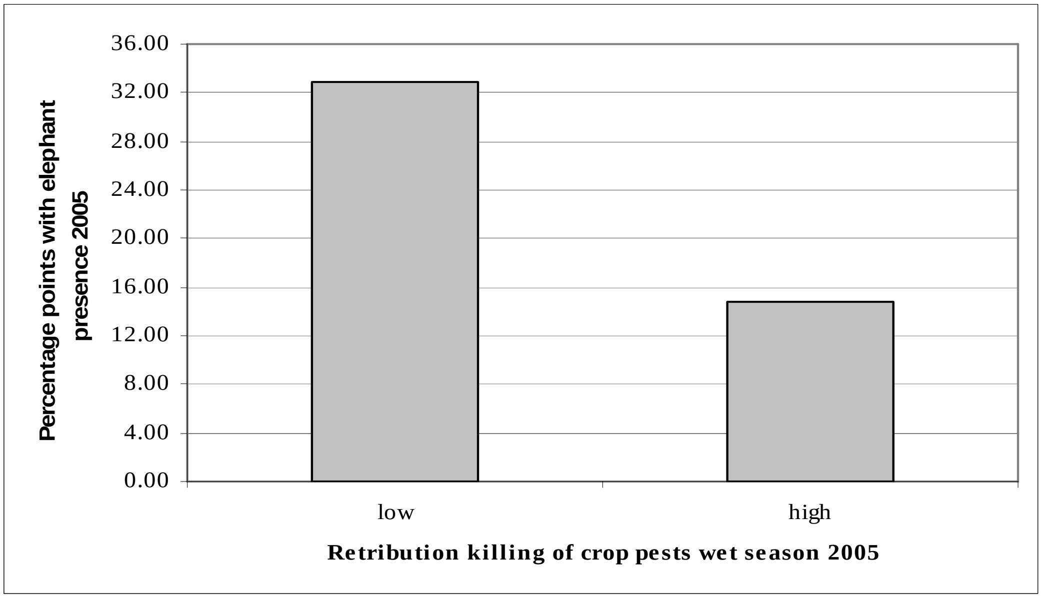


Figure 4.10: Elephant presence in the wet season 2005 within transects across the Greater Mara Ecosystem. 1 indicates presence and 0 indicates absence.

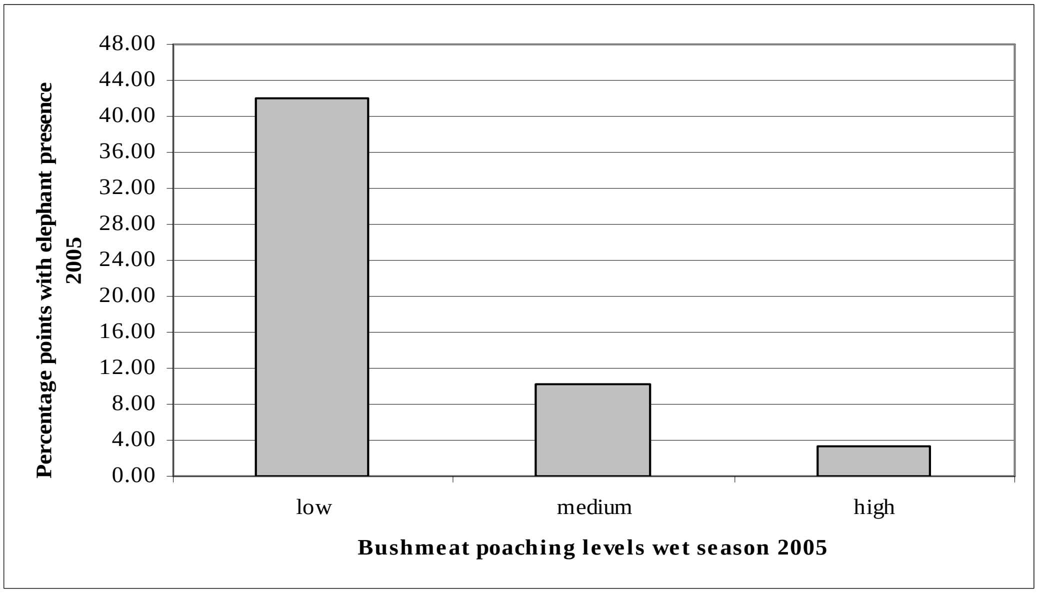
During the 2005 wet season, elephants were present on 56% of the transects (n = 49). The landscape variables that best explained the probability of elephant presence was related to bushmeat poaching and retribution killings of wildlife crop pests (Table 4.3, Figures 4.11 and 4.12). Elephants were more likely to be present in areas with lower levels of bushmeat poaching and lower levels of retribution killings of wildlife crop pests. The model showed that there was no effect from medium levels of retribution killing of crop pests on elephant presence. The logistic regression model explained 73.9% of the original observations and was not affected by spatial autocorrelation (Moran's $I = 0.02$, $P > 0.1$). The final model had an AUC value of 0.799 indicating an accurate fit.

Table 4.3: Best binary logistic regression model describing the relationship between threat variables and elephant presence across the Greater Mara Ecosystem

Variable	B ± S.E.	Wald	df	*P*
Poaching for bushmeat (high)		16.361	2	0.000
Poaching for bushmeat (low)	3.119±0.832	14.064	1	0.000
Poaching for bushmeat (medium)	4.446±1.418	9.833	1	0.002
Retribution killing of crop raiding species (high)		10.598	2	0.005
Retribution killing of crop raiding species (low)	2.106±0.653	10.413	1	0.001
Retribution killing of crop raiding species (medium)	0.488±0.906	0.290	1	0.590
Constant	-3.453±0.901	14.670	1	0.000



Figures 4.11: Presence of elephants in the 2005 wet season relative to percentage of points with low or high levels of retribution killing of crop pests.



Figures 4.12: Presence of elephants in the 2005 wet season relative to percentage of points with low, medium or high levels of bushmeat poaching.

Dry Season

During the 2005 dry season, elephants were present on 64% of the transects (n = 56). There were no significant variables found which had an affect on elephant presence during the 2005 dry season across the Greater Mara Ecosystem.

4.2.2 Lion

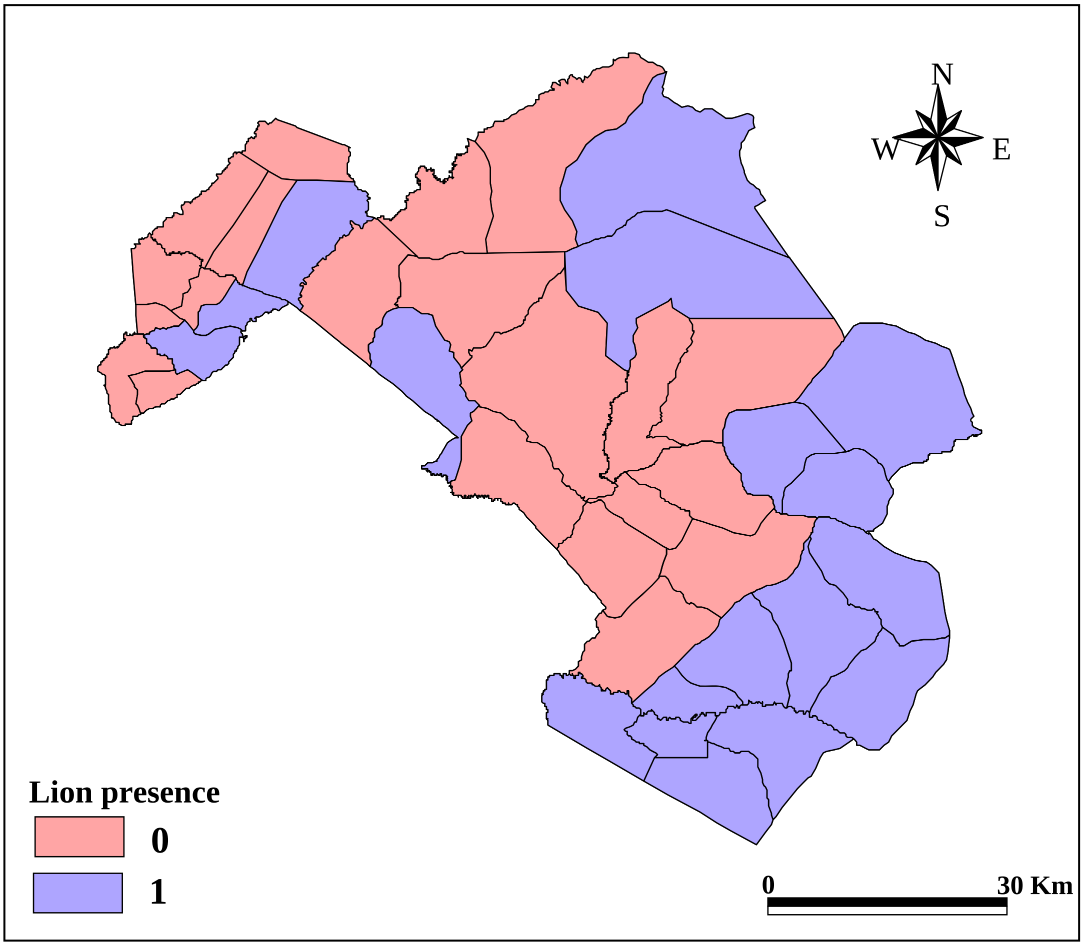


Figure 4.13: Lion presence in the wet season 2005 within clusters across the Greater Mara Ecosystem. 1 indicates presence and 0 indicates absence.

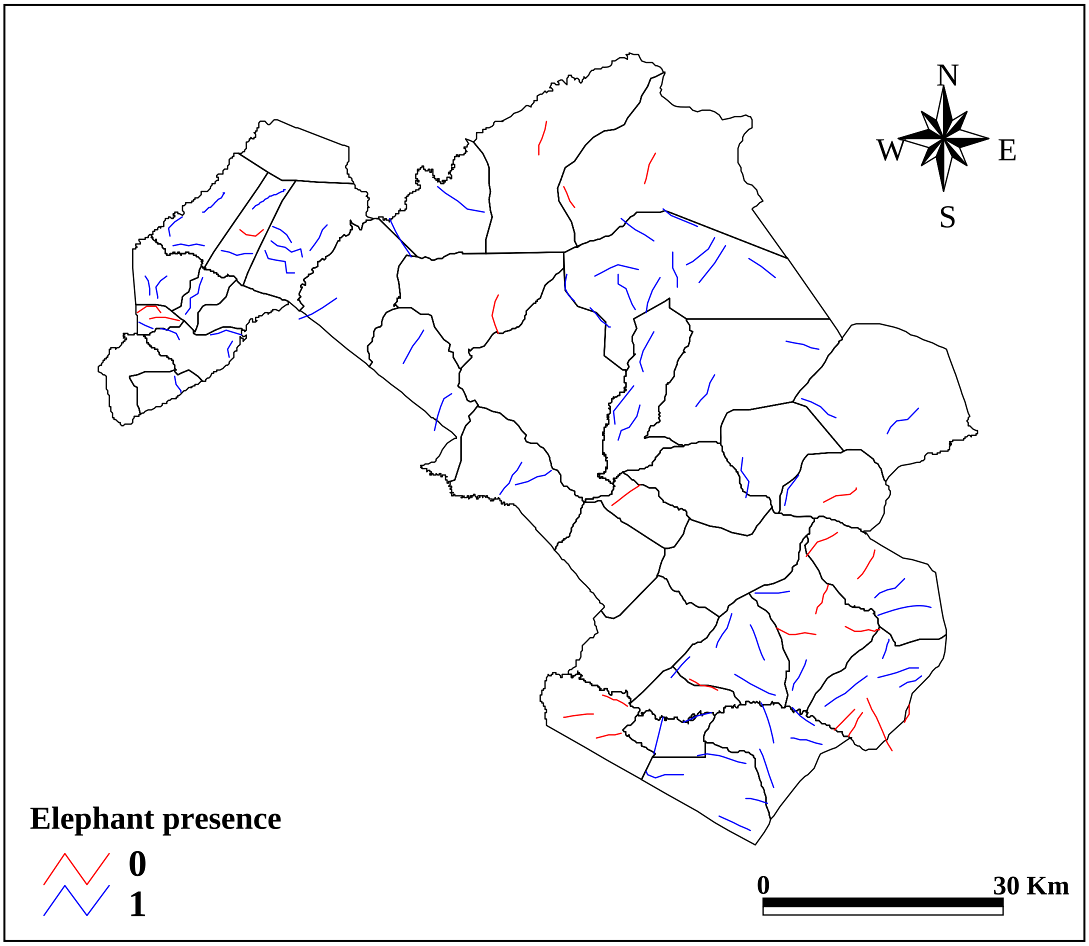


Figure 4.14: Lion presence in the wet season 2005 within transects across the Greater Mara Ecosystem. 1 indicates presence and 0 indicates absence.

During the 2005 wet season, lions were present on 47% of the transects (n = 41). The landscape variables that best explained the probability of lion presence was related to $\log_{10}$ distance to roads, $\log_{10}$ distance to the MMNR and retribution killings of wildlife livestock predators (Table 4.4, Figures 4.15, 4.16 and 4.17). Lions were more likely to be present in areas with medium levels of retribution killings of livestock predators, closer to the MMNR and further from roads. The model showed that lower levels of retribution killing of livestock predators had no effect on lion presence. The logistic regression model explained 67.0% of the original observations and was not affected by spatial autocorrelation (Moran's I = 0.02, $P > 0.1$). The final model had an AUC value of 0.754 indicating an accurate fit.

Table 4.4: Best multiple logistic regression model describing the relationship between landscape variables and lion presence across the Greater Mara Ecosystem

Variable	B ± S.E.	Wald	df	*P*
Log_{10} distance to roads	1.833±0.761	5.794	1	0.016
Log_{10} distance to the MMNR	-1.877±0.834	5.063	1	0.024
Retribution killing of livestock predators (high)		10.405	2	0.006
Retribution killing of livestock predators (low)	1.052±0.713	2.175	1	0.140
Retribution killing of livestock predators (medium)	2.130±0.667	10.196	1	0.001
Constant	0.228±4.171	0.003	1	0.956

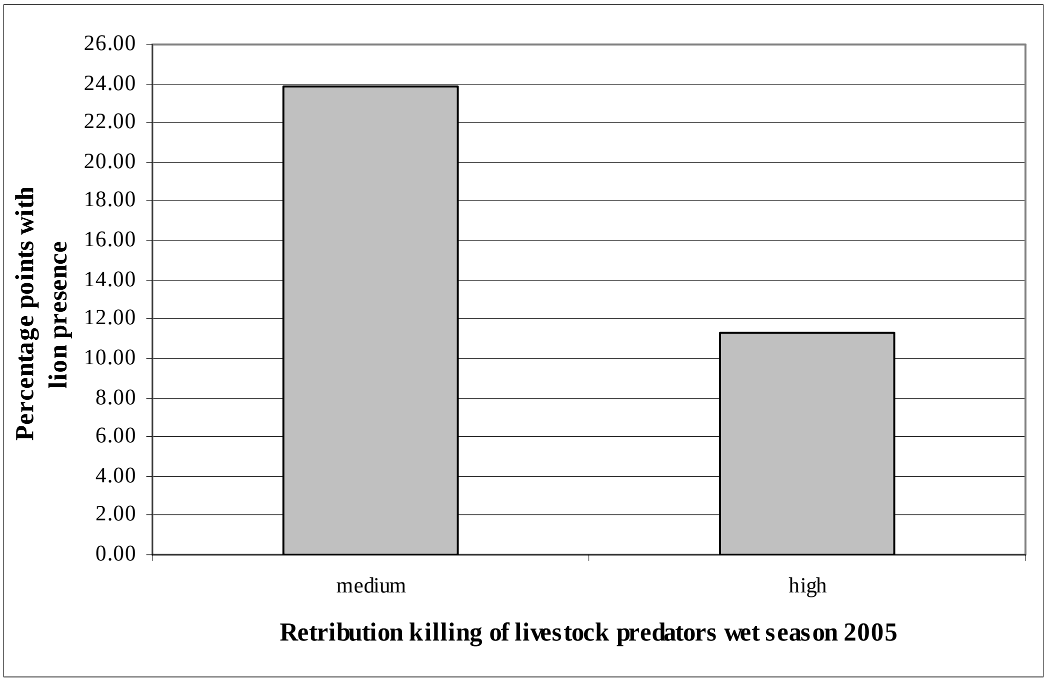


Figure 4.15: Presence of lions in the 2005 wet season relative to percentage of points with medium or high retribution killings of livestock predators.

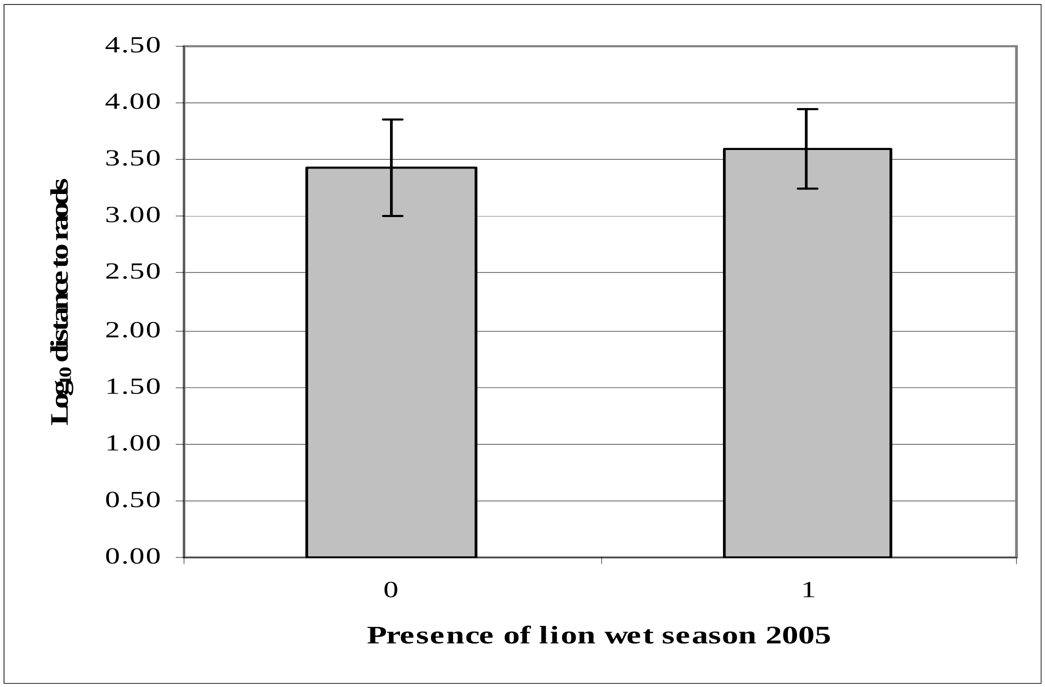


Figure 4.16: Likelihood of lion presence in the 2005 wet season related to mean $\log_{10}$ distance to roads (with S.E. bars).

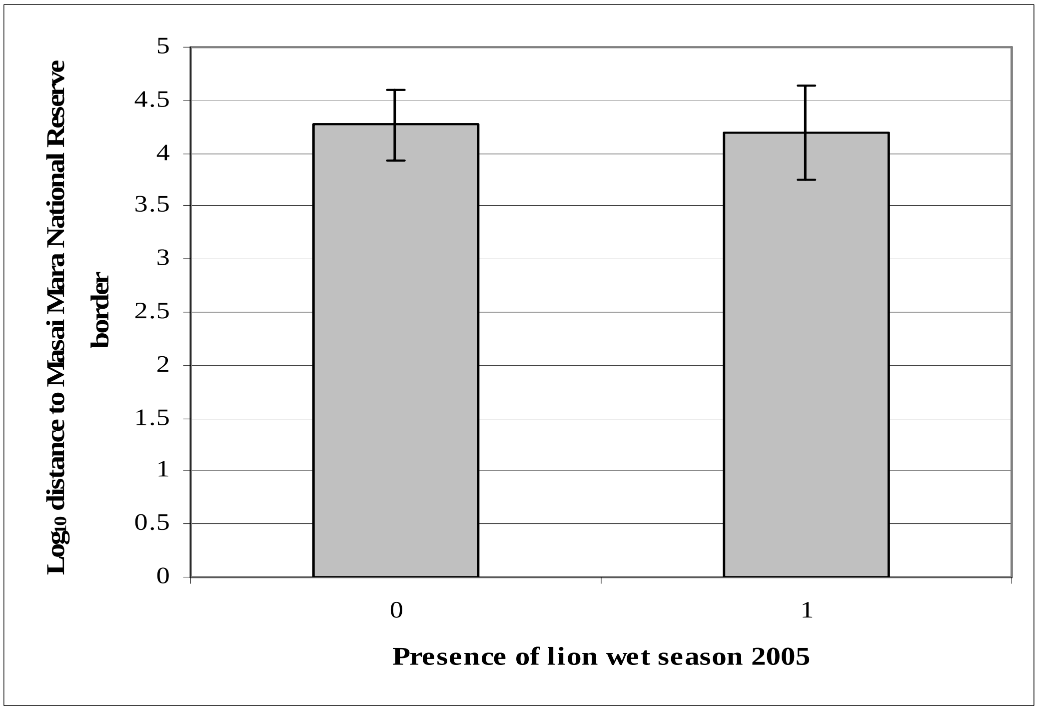


Figure 4.17: Likelihood of lion presence in the 2005 wet season related to mean $\log_{10}$ distance to Masai Mara National Reserve border (with S.E. bars).

Dry Season

During the 2005 dry season, lions were presence on 50% of the transects (n = 44). The binary logistic model identified that there were no significant variables that had an effect on lion presence during the 2005 dry season across the Greater Mara Ecosystem.

4.2.3 Wild dog

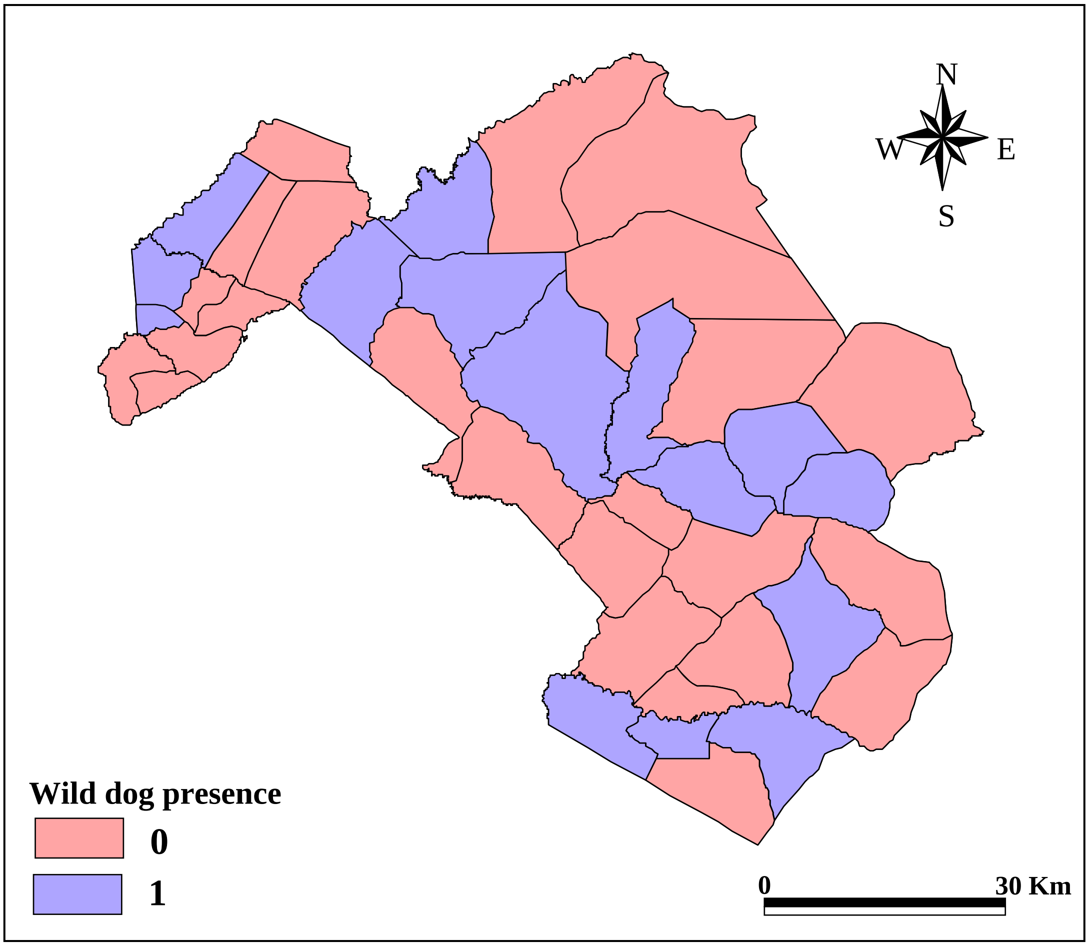


Figure 4.18: Wild dog presence in the wet season 2005 within clusters across the Greater Mara Ecosystem. 1 indicates presence and 0 indicates absence.

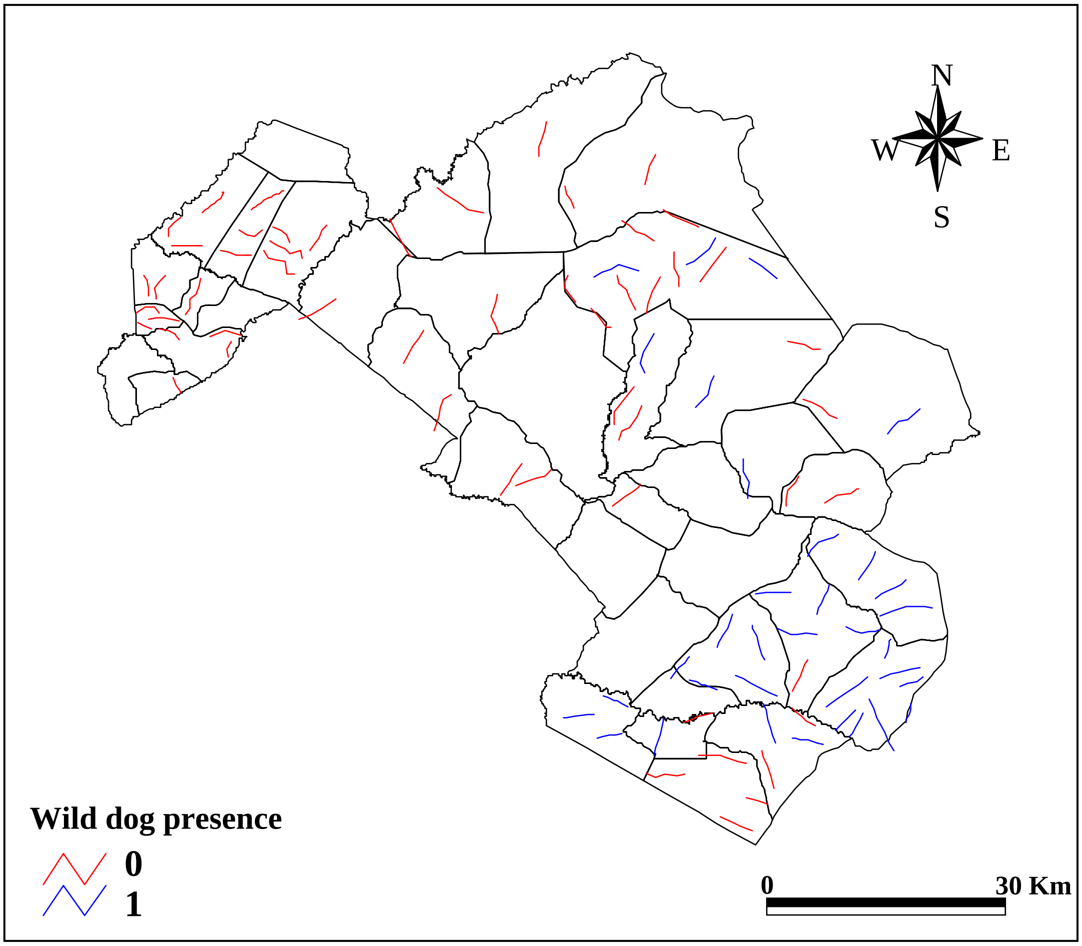


Figure 4.19: Wild dog presence in the wet season 2005 within transects across the Greater Mara Ecosystem. 1 indicates presence and 0 indicates absence.

During the 2005 wet season, wild dogs were present on 47% of the transects (n = 32). The landscape variables that best explained the probability of wild dog presence were related to $\log_{10}$ distance to rivers and $\log_{10}$ elevation (Table 4.5, Figures 4.20 and 4.21). Wild dogs were more likely to be present in areas with a higher elevation and nearer to rivers. The logistic regression model explained 67.6% of the original observations and was not affected by spatial autocorrelation (Moran's $I = 0.017$, $P > 0.1$). The final model had an AUC value of 0.770 indicating an accurate fit.

Table 4.5: Best multiple logistic regression model describing the relationship between landscape variables and wild dog presence across the Greater Mara Ecosystem.

Variable	B ± S.E.	Wald	Df	*P*
Log_{10} elevation	27.268±8.361	10.636	1	0.001
Log_{10} distance to rivers	-1.543±0.750	4.228	1	0.040
Constant	-85.021±27.129	9.822	1	0.002

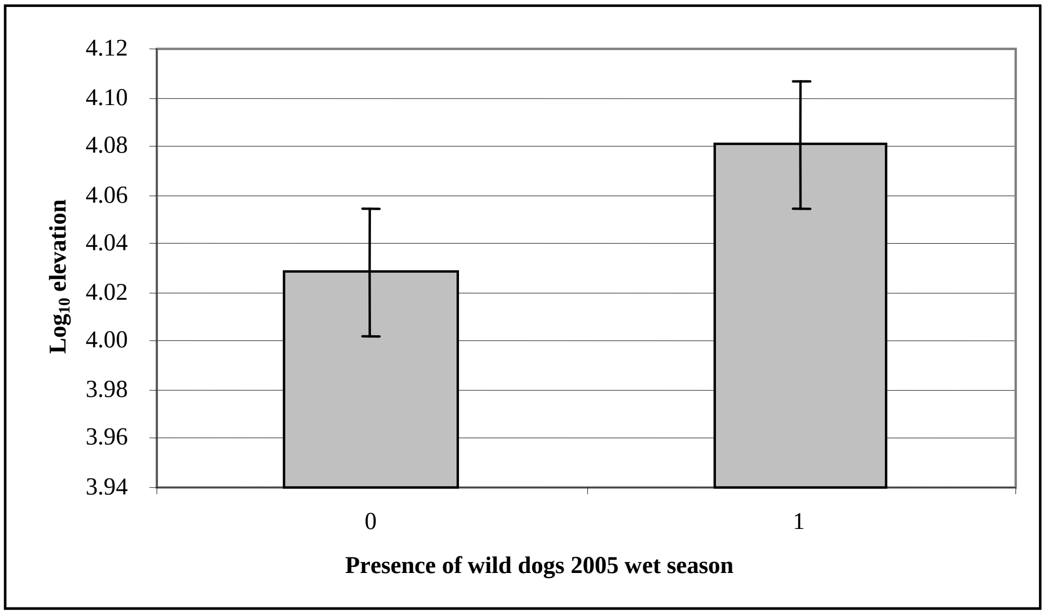


Figure 4.20: Likelihood of wild dog presence in the 2005 wet season related to mean $\log_{10}$ elevation (with S.E. bars).

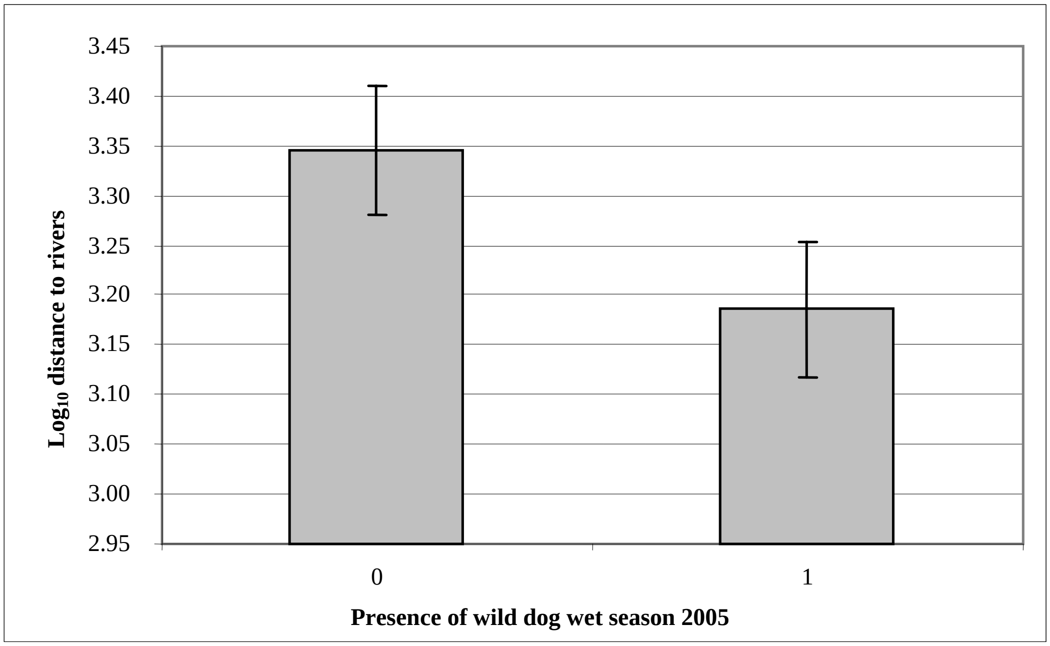


Figure 4.21: Likelihood of wild dog presence in the 2005 wet season related to mean $\log_{10}$ distance to rivers (with S.E. bars).

During the 2005 dry season, wild dogs were present on 41% of the transects (n = 28). The landscape variables that best explained the probability of wild dog presence was related to $\log_{10}$ elevation (Table 4.6, Figure 4.22). Wild dogs were more likely to be present in areas that have higher elevation. The logistic regression model explained 69.1% of the original observations and was not affected by spatial autocorrelation (Moran's $I = 0.02$, $P > 0.1$). The final model had an AUC value of 0.782 indicating an accurate fit.

Table 4.6: Best multiple logistic regression model describing the relationship between landscape variables and wild dog presence across the Greater Mara Ecosystem.

Variable	B ± S.E.	Wald	df	*P*
Log_{10} elevation	32.638±9.212	12.554	1	0.000
Constant	-108.1±30.432	12.618	1	0.000

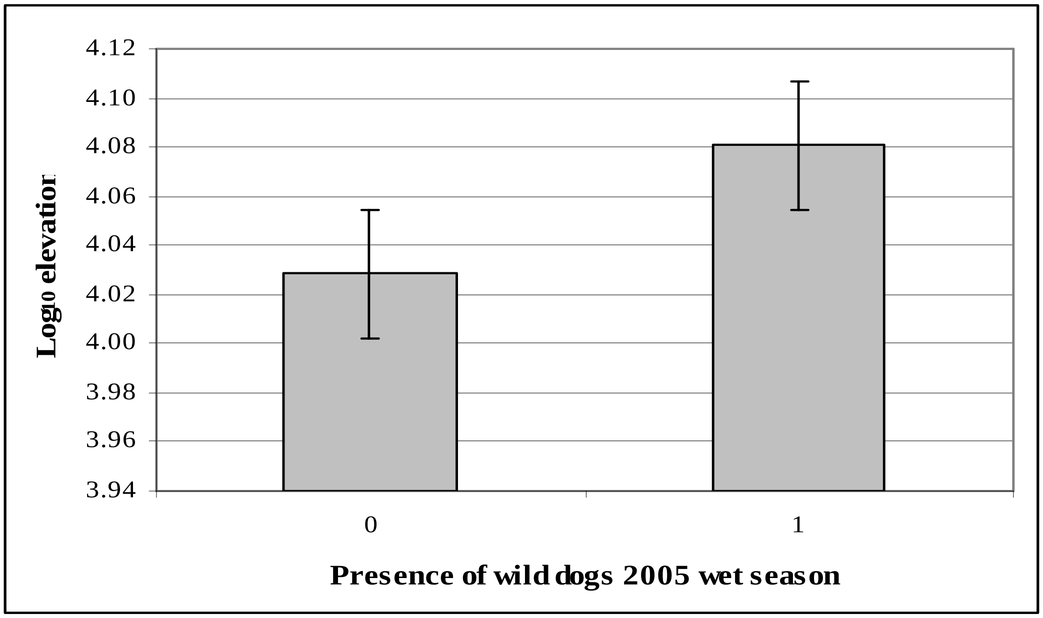


Figure 4.22: Likelihood of wild dog presence in the 2005 dry season related to mean $\log_{10}$ elevation (with S.E. bars).

4.2.4. Zebra

During the 2005 wet season and 2005 dry season, zebras were present on 58% and 74% of the transects respectively (n = 51 and 65). The binary logistic regression models showed that for both the 2005 dry and wet season there were no significant factors affecting the presence of zebra across the Greater Mara Ecosystem.

5. Discussion

This study investigated the synergistic effects of physical and threat factors on elephant, lion, wild dog and zebra population trends and presence across the GME. Zebras and elephants underwent the most extensive change with declines across 53% and 50% of the transects surveyed during the wet seasons of 2005 and 2006. Lions declined across 45% of the transects and wild dogs underwent the lowest decline, across only 10% of the transects. Elephants and lions were found to be most vulnerable to threats, in particular retribution killings arising from human-wildlife conflict incidents. Consequently, these species were more likely to be present in cluster areas with lower levels of these threat types, but within these areas elephant and lion populations were still in decline. In contrast, wild dogs which had previously undergone substantial population declines across the GME due to disease and human persecution were found to be making a recovery across the eastern side of the GME.

5.1 Study Design

The encounter rate and presence based methods used in this study produced data that accurately fitted the logistic regression models, as shown by their AUC values. Brashares and Sam (2005) identified that as the number of monitored sites decreased the greater the negative effect on the probability of detecting the true population trends. The benefit of using community scouts throughout the GME was that a larger area was covered with a sufficient number of monitoring sites. The scouts collected encounter rate data between 2004 and 2006 with repetition of transects between years and seasons. Data from 2004 was not analysed within this study because the DICE/Friends of Conservation programme was still recruiting scouts from several group ranches. The slower approach adopted in scout recruitment was due to the need to capture and strengthen local community support for the programme and so a series of community workshops were run to increase community participation and sense of proprietorship in the programme.

The encounter rate method applied during this study and by the scout programme provided basic, but nevertheless, reliable data. For the duration of the study, it was not possible to regulate the number of repetitions of transect walked between cluster areas. This in turn created a slight bias because some transects were sampled much more than others and, possibly, species population trends may not have been recognized in areas with lower sampling effort. However, converting the encounter rate data to a binary code is thought to have reduced this bias. It is important to note that the binary logistic model can be affected by random misclassification, with falsely recorded occurrences of species treated equally (Gu and Swihart 2004). Repeat surveys along transects would have minimised the chances of recording ‘false absences’. This statistical consideration mainly applies to rare or shy species that have a high rate of non-detection. The only focal species in this study that may have been affected is the wild dog. This may be due to the wild dog’s increased fear of humans and low density within the sampling area. The study only used direct sightings as the levels of variation and inaccuracies within the indirect data collection were high. Spatial uncertainties could have been caused by lack of sufficient data points due to an insufficient time scale, insufficient information on microclimate variations, incomplete series of land use changes and settlement expansion data. However, the land clearance and bushmeat poaching threat maps developed from the consensual opinions of the expert panel were verified using independently derived data sources. It was not possible to test the validity of the human-wildlife conflict threat maps. Whilst this verification was necessary, it was not possible due to a lack of independently and systematically collected data. However, the fact that both of the other threat maps that could be tested, concurred with the independent datasets, increases confidence in the expert panels remaining untested maps.

5.2 Species presence and population change

5.2.1 Elephant

The relation between population trends and presence of elephants across the GME showed a correlation with some spatial factors during the wet seasons only. The seasonal patterns may have been related to the maize crops ripening during the wet season, after which there is a reduction in natural vegetation biomass in the GME (Sitati 2003). Sitati *et al.* (2005) identifies that across the Transmara District local farmer’s tolerance towards elephants is reducing. If this attitude was to spread across the GME it could mean increased retribution killing threatening the already vulnerable elephant populations. Although this study did not identify distance to towns as significant factors for elephant presence, other studies (Sitati *et al.* 2003) have shown male elephants are more likely to crop raid nearer to towns. As settlements and agricultural practices expand across the GME male elephants, who take greater risks (Sitati *et al.* 2003) may become persistent crop raiders, which in the long-term will have to be resolved by Problem Animal Control Units (Leader-Williams *et al.* 2001). Resolution of crop raiding is partly reflected in proximity to dense refuges where elephants forage at night (Sitati *et al* 2003). In conjunction with Sitati *et al* (2003) Naughton-Treves (1998) identified a correlation between forest-agriculture edge habitat and increased exploitation of crops. One mitigation method to reduce crop raiding and so retribution killing of crop pests could be to identify these refuges used and plant a non-palatable vegetation barrier or buffer clearing (Hill *et al.* 2002). As areas become deforested across the GME may produce a shift in spatial patterns of retribution killing of crop pests may occur. Elephant population trends showed a significant decline in areas with low levels of retribution killings of crop pests and in areas with lower levels of bushmeat poaching. Whilst these findings may seem counterintuitive, elephant presence was mainly found in areas with lower threat levels, suggesting that this species had largely disappeared from the areas with higher levels of poaching and retribution killings of crop pests.

Bushmeat poaching can be opportunistic, but elephants are targeted due to their large body size. High levels of human disturbance would occur in areas that are continuously hunted and this could disturb elephants and cause the group to move to other areas with fewer disturbances

5.2.2 Lion

Similar to elephant spatial patterns, lion population trend changes and presence showed spatial significance during the wet seasons of 2005 and 2006. A similar relationship was found in elephants, wild dogs and lions in the GME, where livestock depredation frequency showed a positive and significant relationship with rainfall (Kolowski and Holekamp 2006). The variation between the seasons may be explained by natural prey availability. However, Pattern *et al.* (2004) states that livestock predation would increase during the dry season after the rains as native prey movements vary in different regions according to the seasons. If native prey is abundant during the wet season livestock predation will decrease with the inverse being shown in areas where prey numbers peak in the dry season (Kolowski and Holekamp 2006). Population trends were only significantly affected by retribution killing of livestock predators, with population declining principally in areas with medium levels of killing.

The expert panel has designated ten clusters as having high levels of retribution killing of predators (Appendix 4, Figure A4.10) where lions are no longer present. As with elephants, these areas with high levels of HEC retribution killings may have already driven lions out into surrounding areas with lower levels of threat. The majority of studies found that lions were responsible for a large proportion of livestock predation (Ogada *et al.* 2003, Kolowski and Holekamp 2006, Pattern *et al.* 2004) with attacks mainly occurring at night. This may bias the results as informants of attacks may assume it was a lion, but hyenas and leopards also attack livestock during the night. One way to decrease the amount of attacks as suggested by Pattern *et al.* (2004) is to keep native ungulate population at a healthy level as only 5.8% of a lions diet consists of livestock. When looking at lion presence (Figure 4.13) in comparison with zebra distribution (Appendix 4 Figure A4.6) lions are only found in cluster areas containing zebras. Lions are also present in all but four clusters that are described as having high levels of livestock depredation killings (Appendix 4 A4.9). Kenya has recently put forward a proposal to the IUCN requesting the transfer of lions from Appendix II to Appendix I. The reasons behind this request lie with the already vulnerable species being unsustainably hunted for trophies in other African countries together with rapid fragmentation of habitats causing populations to become isolated. The issue is yet to be resolved but reducing levels of human-lion conflict by improving the levels of animal husbandry through community-based awareness programmes would improve lion population viability in the GME. Depredation of livestock can be prevented with mitigation methods that might include the use of dogs, increased boma height, modifying boma design with simple low technology (Ogada *et al.* 2003, Walpole & Kisotu unpublished).

5.2.3 Wild dog

Wild dogs are social animals, living in packs that hunt, rest, and move together (McCreery and Kim 2000). Little is known about the present situation of wild dogs in the GME as the last known pack migrated in 1991 (Woodroffe 1997). The recent sighting of wild dogs in the eastern side of the GME is an encouraging result with den sites also being located within the Niakarra cluster area (Kistou pres. coms). Unlike lions and elephants, wild dog spatial patterns were found to be related to both the wet and dry season. The occurrence of wild dogs or change in population trends showed no significance to any of the threat activities. Possible explanations for this could be that packs are only temporary residents and migrate following prey. As livestock predation is due to lack of natural prey wild dogs solve this problem by migrating with the herds. Their reputation as livestock killers is unjustified (Woodroffe 1997). As with lion's livestock depredation will rise as natural prey declines (Woodroffe 2005). Wild dogs were present in eight clusters marked as high levels of retribution killing and in seven areas with medium levels of killings. The reason being wild dogs may not be targeted in these areas due to their concealment and dislike of human contact. This relationship also agrees with other studies showing wild dogs are not persistent livestock killers. This trend may also relate to lower levels of lion presence in these areas.

Landscape features that affected the presence of wild dogs during both wet and dry seasons were related to elevation, with wild dogs being more likely to be found in areas with higher altitude. Distance to rivers significantly effected wild dog presence during the dry season, with areas closer to rivers being more likely to contain wild dogs. The lower lying plains have easier access for the larger farm machinery leading to intensification of agriculture and reducing the amount of suitable habitat available for wild dogs. The higher altitude areas will not be affected in this way, and will possibly have higher vegetation density and reduced human disturbance. Alternatively the human disturbance on the low lying plains may be the cause for wild dogs to retreat to higher areas. For wild dogs the distance to rivers variable has not been specifically documented by other studies; the relevance in this study could be due to increased prey availability and better cover for stalking these prey. During the dry season, ephemeral rivers dry up and the prey move on to different areas, which might explain why distance to rivers was the only significant during the 2005 wet season. The presence of wild dogs (Figure 4.18) show a clear trend across the middle of the group ranches, forming a continuous band related to the position of rivers (Appendix 4 Figure A4.5). Comparing lion and wild dog presence overlap revealed that only six clusters out of 39 contained both species. This agrees with other studies which have shown wild dogs try to avoid large predators as lions are a major cause of wild dog mortality (Mills 1997).

Wild dogs are a charismatic and flagship species and offer an opportunity for the group ranches in the GME to benefit from nature tourism by maintaining viable populations. As shown in Kruger National Park (NP), South Africa, the eco-tourism benefits from one pack is equal to $9045 per year derived from contingent valuation of a potential market good (Lindsey *et al.* 2005). The wild dog populations in Kruger NP are far larger than the GME at this time but by providing economic incentives as to why local communities should preserve wild dog population could in the long-term maintain wild dogs throughout the GME.

5.2.4. Zebra

The study showed that no spatial variables explained either zebra population trends or presence. Homewood *et al.* (2001) found that zebra abundance was related to droughts, poaching and loss of woody vegetation. However, as the analysis in this study was only carried out over a one year period, variations arising from long-term anthropogenic and environmental factors may not be adequately reflected.

Zebra is a common species with few specific habitat requirements. As already identified, ungulate population birth rates are affected by rainfall caused by variation in the ENSO (Ogutu unpublished, Serneels *et al.* 2001). As the consequences of global warming influence changes in regional climates, ungulate populations may change accordingly. The annual rainfall across the GME showed a decline from 2004 to 2005 (Appendix 3 Figure A3.2). Overall, the severer weather conditions of droughts and floods are increasing, with the wet season showing a temperature rise (Ogutu unpublished) these results could be an indication of changes in the near future. Zebras, along with wildebeest, are famous as being part of the annual migrations from the Serengeti to the GME. As hunting rates rise, the detection rate should reflect this increase, this may not be the case as the MMNR law enforcement and the community scouts are unable to increase personnel numbers and patrols to counter act this threat. As with the elephants no real distribution pattern could be found this is to be expected as zebra are common throughout the GME.

6. Conclusion

Human-wildlife conflict, the bushmeat crisis (Robinson and Bennett 2002) and habitat clearance are not new issues; they form the central structure around which conservation organizations allocate resources and funds. This study shows how monitoring of human activities can be combined with reliable wildlife monitoring and conducted by local community scouts. As wildlife declines across the GME, a solution might be to focus resources on conserving biodiversity inside the MMNR, or expand the reserve. However, the focal wildlife species from this study require large ranges to maintain viable populations and, so, excluding these species from outside the MMNR is not a realistic option. Therefore, community-based initiatives are required if conservation strategies are to succeed across the GME.

Economic diversification of traditional sectors into other sustainable areas along with raising awareness of environmental degradation and simple solutions are ways in which local communities can use their natural resources sustainable. The GME is a semi-natural habitat managed and maintained by the Maasai traditional land use practices. As the human population increases, the demands for food and land space will increase also. These issues will have to be addressed to ensure long-term species survival. Throughout the GME, livestock and large herbivores numbers are in direct competition for land, water and foraging (Young *et al.* 2005), as livestock number increase native herbivores are out competed, creating a knock-on effect to predators.

Community participation in all areas of conservation is vital; using community scouts can develop and improve relationships with the local communities. This in turn can allow for threat activities to be monitored and recorded without fear of repercussions. Scouts have proven to be a cost-effective way to collect large amounts of information across an extensive area over a several years.

Habitat suitability models are increasingly being used to assess the impact of future land use, climate changes or designing ecological networks on large spatial scales (Brontons *et al.* 2004). Identifying the spatial factors that explain species presence across the GME provides key information needed to determine habitat suitability. Producing habitat suitability models for the GME is the next step to allow for appropriate land use designation to be created which benefits both wildlife and the local communities. Serneels's *et al.* (2001) and Ogutu's (in press) findings are recognized within this study, showing that seasonal variation related to rainfall has long-term consequences on species distributions and patterns. For future studies of this kind climatic information is a vital variable that needs to be taken into consideration when understand the rationale behind species patterns, which have been established by the study.

Across the GME, some group ranches are voting to subdivide the land into individual small holdings (Lamprey and Reid 2004). In 2003, the Koyaiki group ranch was subdivided and plots averaging 60 ha were allocated to 1020 ranch members (Lamprey and Reid 2004). This recent division of land is a worrying step towards the total exclusion of wildlife outside of the MMNR as a result of fences and intensification of agriculture. Over the next decade, the GME faces an uncertain future. The findings from this study show that wildlife are sensitive to the different threats across the GME, and these threats are anticipated to increased as land use management practices change.

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Appendix 1

WILDLIFE MONITORING PATROL SHEET

Scout Pair: Cluster/Patrol Area:

Date: GPS ID: Transect ID:

Start Time: Start Point (GPS):

Finish Time: Finish Point (GPS):

Weather: Main Veg. type:

Animal	**DIRECT sighting**			**INDIRECT sighting**		
	Total (T)	**Adult (A)**	**Calf/Cub (C)**	**Total (T)**	**Adult (A)**	**Calf/Cub (C)**
Ungulates						
Black Rhino						
Buffalo						
Bush pig						
Bushbuck						
Domestic cattle						
Eland						
Elephant						
Giraffe						
Grant's gazelle						
Hartebeest						
Impala						
Kudu-Great						
Thomson's gazelle						
Topi						
Warthog						
Waterbuck						
Wildebeest						
Zebra						
Carnivores						
Cheetah						
Hyena-Spotted						
Hyena-Striped						
Leopard						
Lion						
Wild-dog						
Primates						
Baboons						
Monkey-Colobus						

Appendix 2
Threat Survey Sheet

THREAT SURVEY SHEET

Types of Activity:

1. Snare traps
2. Fire arms
3. Bows and arrows
4. Hunting with dogs
5. Poison
6. Poacher camps
7. Charcoal burning
8. Land clearing
9. Timber felling
10. Wild fires
11. Transport/ Sale of charcoal
12. Transport/ Sale of bushmeat
13. Possession of Trophy
14. Transport/ Sale of Timber
15. Bribe related activities

Scout Pair:

Season:

Cluster/Patrol Area	Start time	Start point (GPS):	Finish time:	Finish point (GPS):	Type of Activity	Date Seen	Time Seen	GPS#	GPS location	Comments

Appendix 3

Vegetation index and yearly rainfall graphs

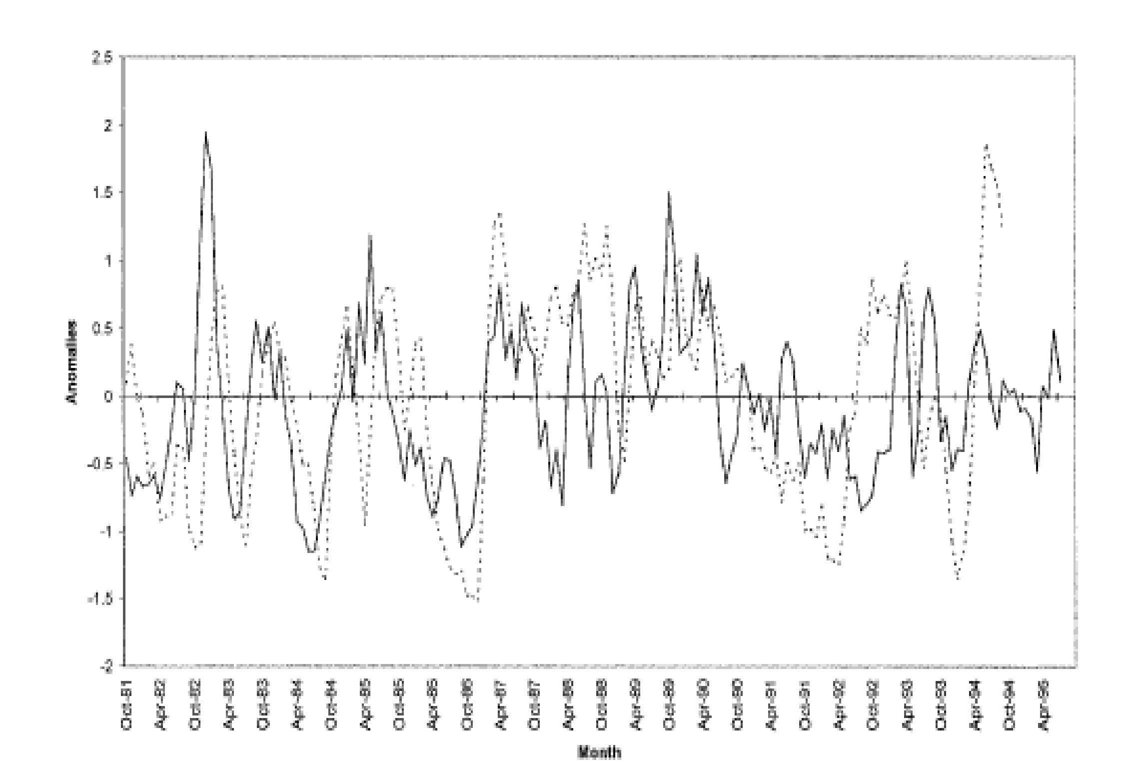

Figure A3.1: Normalized difference vegetation index across the Greater Mara Ecosystem (Serneels *et al.* 2001).

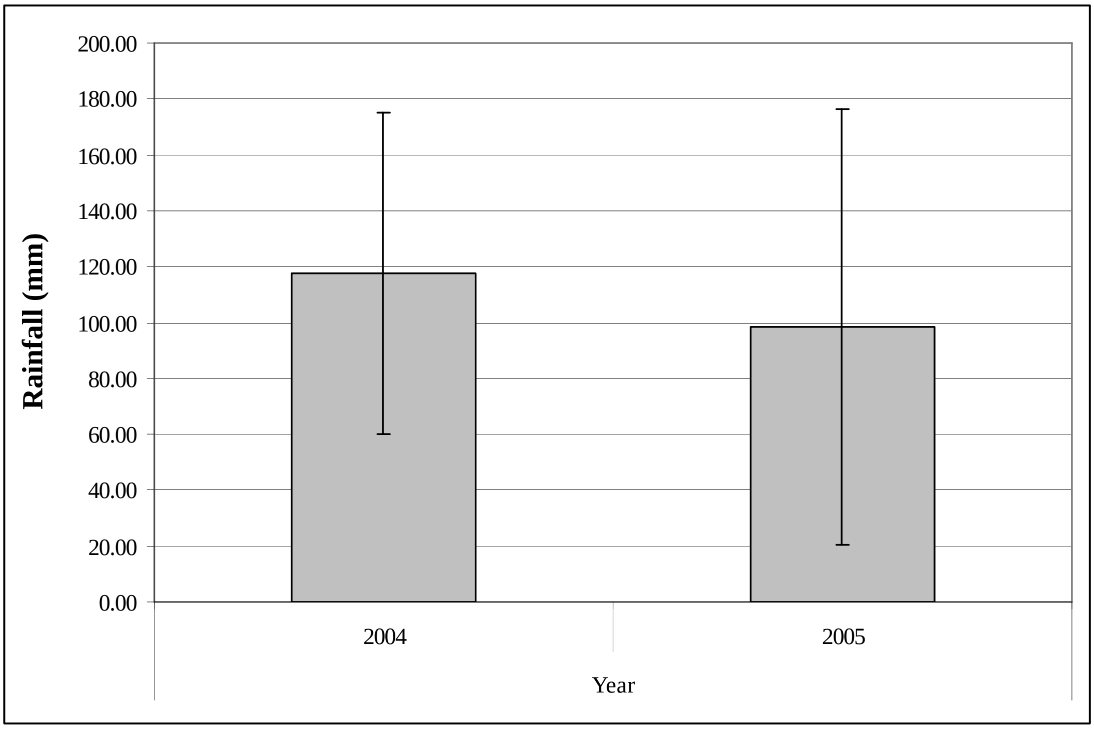

Figure A3.2: Rainfall variation between 2004 and 2005 across the Greater Mara Ecosystem (with S.E. bars)

Appendix 4

GIS Map Results

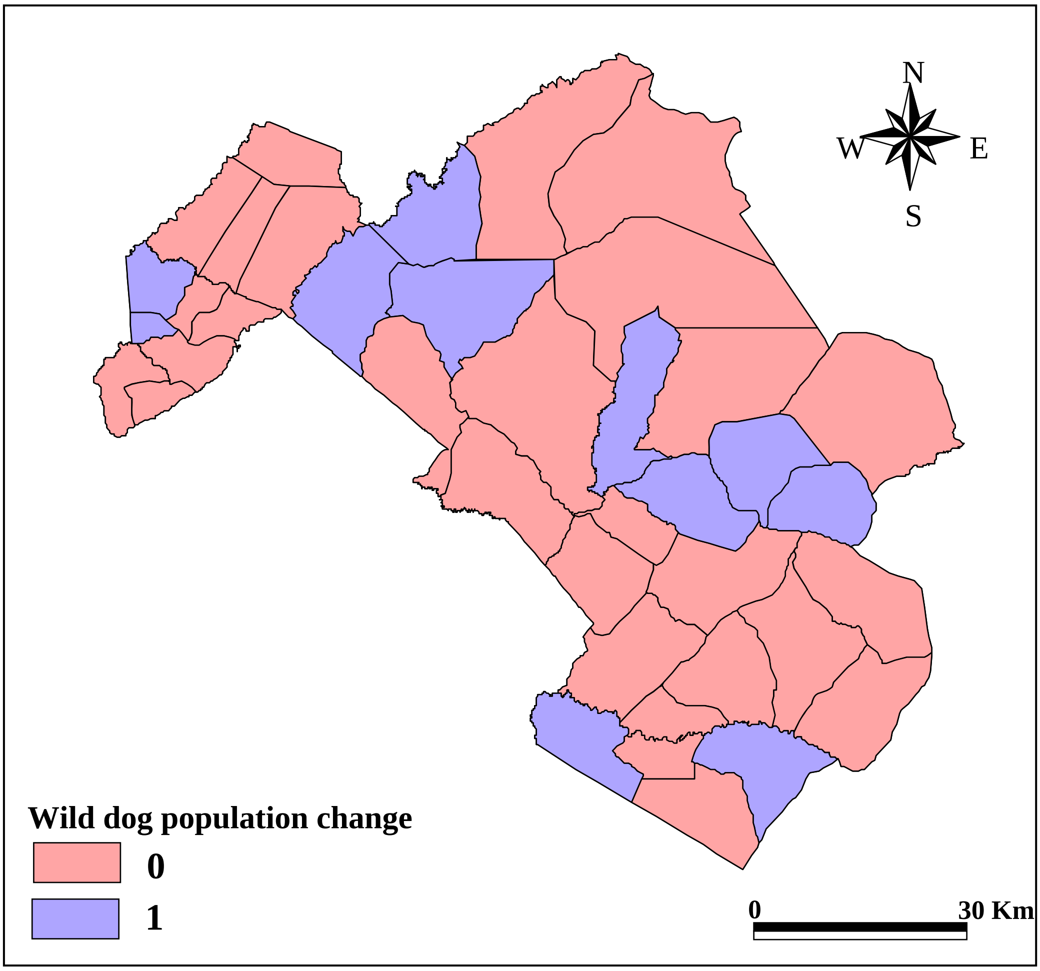

Figure A4.1: Wild dog population change in wet seasons 2005 and 2006 within clusters across the Greater Mara Ecosystem. 0 indicates a decline with 1 indicating no or positive increase.

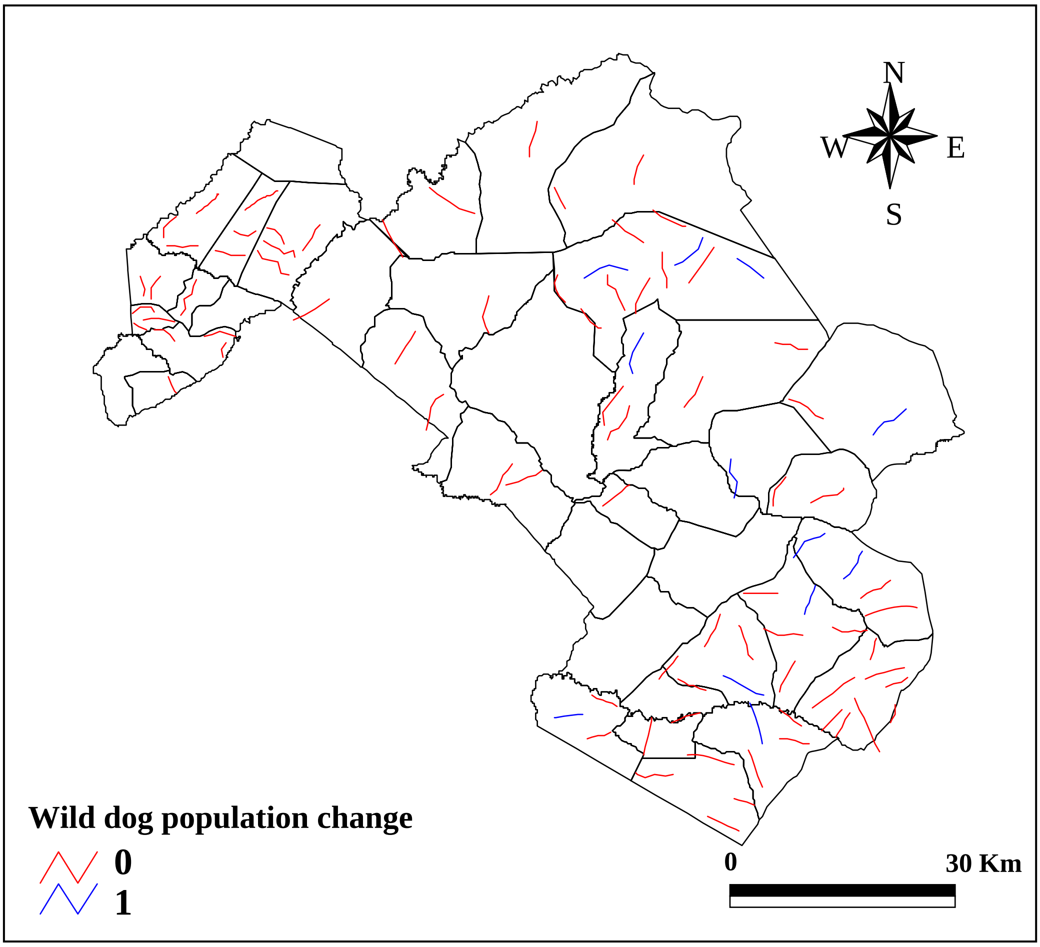

Figure A4.2: Wild dog population change in wet seasons 2005 and 2006 within transects across the Greater Mara Ecosystem. 0 indicates a decline with 1 indicating no or positive increase.

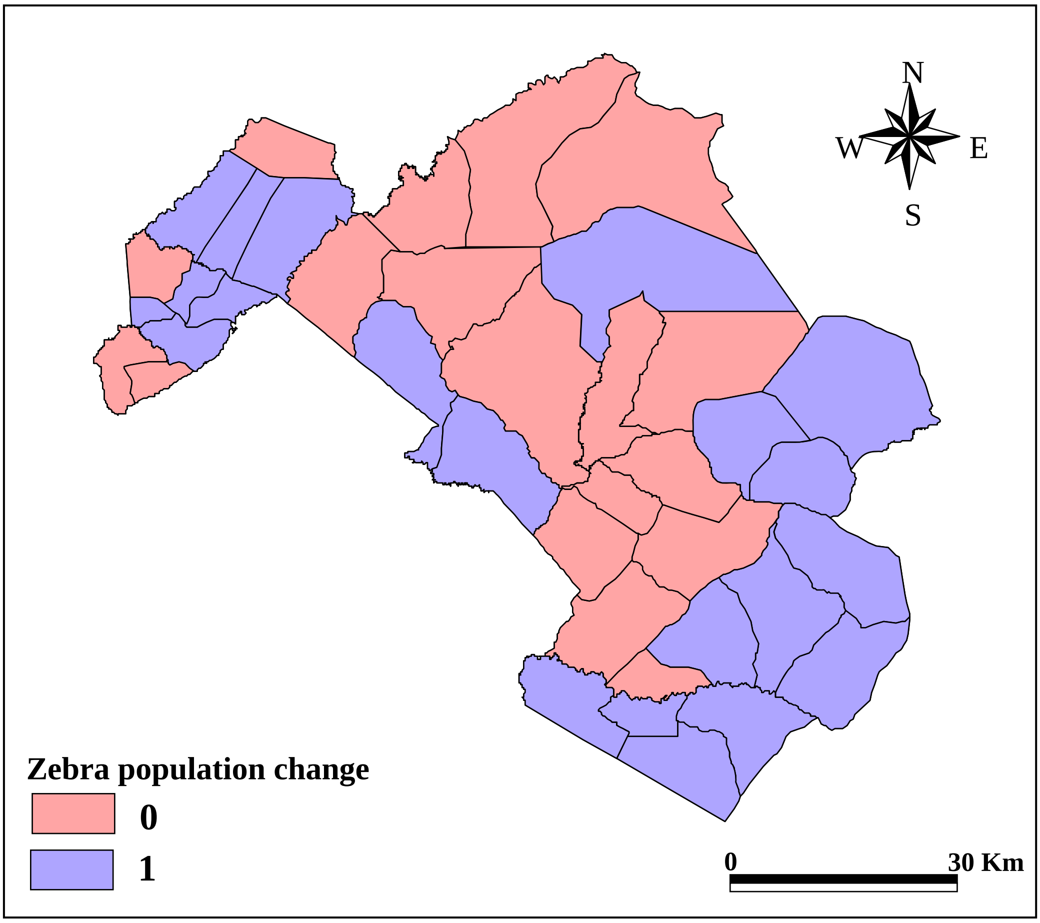

Figure A4.3: Zebra population change in wet seasons 2005 and 2006 within clusters across the Greater Mara Ecosystem. 0 indicates a decline with 1 indicating no or positive increase.

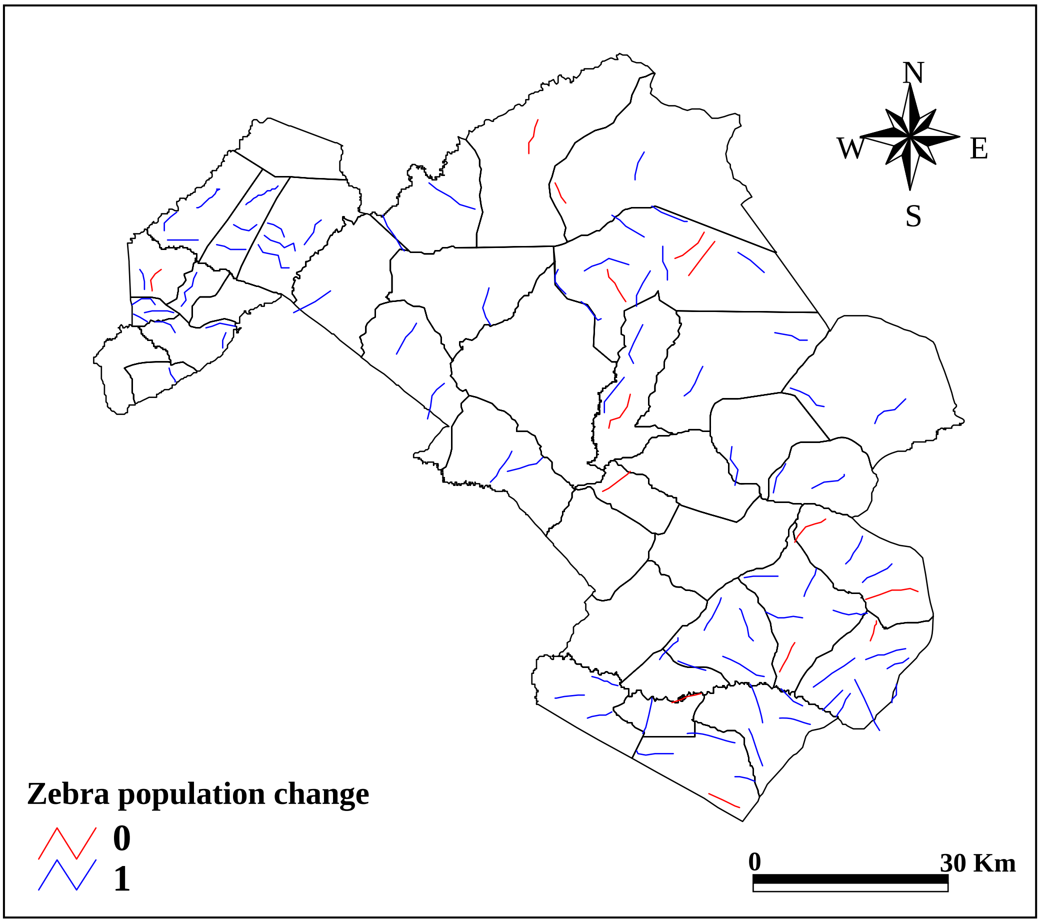

Figure A4.4: Zebra population change in wet seasons 2005 and 2006 within transects across the Greater Mara Ecosystem. 0 indicates a decline with 1 indicating no or positive increase.

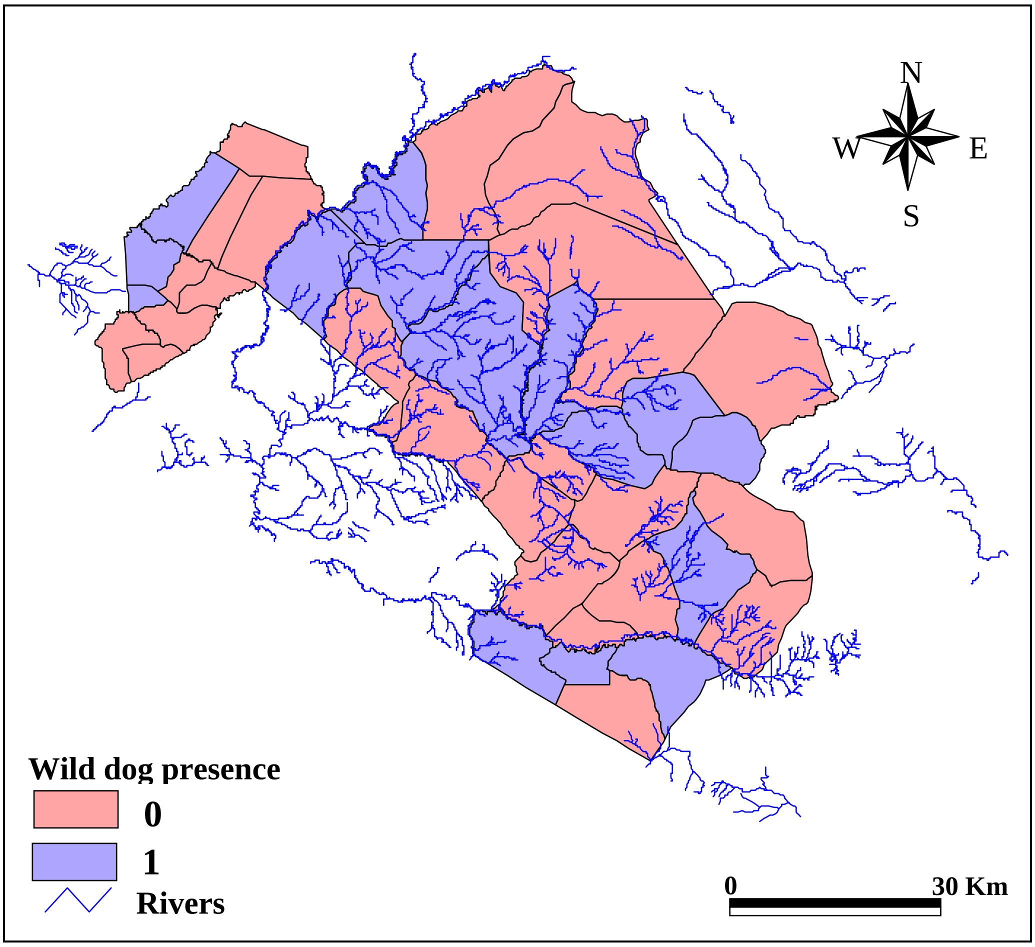

Figure A4.5: Wild dog presence in the wet season 2005 within clusters in relation to rivers across the Greater Mara Ecosystem. 1 indicates presence and 0 indicates absence.

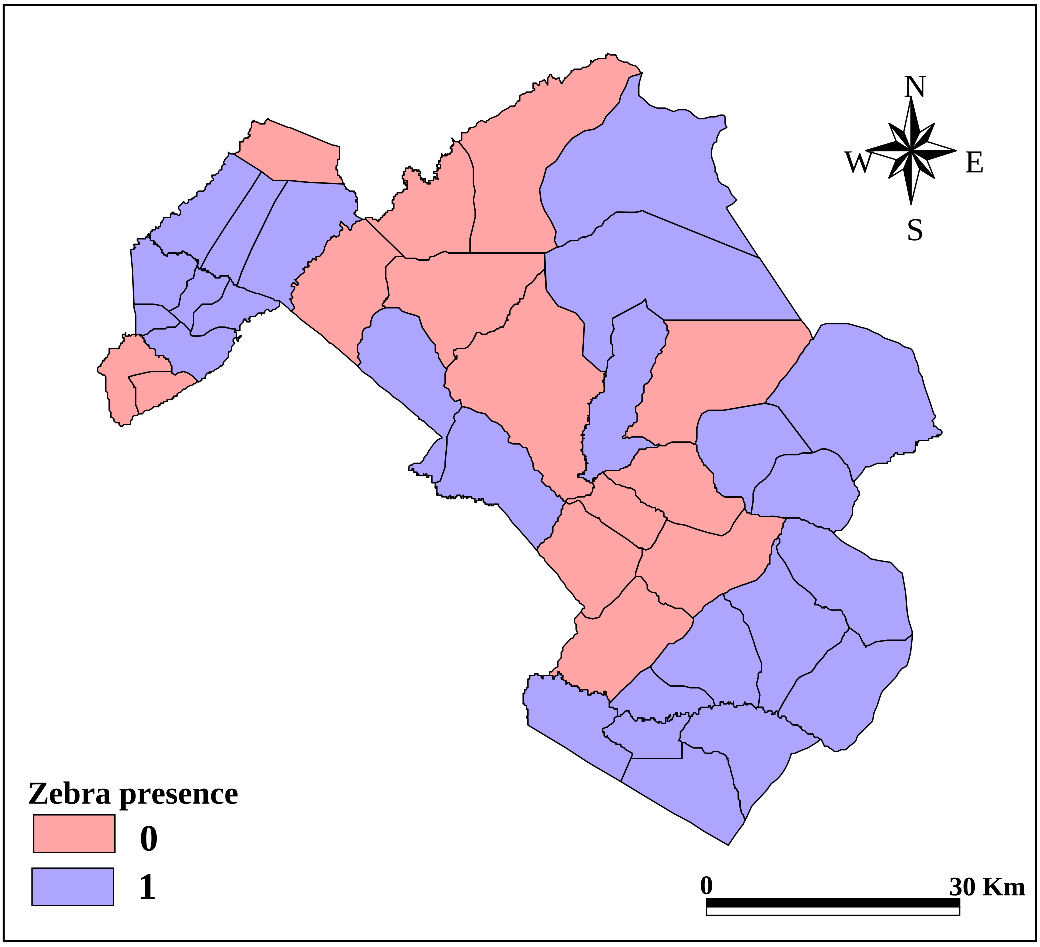

Figure A4.6: Zebra presence in the wet season 2005 within clusters across the Greater Mara Ecosystem. 1 indicates presence and 0 indicates absence.

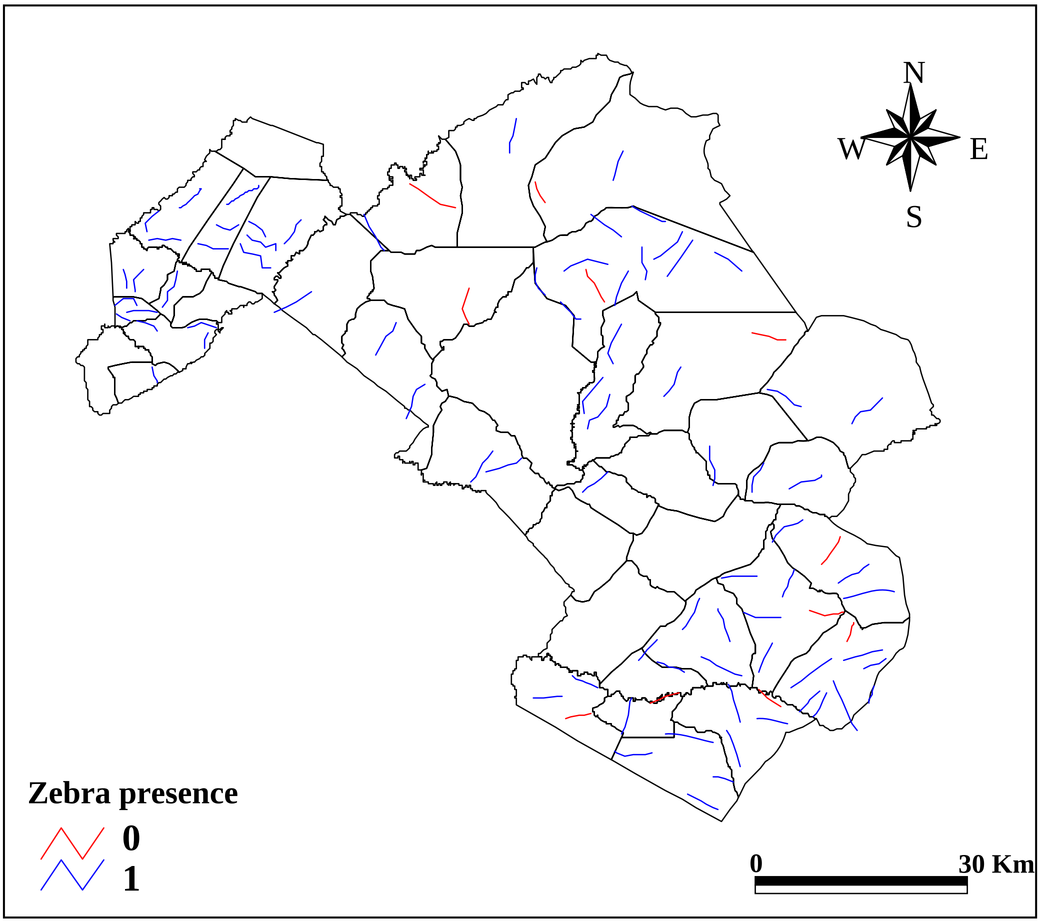

Figure A4.7: Zebra presence in the wet season 2005 within transects across the Greater Mara Ecosystem. 1 indicates presence and 0 indicates absence.

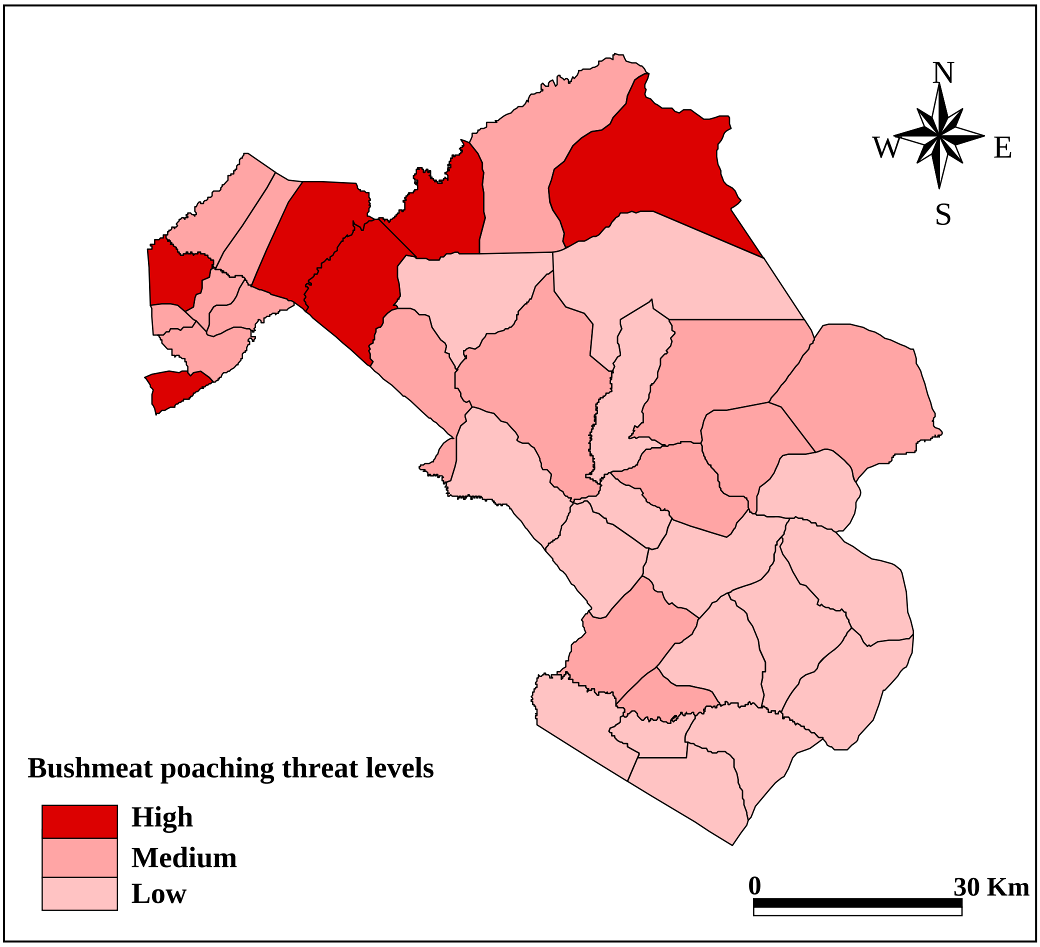

Figure A4.8: Bushmeat poaching threat levels of low, medium and high within clusters across the Greater Mara Ecosystem.

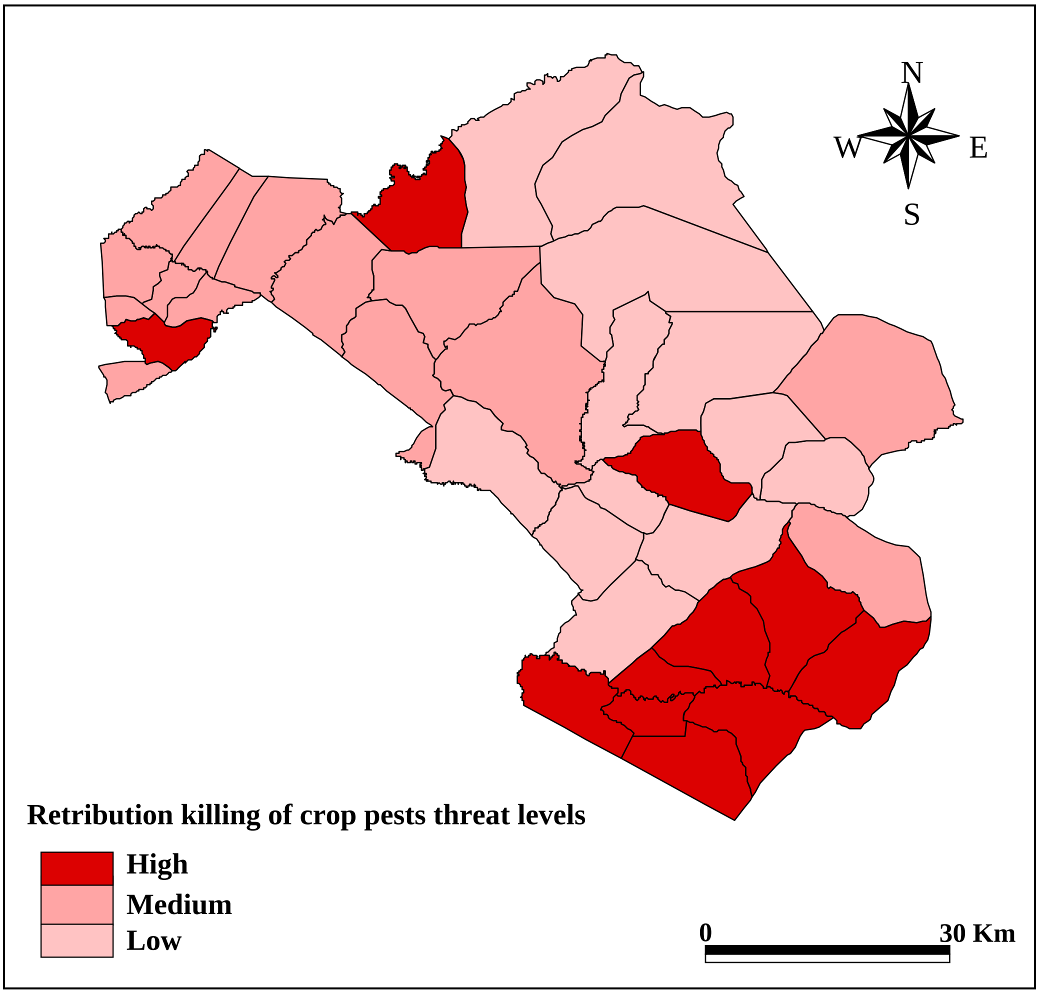

Figure A4.9 Retribution killing of crop pests threat levels of low, medium and high within clusters across the Greater Mara Ecosystem.

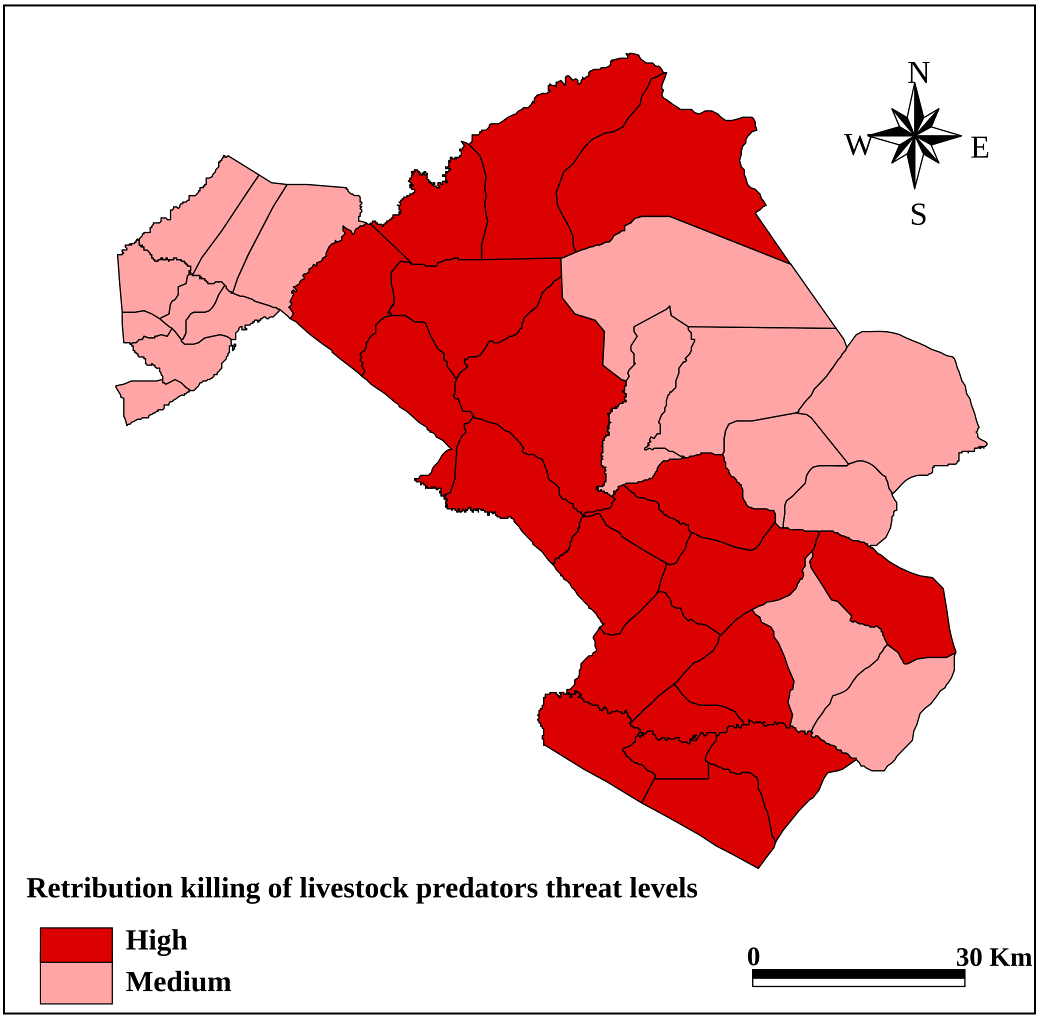

Figure A4.10 Retribution killing of livestock predators threat levels of medium and high within clusters across the Greater Mara Ecosystem.